Appendix B

Basso, R. 2010. Predicted groundwater withdrawal impacts to Homosassa Springs based on numerical model results. Technical memorandum dated February 15, 2010. Southwest Florida Water Management District. Brooksville, Florida.

February 15, 2010

Technical Memorandum

TO: Doug Leeper, Chief Environmental Scientist, Ecological Evaluation Section
Marty Kelly, Ph. D., Manager, Ecological Evaluation Section

THROUGH: Mark Barcelo, P.E., Manager, Hydrologic Evaluation Section

FROM: Ron Basso, P.G., Senior Professional Geologist, Hydrologic Evaluation Section

SUBJECT: Predicted Groundwater Withdrawal Impacts to Homosassa Springs based on Numerical Model Results

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1.0 Introduction

The Southwest Florida Water Management District (SWFWMD or District) is currently developing minimum flows for the Homosassa River and springs system. These regulatory flows will represent limits at which further withdrawals would be significantly harmful to the water resource or ecology of the area. Prior to establishment of the minimum flows, an evaluation of hydrologic changes in the vicinity of the river/springs system is necessary to characterize changes in flows associated with existing groundwater withdrawals. This memorandum describes the hydrologic setting near the Homosassa River and springs system and provides the results of a numerical model simulation of predicted spring flow change due to current groundwater withdrawals. Information regarding the establishment of minimum flows for the system is not included in this memorandum.

The Homosassa River and springs system is located in southwest Citrus County within the District (Figure 1). A large spring and numerous smaller springs provide flow to the Homosassa River, which winds through nearly six miles of lowland swamps and discharges into the Gulf of Mexico (Cherry and others,1970). Freshwater flow to the Homosassa River is the result of discharge from Homosassa Springs, springs supplying flow to the southeast fork of the Homosassa River, and springs supplying flow to Halls River (Knochenmus and Yobbi, 2001). These springs collectively are herein referred to as the Homosassa Springs group.

2.0 Hydrogeologic Conditions

The hydrogeologic framework in the vicinity of the Homosassa Springs group includes a surficial aquifer system, a discontinuous intermediate confining unit, and a thick carbonate Upper Floridan aquifer. At land surface and extending several tens of feet deep are generally fine-grained quartz sands that grade into clayey sand just above the contact with limestone. A thin, sometimes absent, sandy clay layer forms the intermediate confining unit (ICU) and overlies the limestone units of the Upper Floridan aquifer (UFA). In general, a regionally extensive surficial aquifer system is not present because the clay confining unit is thin, discontinuous, and breeched by numerous karst features. Because of this geology, the UFA is unconfined over most of the southwest Citrus County area.

The geologic units, in descending order, that form the freshwater portion of the UFA include the Oligocene age Suwannee Limestone, the upper Eocene age Ocala Limestone, and the middle Eocene age Avon Park Formation (Table 1). In northern Pasco and Hernando counties, the Suwannee Limestone is the uppermost unit. Further north in Citrus County, the Ocala Limestone forms the top of the UFA, except in extreme southern Levy County where the Avon Park Formation is exposed near land surface. The entire carbonate sequence of the UFA thickens and dips toward the south and southwest. Average thickness of the UFA ranges from 500 feet in southern Levy

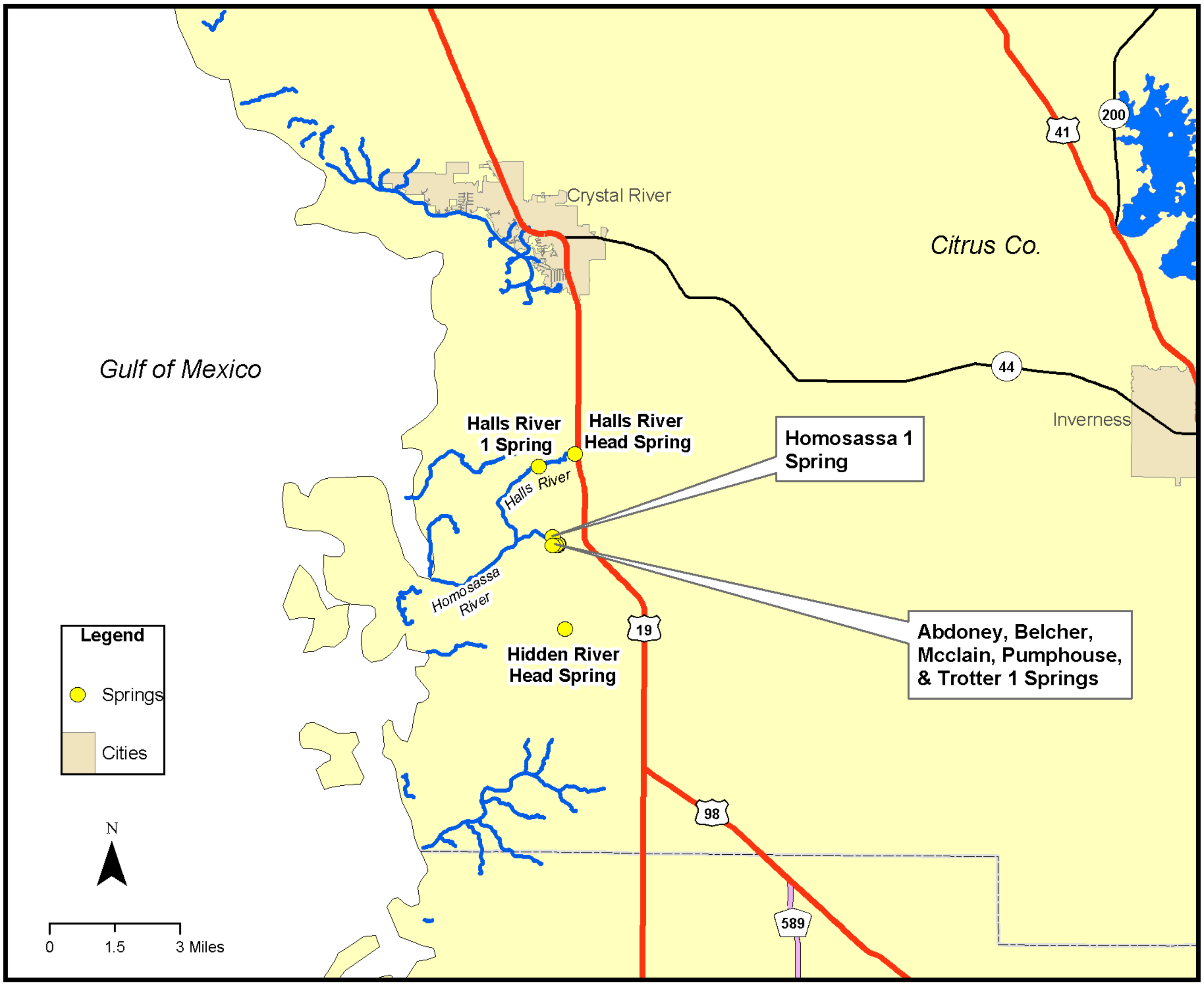

Figure 1. Location of Homosassa River and springs system.

County to 1,000 feet in central Pasco County (Miller, 1986). The base of the UFA generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit is regionally extensive and is generally referred to as middle confining unit II (Miller, 1986).

In southwest Citrus County, the UFA is regionally unconfined and is located within a highly karst-dominated region. Dissolution of limestone is an active process via infiltration of rainwater because the limestone units of the UFA are close to land surface and poorly confined. Numerous sinkholes, internal drainage, and undulating topography that are typical of karst geology dominate the landscape. These active karst processes lead to enhanced permeabilities within the Floridan aquifer. The median transmissivity value of the UFA based on five aquifer performance tests in western Hernando and Citrus Counties is 210,000 ft^2/day (SWFWMD, 2006). The highest recharge rates to the UFA occur in west-central Hernando and Citrus Counties with values ranging between 10 and 25 inches per year (Sepulveda, 2002). There are two first-magnitude springs (flow greater than 100 cubic feet per second (cfs) discharge) found within this region: Weeki Wachee Spring and the Crystal River group. Collectively, the springs discharging to the Homosassa River and the Chassahowitzka River also exceed the 100 cfs first magnitude spring threshold.

Table 1. Hydrogeology of the Homosassa Springs group area (Modified from MIller,1986, Sacks and Tihansky, 1996).

<table>
<tr><th>Series</th><th>Stratigraphic Unit</th><th colspan="2">Hydrogeologic Unit</th><th>Lithology</th></tr>
<tr><td>Holocene to Pliocene</td><td>Undifferentiated Surficial Deposits</td><td colspan="2">Unsaturated Zone, Surficial Aquifer or locally perched Surficial Aquifer</td><td>Sand, silty sand, clayey sand, sandy clay, peat, and shell</td></tr>
<tr><td>Oligocene</td><td>Suwannee Limestone</td><td rowspan="2">Upper Permeable Zone</td><td rowspan="2">Upper Floridan Aquifer</td><td>Limestone, cream to tan, sandy, vuggy, fossiliferous</td></tr>
<tr><td rowspan="4">Eocene</td><td>Ocala Limestone</td><td>Limestone, white to tan, friable to micritic, fine-grained, soft, abundant foraminifera</td></tr>
<tr><td rowspan="2">Avon Park Formation</td><td colspan="2">Middle Confining Unit 2</td><td>Dolomite is brown, fractured, sucrosic, hard. Interstitial gypsum in MCU 2</td></tr>
<tr><td rowspan="2">Lower Permeable Zone</td><td rowspan="2">Lower Floridan Aquifer</td><td rowspan="2">Limestone and dolomite. Limestone is tan, recrystallized. Anhydrite and gypsum inclusions.</td></tr>
<tr><td>Oldsmar Formation</td></tr>
<tr><td>Paleocene</td><td>Cedar Keys Formation</td><td colspan="2">Basal Confining Unit</td><td>Massive anhydrites</td></tr>
</table>

The ground-water basin for the Homosassa Springs group is approximately 292 square miles in size and located in north-central Hernando and southwestern Citrus Counties (Figure 2). The United States Geological Survey (USGS) developed a water budget for the basin for calendar years 1997 and 1998 (Knochenmus and Yobbi, 2001). According to Knochenmus and Yobbi's calculations, average annual values for the following water budget components were:

Rainfall = 52 inches (in)/yr,
Evapotranspiration = 32 in/yr,
Springflow = 12.5 in/yr,
Groundwater Withdrawals = 0.6 in/yr,
Groundwater Outflow = 6.7 in/yr and
Change in Storage = 0.2 in/yr

Based on the USGS water budget, net recharge to the UFA averaged 20 in/yr for the two-year period. As a percentage of recharge, groundwater withdrawals averaged about three percent of annual recharge.

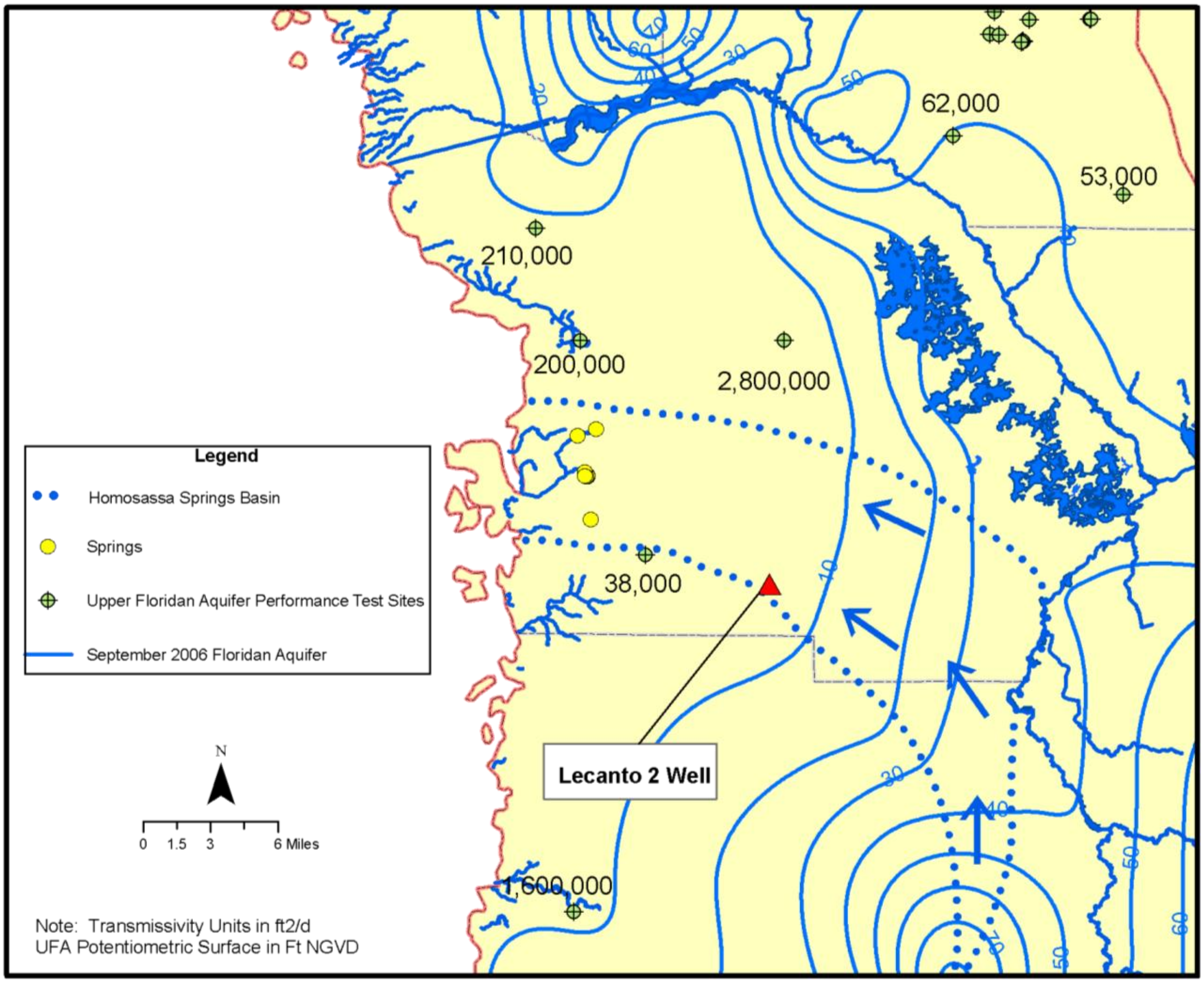

Figure 2. Location of the Homosassa River Springs group ground-water basin, the Lecanto 2 Upper Floridan aquifer well, transmissivity from aquifer performance tests, and the September 2006 potentiometric surface of the Upper Floridan aquifer (Arrows show general direction of ground-water flow).

2.1 Groundwater withdrawals in the vicinity of the Homosassa Springs group

The District currently maintains a database of metered and estimated water use from 1992 through 2006. Groundwater withdrawals in the vicinity of Homosassa Springs group for 2005 are shown in Figure 3. Groundwater withdrawn within a five-mile radius of Homosassa 1 Spring vent is relatively low and was 1.3 million gallons per day (mgd) in 2005. Ground water withdrawn within a 10-mile radius of the spring was 8.2 mgd in 2005.

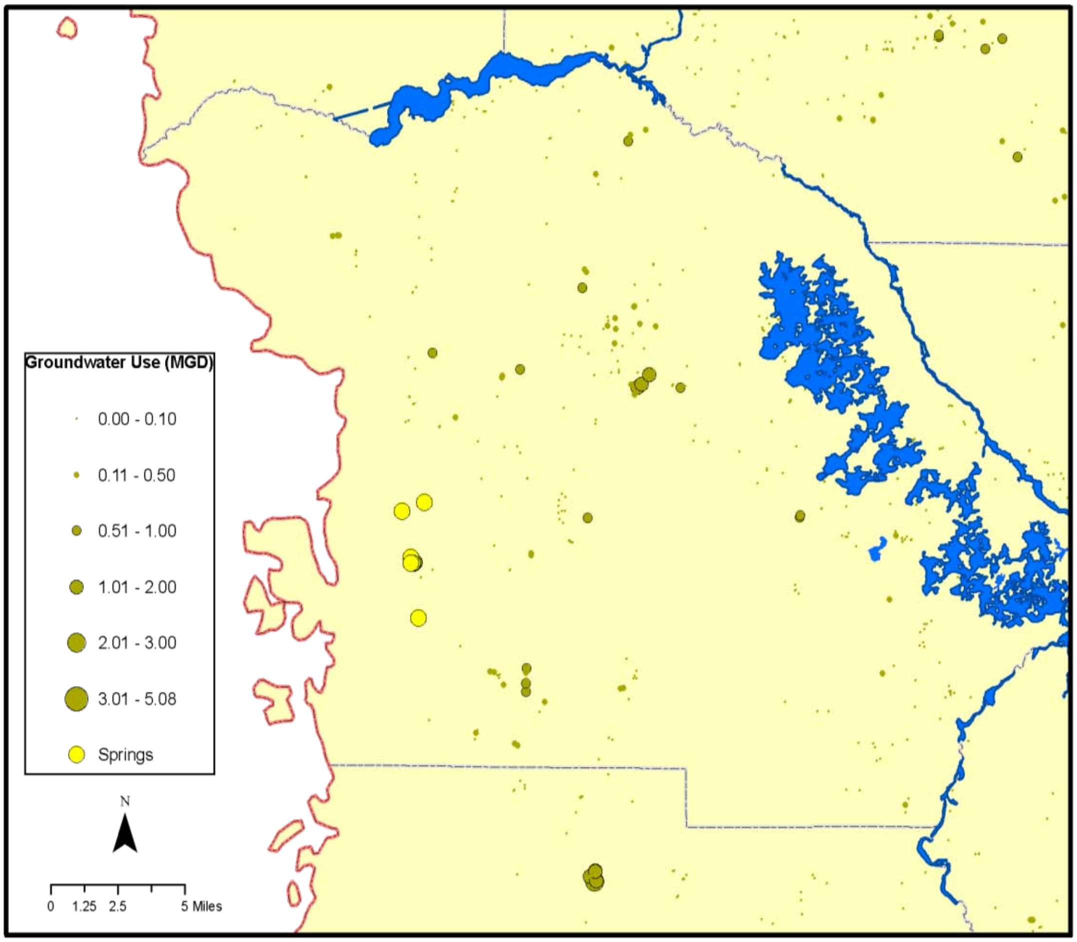

Figure 3. Upper Floridan aquifer groundwater withdrawals in the vicinity of **the** Homosassa Spring**s** group during 2005.

2.2 Spring discharge, UFA water levels, and Rainfall

Homosassa 1 Spring discharge has been recorded by the USGS since 1995 at a gage on the spring run about 400 feet from the main vent (Figure 4). From October 1995 to January 2010, median spring discharge was 88 cubic feet per second (cfs) or 57.7 mgd. This site includes flow from the main vent and several smaller springs. Prior to this date, there were only infrequent measurements of discharge from the spring. In addition to Homosassa 1, discharge has been recorded at the SE Folk of the Homosassa River, Hidden River, and downstream of where the Halls River enters the Homosassa River by the USGS. However, the Homosassa River downstream of the Halls River is tidally-influenced. Median daily discharge of the Homosassa River using tidally-filtered data from the USGS was 251 cfs from 2004 through 2009.

The Lecanto 2 UFA well is located within the Homosassa Springs group ground-water basin about 9.5 miles southeast of the Homosassa 1 Spring (see Figure 2). This well was selected for characterization of UFA water levels because it is the closest well to the springs with a relatively long period of continuous measurements. Water levels in the well were first recorded in 1965 and are shown in Figure 5. Aquifer water levels have generally fluctuated between 5 and 15 Ft NGVD over the last 45 years. Simple linear regression of the monthly water levels since 1965 shows a statistically significant downward trend of -0.048 ft/year or about -2.1 ft. for the period 1965-2009. Much of this decline is related to lower than average rainfall during the period.

Analysis of Brooksville, Inverness, and Ocala National Weather Service station rainfall from 1930 through 2008 shows a declining trend after 1970, with declines especially pronounced after 1989 (Figure 6). Cumulative departure from mean annual rainfall for the period from 1970 to 2008 is -71.2 inches. In contrast, the cumulative departure from mean rainfall from 1931-1969 is +74 inches. The declining trend in rainfall after 1970 corresponds to the change in the Atlantic Multidecadal Oscillation cycle from a warm (wet) to a cool (dry) period (Enfield and others, 2001). Annual departures from mean rainfall indicate that rainfall was below average during 26 of the 38 years evaluated after 1970 (Figure 7).

As another method to measure potential impact to UFA water levels near the Homosassa Springs group, a cumulative sum graph was created of annual Brooksville rainfall versus mean annual water level from the Lecanto 2 well for the period from 1965 through 2008 (Figure 8). In the cumulative sum analysis, any major deviation in slope that occurs for more than five years would indicate an influence other than rainfall affecting water levels in the well. No obvious deviations in slope were detected, suggesting climatic influences dominate the historic fluctuation of water levels at this well.

3.0 Numerical Model Results

A number of regional groundwater flow models have included the Homosassa River and springs system area. Ryder (1982) simulated the entire extent of the SWFWMD. In 2002, the USGS simulated the entire Florida peninsula in their Mega Model of regional groundwater flow (Sepulveda, 2002).

3.1 Northern District Model

The SWFWMD Northern District groundwater flow model (NDM) was completed in May 2008 by the consulting firm Hydrogeologic Inc. (2008). The domain of the NDM includes portions of the SWFWMD, the St. Johns River Water Management District, and the Suwannee River Water Management District. The flow model encompasses the entire extent of the Central West-Central Florida Groundwater Basin and the Northern West-Central Florida Groundwater Basin. The eastern boundary of the regional groundwater flow model extends just east of the Lake County/Orange County line. The western boundary of the model domain extends approximately five miles offshore of the Gulf of Mexico.

The regional model finite-difference grid consists of 182 columns and 275 rows of 2,500 ft uniformly spaced cells (Figure 9). The NDM is fully 3-Dimensional with top and bottom elevations specified for each model layer. Topographic elevations were assigned to the top of model layer 1 from a digital elevation model provided by SWFWMD, based on the USGS 30m National Elevation Dataset. The Florida Geological Survey supplied elevation data for all other layers in the model.

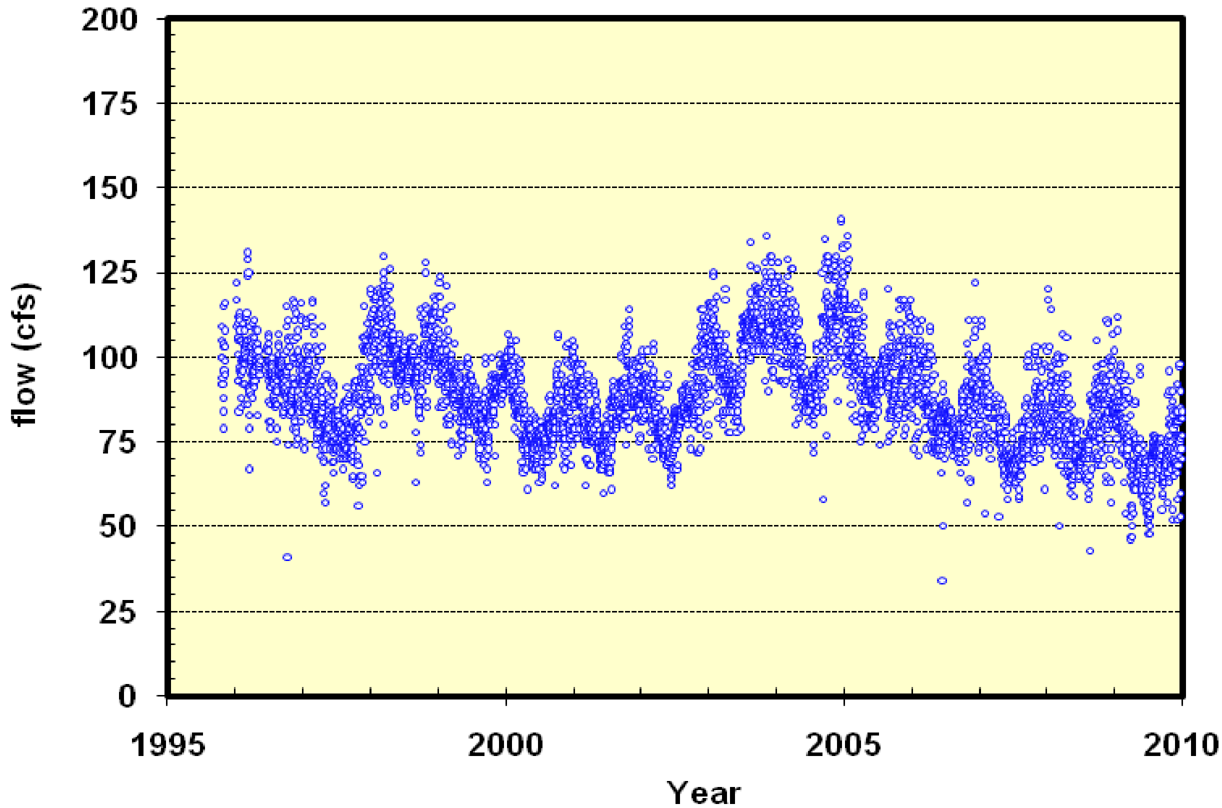

Figure 4. Daily discharge history of Homosassa 1 Spring as reported by the United States Geological Survey.

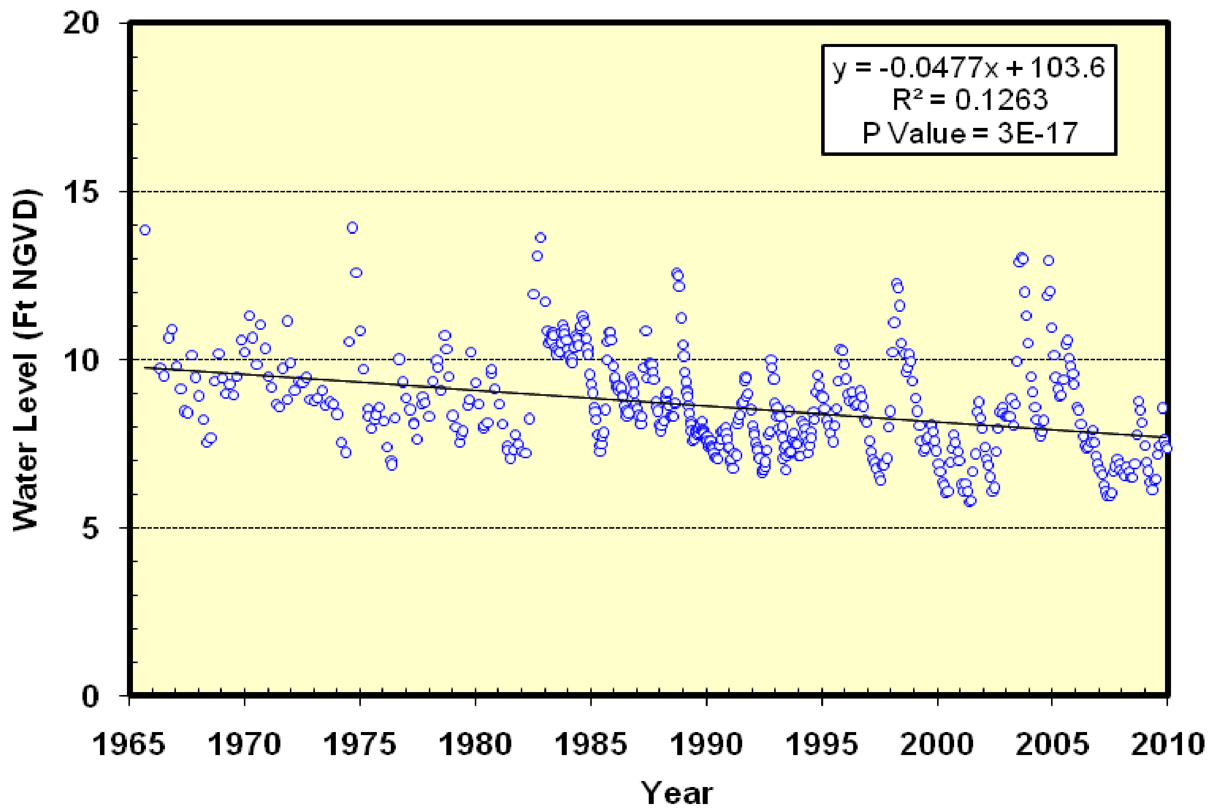

Figure 5. Simple linear regression of monthly water levels from the Lecanto 2 Upper Floridan aquifer well from 1965-2010 (P value significance ≤ 0.05).

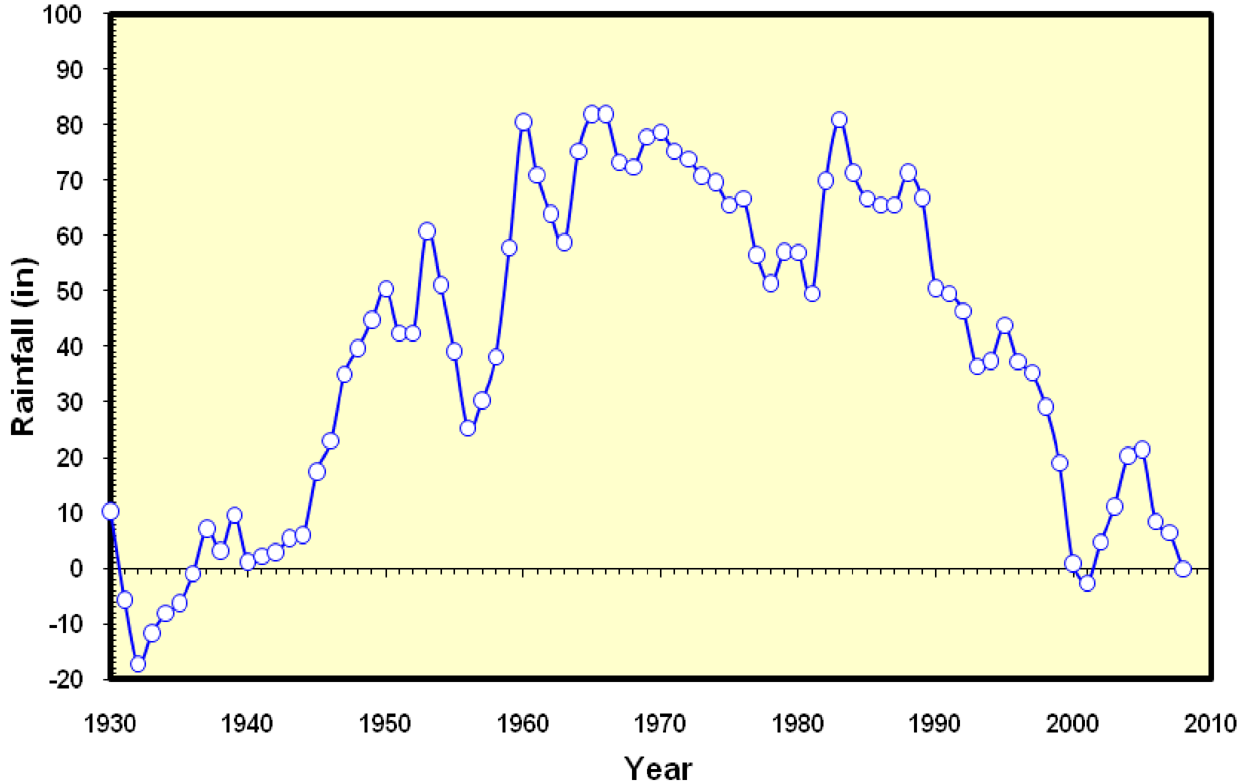

Figure 6. Cumulative departure from mean annual rainfall from 1930 through 2008 based on rainfall values averaged from the Inverness, Ocala and Brooksville National Weather Service stations.

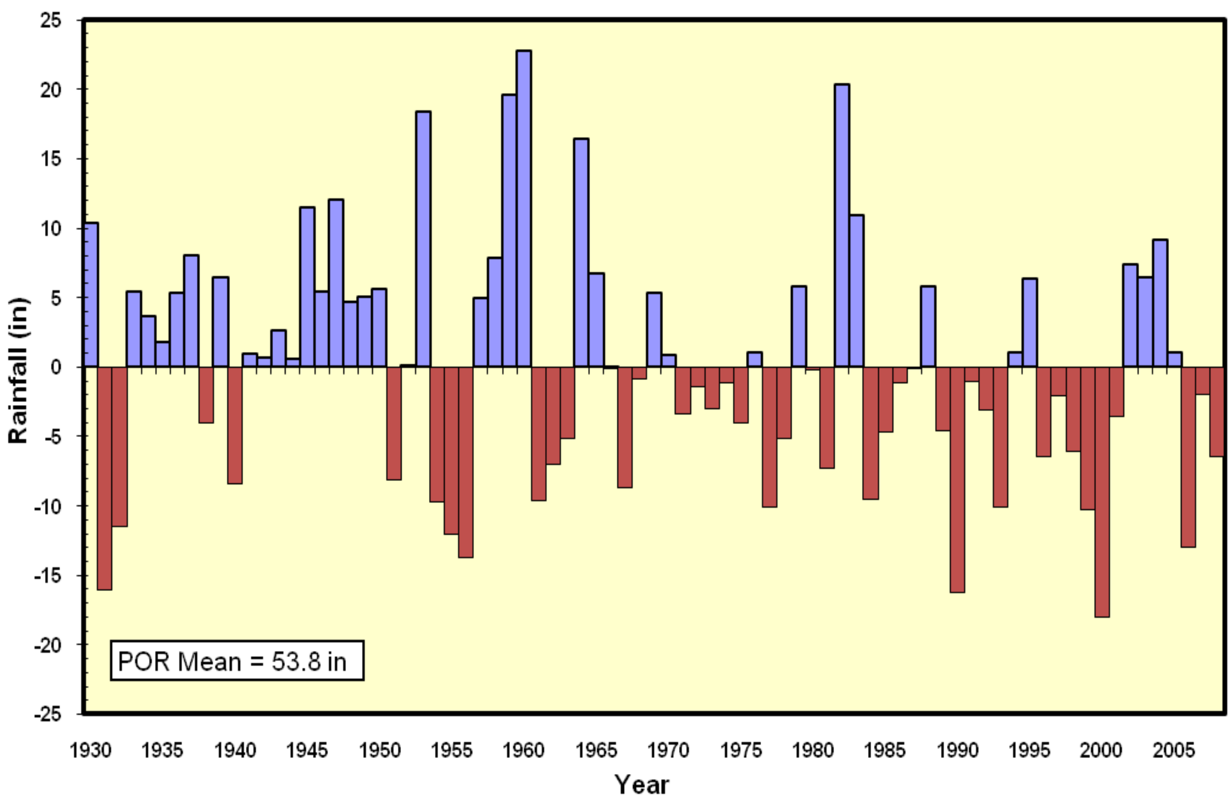

Figure 7. Annual departure in mean rainfall from data averaged from the Brooksville, Inverness, and Ocala National Weather Service stations (1930-2008).

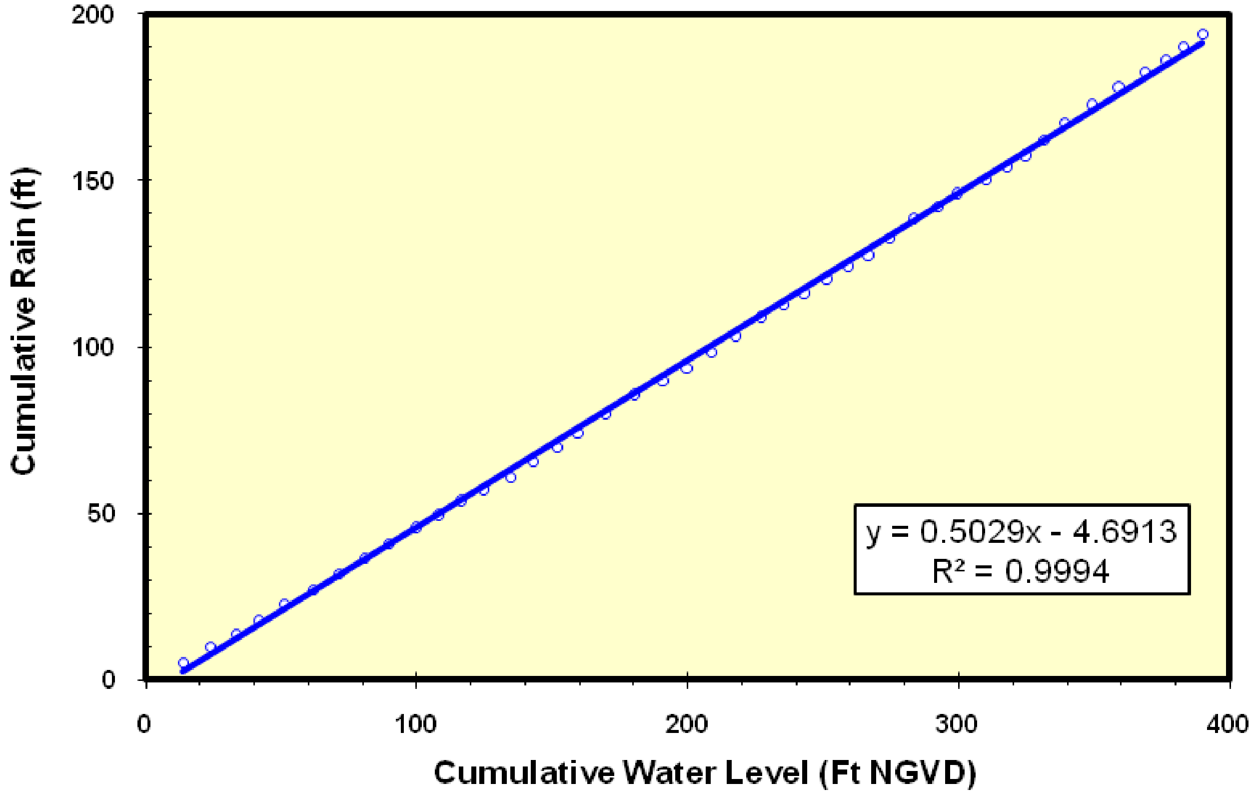

Figure 8. Cumulative sum of Lecanto 2 well mean annual water level versus Brooksville rainfall (1965-2008).

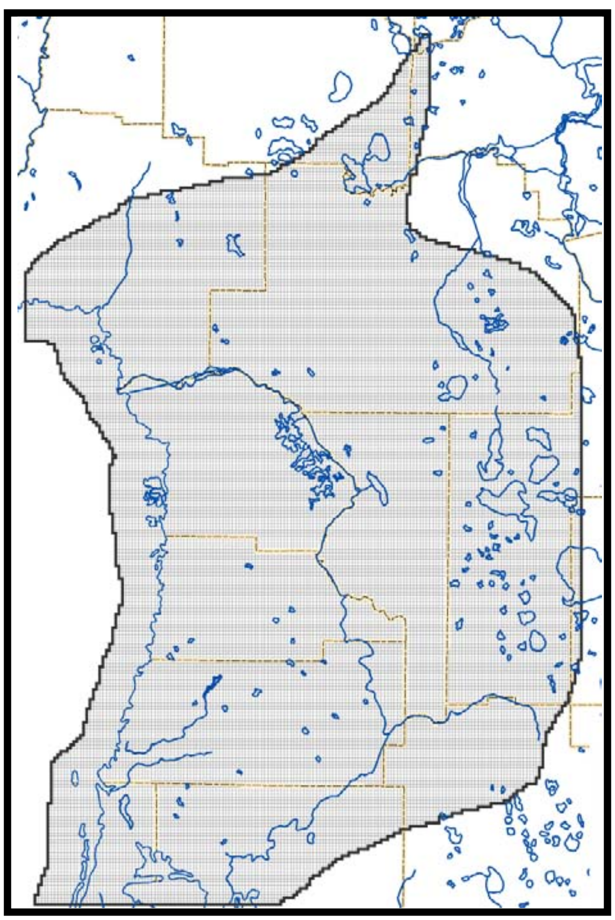

Figure 9. Groundwater grid in the Northern District model.

The NDM consists of seven layers that represent the primary geologic and hydrogeologic units including: 1. Surficial Sands; 2. Intermediate Confining Unit (ICU); 3. Suwannee Limestone; 4. Ocala Limestone; 5. upper Avon Park Formation; 6. Middle Confining Unit (MCU) I and MCU II; and 7. lower Avon Park Formation or Oldsmar Formation. The UFA is composed of the Suwannee Limestone, Ocala Limestone, and Upper Avon Park; the Lower Floridan aquifer (LFA) is composed of the permeable parts of both the lower Avon Park and the Oldsmar Formation. Due to the permeability contrasts between the units, each unit is simulated as a discrete model layer rather than using one model layer to represent a thick sequence of permeable units (e.g., UFA).

In regions where the UFA is unconfined, the second model layer represents the uppermost geologic unit in the UFA. The Suwannee Limestone is absent over a large part of the model domain. Where the Suwannee Formation is absent, model layers 3 and 4 represent the Ocala Limestone. The Ocala Limestone is absent in some local areas in the northernmost region of the model domain. In those areas, model layers 3 through 5 represent the Avon Park Formation. With the exception of the eastern part of the domain, the Oldsmar Formation is assumed to have a relatively low permeability being similar to the permeability of the overlying MCU II, which includes the lower Avon Park. Consequently, with the exception of the eastern part of the model domain, the finite-difference cells representing the LFA (model layer 7) are inactive and groundwater flow is not simulated.

The NDM was calibrated to steady-state 1995 calendar year conditions and transient conditions from 1996 through 2002 using monthly stress periods. This model is unique for west-central Florida in that it is the first regional flow model that represents the groundwater system as fully three-dimensional. Prior modeling efforts, notably Ryder (1985), Sepulveda (2002), and Knowles and others (2002), represented the groundwater system as quasi-three-dimensional.

The groundwater flow and solute transport modeling computer code MODFLOW-SURFACT was used for the groundwater flow modeling (Hydrogeologic, Inc., 2008). MODFLOW-SURFACT is an enhanced version of the USGS modular three-dimensional groundwater flow code (McDonald and Harbaugh,1988).

3.2 2005 Scenario

To determine drawdown in the UFA and potential impacts to springflow in the Homosassa River system, average annual groundwater withdrawals in 2005 (438.1 mgd) were simulated in the NDM under long term transient conditions (five years) and compared to non-pumping conditions (zero withdrawals). UFA heads generated at the end of the 2005 simulation were subtracted from UFA heads at the end of the non-pumping simulation to determine aquifer drawdown. Differences in spring discharge for the 2005 and non-pumping simulations were similarly evaluated.

The model-predicted drawdown in the UFA for the 2005 withdrawal scenario was less than 0.25 feet in most of the northern portion of the model domain (Figure 10). In the vicinity of the Homosassa Springs group, the aquifer drawdown associated with 2005 conditions was less than 0.1 feet. Based on 438.1 mgd of groundwater withdrawn within the NDM domain in 2005, predicted reduction in Homosassa 1 Spring discharge was 0.7 cfs or one percent of the modeled non-pumping discharge (Table 2). This 0.7 cfs reduction represents a 0.8 percent reduction from the median discharge (88 cfs) based on measured values between October 1995 and January 2010.

Predicted changes in discharge for other springs in the Homosassa Springs group were comparable to those reported for Homosassa 1 Spring (Table 2). The percentage change in flows from the Hidden River Head Spring were slightly higher, with a four percent difference predicted between the non-pumping and 2005 withdrawal scenarios. However, the predicted change in flow for the Hidden River Head Spring was only -0.3 cfs. The total simulated springflow change for all

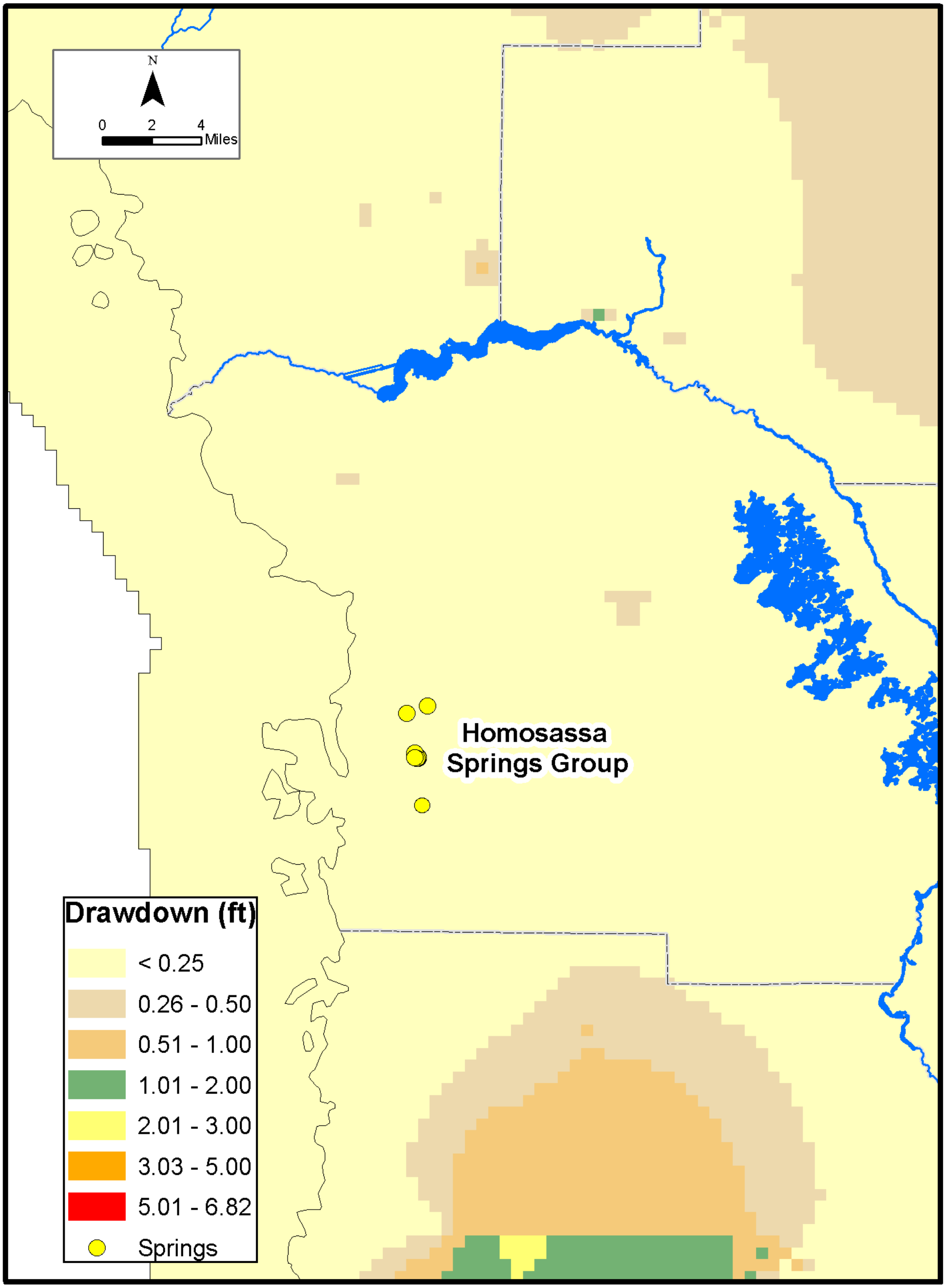

Figure 10. Predicted drawdown in the UFA due to 2005 groundwater withdrawals. Although not depicted in this figure, the predicted UFA drawdown in the vicinity of the Homosassa Springs group was less than 0.1 feet.

Table 2. Predicted discharge for springs in the Homosassa Springs group based on the Northern District groundwater flow model for non-pumping and 2005 withdrawal scenarios.

Spring Name	Discharge for Non-Pumping Scenario (cfs)	Discharge for 2005 Pumping Scenario (cfs)	Difference (cfs)	Percent Difference
Abdoney Spring	4.98	4.93	-0.05	-0.9
Belcher Spring	4.98	4.89	-0.10	-2.0
Halls River 1 Spring	5.00	4.95	-0.05	-0.9
Halls River Head Main Spg	102.11	101.06	-1.05	-1.0
Hidden River Head Spring	6.61	6.35	-0.26	-4.0
Homosassa 1 Spring	71.65	70.98	-0.67	-0.9
Mcclain Spring	4.98	4.93	-0.05	-0.9
Pumphouse Spring	4.97	4.92	-0.05	-0.9
Trotter 1	4.97	4.93	-0.05	-0.9
Total	210.2	207.9	-2.31	-1.1

nine springs in the Homosassa Springs group was -2.3 cfs. This represents a 1.1 percent decline due to 2005 groundwater withdrawals (Table 2).

4.0 Summary

The Homosassa 1 Spring, springs in the southeast fork of the Homosassa River, and springs supplying flow to Halls River form the headwaters of the Homosassa River, which flows west to the Gulf of Mexico approximately six miles through low coastal hardwood hammock and marsh. As many as five springs flow into the upper part of the river and additional springs are known to exist in the lower segment of the river and in the Halls River, which drains to the Homosassa (Rosenau and others, 1977). The springs are located in a karst-dominated region where the Upper Floridan aquifer is largely unconfined. Due to this unique geology, recharge to and permeability within the UFA is very high. Review of long term UFA water levels in the area indicates a declining trend since 1965. This is mostly due to lower than average rainfall over the last 40 years which became more pronounced after 1989.

Statistical analysis indicates that UFA water levels fluctuate closely with rainfall and mirror the long term trend of below average rainfall. Simulation results from the Northern District model indicate a 2.3 cfs reduction in Homosassa Springs group discharge associated with current (2005) groundwater withdrawals. This simulated flow reduction corresponds to about a one percent decline in discharge for the springs within and near the Homosassa River due to current groundwater withdrawals.

References

Cherry, R.N., Stewart, J.W., and Mann, J.A., 1970, General hydrology of the middle Gulf area, Florida: Tallahassee, Florida Bureau of Geology Report of Investigation no. 56, 96 p.

Enfield, D.B., Mestas-Nuñez,, A.M., and Trimble, P.J., 2001, The Atlantic Multidecadal Oscillation and its relation to rainfall and river flows in the continental U.S.: Geophysical Research Letters, v. 28, p. 2077–2080.

Hydrogeologic, Inc., 2008, Computer Flow and Saltwater Intrusion Model for the Northern District Water Resources Assessment Project.

Knochenmus, L.A. and D.K. Yobbi, 2001, Hydrology of the Coastal Springs Ground-Water Basin and Adjacent Parts of Pasco, Hernando, and Citrus Counties, Florida, U.S. Geological Survey Water-Resources Investigations Report 01-4230, 88 p.

Knowles Jr., L., A.M. O'Reilly, and J.C. Adamaski, 2002, Hydrogeology and Simulated Effects of Ground-Water Withdrawals From the Floridan Aquifer System in Lake County and the Ocala National Forest and Vicinity, North-Central Florida. U.S. Geological Survey Water-Resources Investigations Report 02-4207.

McDonald, M.G. and A.W. Harbaugh, 1988, A modular three-dimensional finite-difference groundwater flow model, U.S. Geological Survey Techniques of Water-Resources Investigations Book 6, Chapter A1.

Miller, J.A. 1986. Hydrogeologic framework of the Floridan aquifer system in Florida and in parts of Georgia, Alabama, and South Caroline: U.S. Geological Survey Water-Resources Investigations Report 84-4135, 69 p.

Rosenau, J.C., Faulkner, G.L., Hendry, C.W., Jr., and Hull, R.W., 1977, Springs of Florida: Florida Geological Survey Bulletin 31 Revised, 461 p.

Ryder, P., 1982, Digital Model of Predevelopment Flow in the Tertiary limestone (Floridan) Aquifer System in West-Central Florida, U.S. Geological Survey Water-Resources Investigations Report 81-54.

Sacks, L. A. and A.B. Tihansky, 1996, Geochemical and isotopic composition of ground water with emphasis on sources of sulfate in the upper Floridan Aquifer and intermediate aquifer system in southwest Florida, U.S. Geological Survey WRI Report 96-4146, 54 p.

Sepulveda, N. 2002. Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer Systems in Peninsular Florida, U.S. Geological Survey WRI Report 02-4009, 130 p.

Southwest Florida Water Management District, 2006, Aquifer Characteristics within the Southwest Florida Water Management District, 28 p.

Appendix C

Wang, P. 2007. Shoreline mapping and bathymetric survey for the Homosassa River systems. University of South Florida. Tampa, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

Shoreline Mapping and Bathymetric Survey for the Homosassa River Systems

Final Report

Submitted by

Ping Wang, Ph.D.
Department of Geology
University of South Florida
Tampa, FL 33620
Phone: 813-974-9170
Fax: 813-974-2654
Email: pwang@cas.usf.edu

Certified By:
GeoMap Technologies, Inc.
3910 U.S. Highway 301 N.
Suite 240
Tampa, Florida 33619
Jeffery P. Hollingsworth, P.S.M.
P.S.M. 4156, L.B. 6761

Submitted to

XinJian Chen, Ph.D., P.E.
Southwest Florida Water Management District
7601 Highway 301 North
Tampa, FL 33637
1-813-985-7481
xinjian.chen@swfwmd.state.fl.us

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INTRODUCTION

The Homosassa River system survey project included: 1) the Homosassa River and all the side creeks, 2) the Homosassa River estuary, and 3) nearly all the navigable tidal creeks in the estuary. The project included two tasks: 1) mapping of the shoreline and 2) surveying of the bathymetry.

The shoreline configuration was mapped in the field using a RTK (Real-Time Kinematics) global positioning system (GPS). The shoreline position was obtained by navigating the survey vessel along the shoreline. The bathymetry was measured using a synchronized precision echo sounder with the GPS. Sections across the water body and centerlines were surveyed.

STUDY AREA

The project area along the Homosassa River system is shown in Figure 1. The survey extended to the spring at the head of the river. The survey coverage at the head spring was limited by the manatee protection areas. All the navigable branches and side creeks were included in the survey, including most of the canals that are connected to the headspring area. A considerable number of tidal creeks exist in the lower stream (Figure 1). The bathymetry measurement included cross-section surveys spaced at 500 ft (150 m) or less and at least one centerline survey. At narrow sections of the river, zigzag survey lines were sometimes added to ensure adequate coverage. The shoreline of the main river and all the branches were mapped in the field by navigating the survey vessel along the shoreline. To cover the entire stretch of the river, the GPS base station (control point) was established at three different locations.

Figure 1. Study area at the Homosassa River system. The project area extends over the entire map.

FIELD METHODOLOGY

A 24-ft pontoon boat and a 15-ft aluminum boat were used for the shoreline and bathymetry survey (Figure 2). Both boats require only 1 ft (0.3 m) or less draft, but needs calm water to operate. The smaller boat was used to survey the shoreline and most of the narrow tidal creeks and the upper stretch of the river. These boats are ideal for this project.

Figure 2. The survey vessels, upper: the pontoon boat; lower: the 15-ft aluminum boat.

Shoreline Mapping

The shoreline was mapped with the RTK GPS mounted on board the survey vessels. The shoreline positions were obtained by navigating the survey vessel as close to the vegetated shoreline as possible. In the present study, the shoreline is defined as the clear boundary between vegetated land and water. Same definition would apply to digitize shoreline from aerial photos or maps. Given the relatively low tidal range, typically less than 3 ft (1 m), the shoreline (as defined here) position is not significantly influenced by tidal water-level variations in most areas. The shoreline survey was mostly conducted during high tide. Most of the vegetated boundary remains clear regardless of tidal stage.

The shoreline survey was conducted using the 15-ft boat. The shoreline mapped here is typically 3 to 6 ft from the actual vegetation line along the riverbank. Given the typical width of several hundred feet, this limitation should not have any significant influence on the mapping of the river configuration. However, this limitation may induce considerable uncertainty in the shoreline position at some of the narrow creeks, simply because 3- to 6-ft length equals a considerable portion of the creek width.

A portion of the middle stretch of the Homosassa River, i.e., near the Hell's Gate area, has numerous rock outcrops. These rock outcrops caused some difficulties of navigating the boat for both shoreline and cross-section surveys. The shoreline survey along this section was conducted at a substantial distance from the actual shoreline to avoid the rocks. Some of the cross-section surveys were also conducted at locations away from the rocks for safety.

The positions of the shoreline were corrected during the data processing phase by manually moving the survey points about 4.5 feet (1.5 m) landward, as discussed and agreed with the SWFWMD researchers. The moved shoreline position is double-checked with rectified LABIN aerial photos. At places where the surveyed shoreline was obviously far from the actual shoreline dune to protruding docks, very shallow water, or rock outcrops, the LABIN photo was used to position the shoreline. No elevation values were assigned to this "edited" shoreline position. Water depth was measured during the mapping of the shoreline. These water depths were used in the mapping of the bathymetric contours.

The software HYPACK version 6.2 was used to manage the sampling of the RTK GPS system and the Syquest survey grade echo sounder. Dynamic sampling regulated largely by the quality of the RTK GPS position reading was conducted using this newest version of HYPACK. The close spacing reduced the uncertainty of interpolation between points. Given the complicated shoreline configuration, closely spaced sampling is important for accurate mapping.

Additional uncertainties in the shoreline mapping were caused by obstacle intrusions, both natural and artificial. Along some parts of the populated shoreline, the protruding boat docks caused some uncertainties for shoreline mapping (Figure 3). The survey vessel had to be navigated around the docks. The relative errors caused by the boat docks are not high because they tend to concentrate in areas with relatively wide water body.

The shoreline mapping is also influenced by various protruding natural objects, particularly overturned tree trunks. These tree trunks might become dangerous navigational hazard because many of them extending underwater. The survey vessel had to be navigated around them. Another shoreline-mapping obstacle is the low overhanging trees, especially those "horizontally-growing" palm trees (Figure 4). It was not possible for the survey vessel to be navigated under the trees. Therefore, the vessel had to deviate from the shoreline to avoid the trees. As discussed above, rock outcrops was a substantial problem for sections of Homosassa River.

Some of the obvious shoreline intrusions, e.g., those that created a sharp concave shape along an otherwise straight stretch of shoreline, were corrected in the lab during the processing of the shoreline data. Also, field notes were taken at some of the substantial intrusions. These were also corrected based on the field notes, and rectified LABIN aerial photos.

Figure 3. Protruding boat docks caused some problem in shoreline mapping.

Figure 4. Protruding palm trees caused some problem in the shoreline mapping.

These obstacles, both artificial and natural, did not have significant influence on the overall shoreline mapping. Their impacts were mostly scarce and local. Limited by the scope and budget of the present project, most of their locations were not marked in the shoreline mapping. These artificial and natural protruding obstacles had minimal impact on the bathymetry survey. The survey lines were selected such that the obstacles were avoided.

Bathymetry Survey

The bathymetry was measured with a narrow-beam (2.8 degrees) echo sounder. The narrow beam sensor was designed to obtain accurate depth measurement over steep slope, which is ideal for the present project. The sensor was mounted at 0.59 ft (18 cm) below the water surface on the pontoon boat and 0.39 ft (12 cm) below on the aluminum boat (Figure 5). The sensor has a minimum range of approximately 1 ft (30 cm). Therefore, the minimum measurable water depth for the present system is roughly 1.6 ft (50 cm).

Under most circumstances, the survey lines are roughly perpendicular to the shoreline (Figure 6). The survey lines were space at 500 ft (150 m) or less to ensure adequate spatial coverage. Additional survey lines were added at areas with complicated bathymetry. Some of the creeks are too narrow, e.g., less than 80 ft (25 m) wide. A large portion of the creek could not be covered by the survey vessel simply because the sensor was mounted in the middle of the vessel. In this case, in addition to cross sections, a survey line following a zigzag pattern along the creek was added. A centerline was surveyed over the entire project area.

Figure 5. The survey echo sounder was mounted at 18 cm below water surface.

The echo sounder is synchronized and co-located with the GPS system. The GPS yields horizontal position, in terms of latitude and longitude, and the echo sounder provides water depth measured at the same time as the geographic position. The survey was administrated using the most recent HYPACK survey software version 6.2.

Figure 6. Surveying cross sections.

Several sources may induce errors in the survey. The echo sounder sometimes became unstable in shallower water, mostly when water depth became shallower than 2 ft (0.6 m) in combination with relatively rough conditions. Occasionally, the echo sounder will return a reading of zero. These erroneous readings were removed during the data processing. The reason for the zero reading is not clear.

Occasionally, the echo sounder returned a reading that was apparently twice the water depth (Figure 7). This seems to be caused by multiple reflections of the sound signal, i.e., the signal was reflected back and forth twice between the bottom and the sensor. Very rarely the signal was reflected back and forth for more than two times. These points were corrected by simply dividing the multiple reflections by two. A computer routine was developed to correct these apparent multi-reflections. The program will check the general trend of water depth and compare with adjacent depth. If a point was approximately twice of those adjacent measurement, it would be corrected by dividing by two (or three or four under rare occasions). Figure 7 illustrates the multiple reflections and the corrected water depth (solid square). The reason for the multiple reflections is not clear. Bottom conditions, e.g., hard sand and oyster-reef bottom versus soft mud bottom, may have some influences. The HYPACK software also allows a certain degree of data smoothing during the initial data quality check and processing.

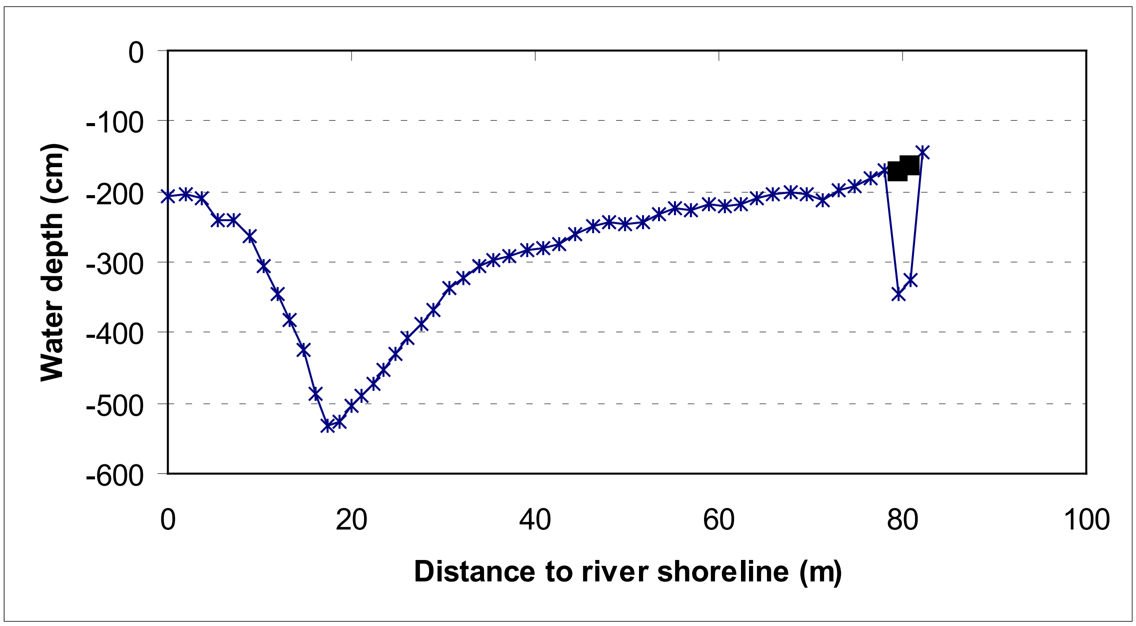

Figure 7. Multiple reflections in the echo sounder record. The solid squares are corrected water depth. An example of a cross section at Peace River (from an earlier SWFWMD project).

Because the echo sounder is mounted on a floating platform, wave motions can cause errors in the measurement. Various software packages are available to remove uncertainties caused by wave motion. Typically, a certain filter is applied to remove regulated wave motions. For the present project, influences of wave motions were minimal due to the relatively restricted water bodies.

The field operation over relatively open water, e.g., in the estuaries, was conducted during calm conditions to minimize influences of waves. No field operation was conducted when the waves were higher than 1 ft. The waves in the project area were largely local-wind generated, with short wavelength and wave period. Most of the time, the wavelength is shorter than the length of the survey vessel. Motions caused by these short waves are not apparent in the record and are not possible to remove. Given that all the field operations were conducted with waves far less than 1 ft, it was decided that wave-motion filtering was not necessary and was not likely to improve the data accuracy.

Wave motions seemed to have some influence on the performance of the echo sounder. Under relatively rough conditions, more zero readings and more multiple reflections were observed. The reason for the reduced sensor performance under rough conditions is not clear. The wave motion may also induce pitch and roll of the survey vessel. The influences of the pitch and roll are not apparent in the data record. It was difficult to detect because of the short wave period and wavelength, which tend to induce rather irregular motion. No procedure was adopted to remove the potential influence of pitch and roll. Their influences are believed to be negligible for this project.

Another uncertainty associated with the floating platform survey was caused by the tidal water-level variations. Nearly the entire study area is influenced by tides, both astronomical and meteorological. To improve the sensor performance, especially in shallow areas, the field operations were mostly conducted during high tides. It is necessary to remove the influence of tidal water-level variations. The elevation of the water surface was measured by the RTK GPS. The trend of tidal water level change was clearly reflected in the GPS elevation measurements. The elevation of the bed level is obtained by subtracting the depth reading obtained from the echo sounder from the water surface elevation obtained from the RTK GPS. This is an improvement from the previous method of using tidal gages that are distributed typically several miles apart. The vertical datum NAVD88 was used in the survey.

Data Format and Organization

The horizontal latitude and longitude positions were recorded by the GPS in reference to NAD83. The latitude and longitude positions were converted to Florida State Plane coordinates (NAD 83) and UTM 17, in meters, using the CORPSCON (Version 6) software developed by the U.S. Army Corps of Engineers. The digital files are submitted in the formats of Excel spreadsheet and ASCII Text. The data are submitted in four sets includes:

Set I: Surveyed data, which include

a) Surveyed shoreline positions in Florida State Plane and UTM 17 coordinates in meters and elevations in centimeters (NGVD88 – cm);
b) Surveyed centerline positions in Florida State Plane and UTM 17 coordinates in meters and elevations in centimeters (NAVD88 – cm);
c) Surveyed cross-sections in State Plane and UTM17 Northing in meters, State Plane and UTM17 Easting in meters, and elevation in centimeters (NAVD88-cm);

Set II: Edited data, which include

a) Edited shoreline positions in UTM17 coordinates in meters with no elevation information;

b) Edited centerline positions in UTM17 coordinates in meters and elevations in centimeters (NAVD88 – cm), largely the same as the surveyed data;

c) Edited cross-sections in UTM17 Northing in meters, UTM17 Easting in meters, and elevation in centimeters (NGVD88-cm), largely the same as the surveyed data;

Set III: GIS maps including the bathymetry contour and shoreline maps of the entire project area, in UTM17 coordinate system.

Set IV: JPG format of the GIS maps including the bathymetry contour and shoreline maps of the entire project area.

The GIS maps are preliminary in the sense that detailed work to improve the map presentation was not conducted. However, the data processing was completed. The details of the contour maps can also be improved by improving the data interpolation schemes in areas with complicated sinuosity. However, the overall bathymetric characteristics are clearly reflected in the present maps. It is beyond the scope of this project to produce detailed local bathymetry maps although the coverage of the field data is adequate to do so. It is worth emphasizing that the bathymetry here is interpreted by the USF researchers and may be different from other interpretations, although the differences are expected to be minor.

Deliverables

The final deliverables include a final report, consisting of two parts. Part I (this volume) documents the field operation procedures, data processing schemes, estimates of uncertainties, and data organization. Part II (accompanying volume) includes the GIS maps (in UTM17 Coordinates in meters, bathymetry in centimeters). All the processed data are delivered on one CD with each set as one folder.

Appendix D

Grabe, S.A. and Janicki, A. 2010. Characterization of macroinvertebrate communities of the Homosassa & Hall's Rivers. St. Petersburg, Florida. Prepared for the Southwest Florida Water Management District. Brooksville, Florida.

CHARACTERIZATION OF MACROINVERTEBRATE COMMUNITIES OF THE HOMOSASSA & HALL'S RIVERS

Purchase Order #07PO0001718

Prepared for:
Southwest Florida Water Management District

Prepared by:
Stephen A. Grabe and Anthony Janicki
Janicki Environmental, Inc.

SEPTEMBER 2010

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Jeffery Winter, assisted by Tim Smith (PBS&J) collected the benthic samples. Mote Marine Laboratory staff, under the direction of Jim Culter were responsible for the analysis of the samples. Michael Dema (Janicki Environmental, Inc.) produced the maps.

Dr. Thomas Frazer and Sky Notestein (Institute of Food and Agricultural Sciences, University of Florida) provided us with information on the vegetation and water quality characteristics of the Homosassa River.

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1.0 INTRODUCTION

The Southwest Florida Water Management District (SWFWMD or District) has requested that the benthic macroinvertebrate communities of the Homosassa River be characterized to facilitate the setting of minimum flows and levels for the system. In the case of the Homosassa River, the objective was to sample the soft-sediment benthos of all major habitats and along the longitudinal salinity gradient. Samples were also collected in the lower 2.5 river kilometers (RKM) of the Hall's River to characterize the structure of that river's benthos as well.

1.1 Minimum Flows and Levels

Minimum flows and levels (MFLs) are the "… flow below which significant harm occurs to the water resources or ecology of the area" (SWFWMD, 2001). Specifically, minimum flows are defined in Florida Statutes (372.042) as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area". MFLs may vary both seasonally and spatially within a river.

The general approach to developing an MFL for an estuarine water body is to establish defensible *quantitative* relationships between key ecological components of the system in question (*e.g.*, freshwater inflow and salinity) and a resource of concern (*e.g.,* benthic macroinvertebrates). The rationale for this approach is that the inflow regime and the resultant salinity distributions affect the structure and function of biological communities.

1.2 Benthic Macroinvertebrates

Benthic (bottom-dwelling) organisms are small but important invertebrates that include taxonomic groups such as aquatic insects, worms, snails, clams, and shrimp. Benthos lives in or on the substrates of rivers, estuaries, *etc.* Benthic organisms are generally sessile, although some species may undergo migrations into the water column (*e.g.*, amphipod crustaceans) or produce planktonic larvae (*e.g.,* polychaete worms). As a group, however, they are relatively sedentary and are considered to be effective integrators of a variety of environmental factors, including salinity (Boesch and Rosenberg, 1981; U.S.E.P.A., 1999). Unlike the more vagile nekton, most benthic invertebrates lack the mobility to escape large or rapid fluctuations in environmental conditions.

Benthic organisms occupy a variety of niches with respect to energy transfer. The benthos process organic material as detritivores, suspension feeders, and deposit feeders, forming an essential link in the transfer of energy to secondary consumers including other benthic organisms, finfish, and avifauna. Tubiculous and fossorial benthic organisms may fulfill an important role in reworking sediments. In this role as bioturbators, they may bring suspended sediments into contact with the water column thereby translocating nutrients and pollutants and oxygenating sediments.

1.3 Relationship Between Flow and Benthic Macroinvertebrates

With respect to supporting MFL development, the benthos is an important biotic resource that is responsive to changes in flow regimes. Flow is an influential component of riverine and estuarine systems. Changes in flow can potentially affect many ecological and environmental variables.

Flow affects the volume and velocity of the river, which directly affects benthos (Figure 1-1). Under extremely high flows, benthic organisms may be physically washed out of the system. Some aquatic insects take advantage of flowing water by undergoing "drift". Aquatic drift can reduce overcrowding and facilitate feeding. Additionally, flow affects salinity, dissolved oxygen, sediments, and nutrients, which also affect the abundance and distribution of the benthos (Figure 1-1).

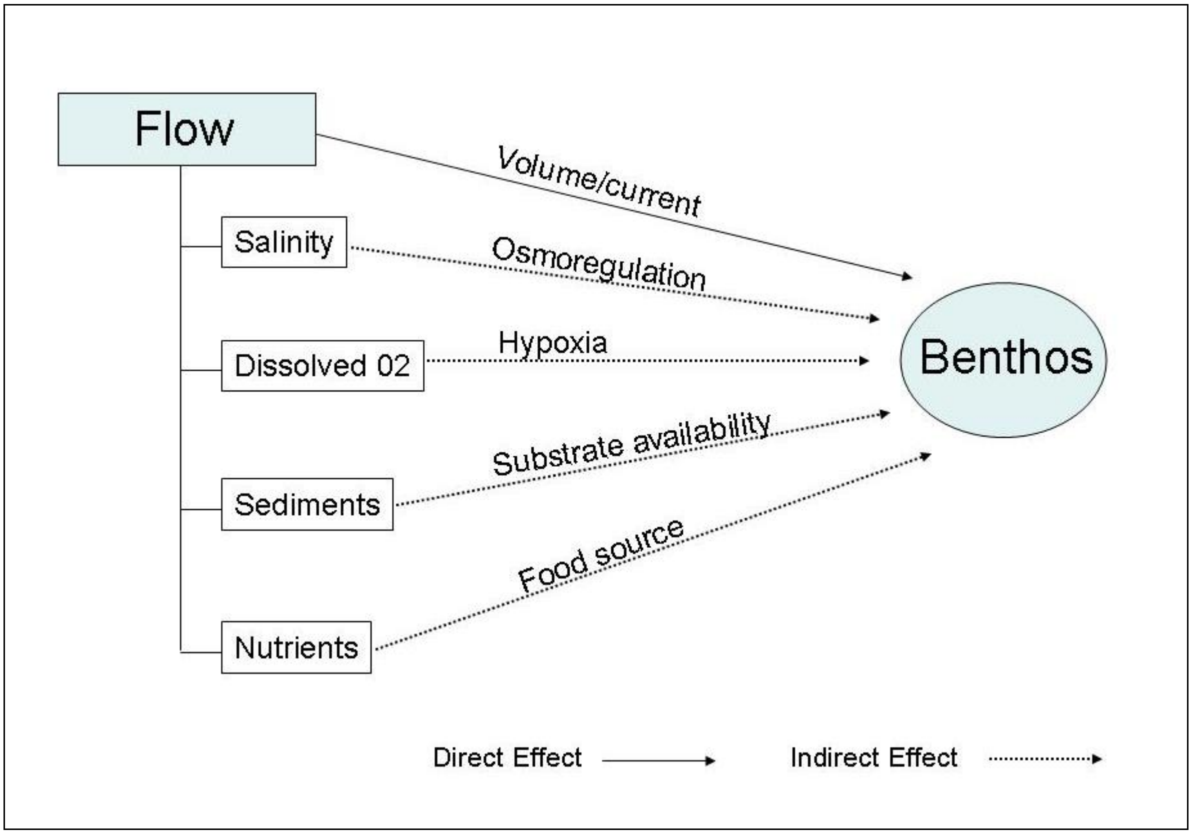


Figure 1-1. Conceptual diagram showing the direct (solid line) and indirect (dashed line) effects of low on benthos.

Salinity is the most important physical factor affecting the biota of tidal rivers. Salinity is largely influenced by the amount of freshwater inflow entering an estuary, and it is typically negatively correlated with flow. Salinity can affect the distribution and abundance of individual species, and the overall composition of the benthic community. During high flow periods, salinity at a particular location is expected to be lower and may provide new habitat for the more motile species that are intolerant of elevated salinities. During low flow periods, saline waters may penetrate further upstream, facilitating upriver habitat expansion for species with higher salinity requirements and compression of the habitats available for freshwater species that are less tolerant of saline intrusion. Generally, the salinity gradient will shift upstream and downstream based on flow conditions.

Benthic organisms are limited in their distribution within a tidal river by the physiological challenges and stresses associated with variable salinity environments. Osmotic limitations restrict the ability of many freshwater species from using habitats in downstream portions that are tidally influenced. Marine species also face osmotic problems, which restrict access to upstream freshwater habitats. True estuarine species typically tolerate a wide-range of salinities, although they may have discrete "preferences" for optimal reproduction and growth.

In summary, salinity is less of an acute stressor and more a chronic stressor for estuarine invertebrates. For example, the common isopod *Cyathura polita* can complete its life cycle over salinities ranging from 0 to 30 ppt. Northeastern populations are, however, capable of osmoregulation in distilled water for up to 12 hours (Kelly and Burbanck, 1976).

Changes in the timing and amount of freshwater inflow may alter the salinity regime such that shifts in dominant species occur. The physical environment may become less favorable for some species and more favorable for others. That is, the "preferred" salinity regime may now occur at a different time, in a different location, or occupy a smaller area of the system than currently. For example, the displacement of a particular salinity regime could move it to a reach of the river where the sedimentary factors are unfavorable (*cf.* "static" *vs.* "dynamic" habitats of Browder and Moore, 1981). Since sediment type is also a key abiotic factor affecting the structure of benthic communities, community structure could be altered. Changes in freshwater inflow then may have profound effects in terms of energy flow within the system as well as the physical reworking of the sediments.

Flow can also affect dissolved oxygen concentrations by modifying residence times and by physically altering stratification conditions. Increased residence times can be associated with decreased dissolved oxygen.

Freshwater flow affects both concentrations and loadings of other water quality constituents (Boynton and Kemp, 2000; Gillanders and Kingsford, 2002). Dissolved constituents such as ions, dissolved nutrients, and metals may be diluted at higher flows and concentrated at lower flows (FDER, 1985; Grabe, 1989). The magnitude and timing of freshwater inflows affects the amount of nutrients and organic matter that enters a waterway. Thus, increased productivity may occur after a period of increased flows (Kalke and Montagna, 1989; Bate *et al*., 2002). Sediment loads downstream are also increased during high flows (*e.g.*, the Mississippi River delta). Loadings of contaminants, including metals and organic compounds that bind to smaller particles (Seidemann, 1991) are often associated with increased sediment loads. Additionally, increased sedimentation may suffocate sediment dwelling organisms.

Freshwater inflow will also affect stream current velocities. Current velocity affects substrate composition by influencing the available parent material as well as organic inputs. The main components of substrate composition are grain-size, the interstitial spaces between the grains, and the presence or absence of organic detritus. Larger grained sediments drop out from the current first, and are deposited furthest upstream. Finer grained sediments are carried further downstream, with the finest sediments being carried the furthest. Organic inputs may be of various sizes, ranging from fallen trees to small organic fragments. The interstices, or the small spaces between larger grained substrate material, form micro-habitats that are used by particular benthic organisms; the interstitial spaces also provide an area for the finer grained organic matter to collect.

Residence time affects the ability of phytoplankton to take up nutrients, as well as the ability for secondary producers to consume phytoplankton, and this extends to other consumers as well. Higher flows are associated with increased nutrient loading. Lower flows permit a longer residence time for chlorophyll and nutrients. During high flow conditions, flushing is more rapid and residence time in the river is reduced (Peterson and Festa, 1984; Jassby *et al*., 1995; Flannery *et al*., 2007).

1.4 Quantitative Responses of Benthic Macroinvertebrates to Changes in Freshwater Inflow

Janicki Environmental, Inc. (2007a) developed a suite of quantitative tools capable of supporting the development of MFLs for the District. The expected quantitative responses of the benthos to changes in freshwater inflow were defined. These quantitative responses are expected to integrate all of the direct influences of flow changes and the indirect influences of flow changes (*e.g.,* salinity changes, dissolved oxygen concentration changes). Quantitative responses were derived in an unbiased manner from a large (>2,000 samples) database extending over two decades from 12 southwest Florida tidal rivers.

The species that make up estuarine benthic communities exist in a continual state of change, but the basic structure of the community may be observed to have a relatively predictable response signal above an often high degree of natural variability.

The spatial and temporal distributions (presence/absence response patterns) of various organisms within a tidal river can be limited by the physiological challenges and stresses associated with variable flow environments. True estuarine species are typically euryhaline and have adaptations that allow them to live within a wide range of salinity conditions.

Species abundances are also affected by the stresses caused by altered flows. Such changes may affect the success of individual animals within a species, consequently affecting the overall abundance of that species. For example, while the distribution of a given species may be determined by salinity, species able to tolerate saline conditions may still be affected by salinity-related stressors. Species typically have an optimal salinity that is somewhere within the range of salinity that they may be able to inhabit. The salinity in which the early life stages of certain species develop, may impact their growth and survival rates. It will also affect the availability of prey and where adults of the species congregate and forage.

Community structure, which integrates species presence and abundance, is also dependent upon the salinity regime. Responses in the benthic community are expected to be the composite result of the affects of salinity on all the individual species within the community, as described previously. Community responses include derived metrics such as taxa richness and diversity and their responses to changes in freshwater inflow. Species abundance responses are expected to be more affected by differences in collection methodologies between monitoring programs, and particular care must be used when analyzing such data across programs.

1.5 Description of the Study Area

The Homosassa River (Figures 1-2 and 1-3), an "Outstanding Florida Water" in Citrus County, Florida, originates at Homosassa Springs and other smaller springs and flows ~12.75 km to the Gulf of Mexico. The main springs cluster (Homosassa Springs #1, #2, and #3) forms a pool ~58-m by 87-m and 19 to 20-m deep (Florida Geological Society, 2008). For the purpose of this report, the approximated 250 m segment of the Homosassa River downstream from this pool is referred to as the spring run. A smaller spring vent, known as Homosassa River #1, is located approximately 150 yards southwest of the main springs cluster. Other small springs in the complex include Blue Hole Spring, Banana Spring, and a number of unnamed springs (Yobbi and Knochenmus, 1989). Homosassa Springs #1, #2, and #3 contribute the most flow. Yobbi and Knochenmus (1989) report an average discharge of 106 cfs for Homosassa Springs.

Jones *et al.* (1997) note that the main springs discharge brackish water and the chemistry of spring-flow varies considerably with the tidal cycle. They report mean conductivities of 3,245, 5,694 and 1,339 μS cm^{-1}, respectively, for Homosassa Springs #1, #2 and #3 at low tide. The Homosassa River #1 spring is also brackish; Jones *et al.* (1997) report a mean conductivity of 4,160 μS cm^{-1} for the spring at low tide.

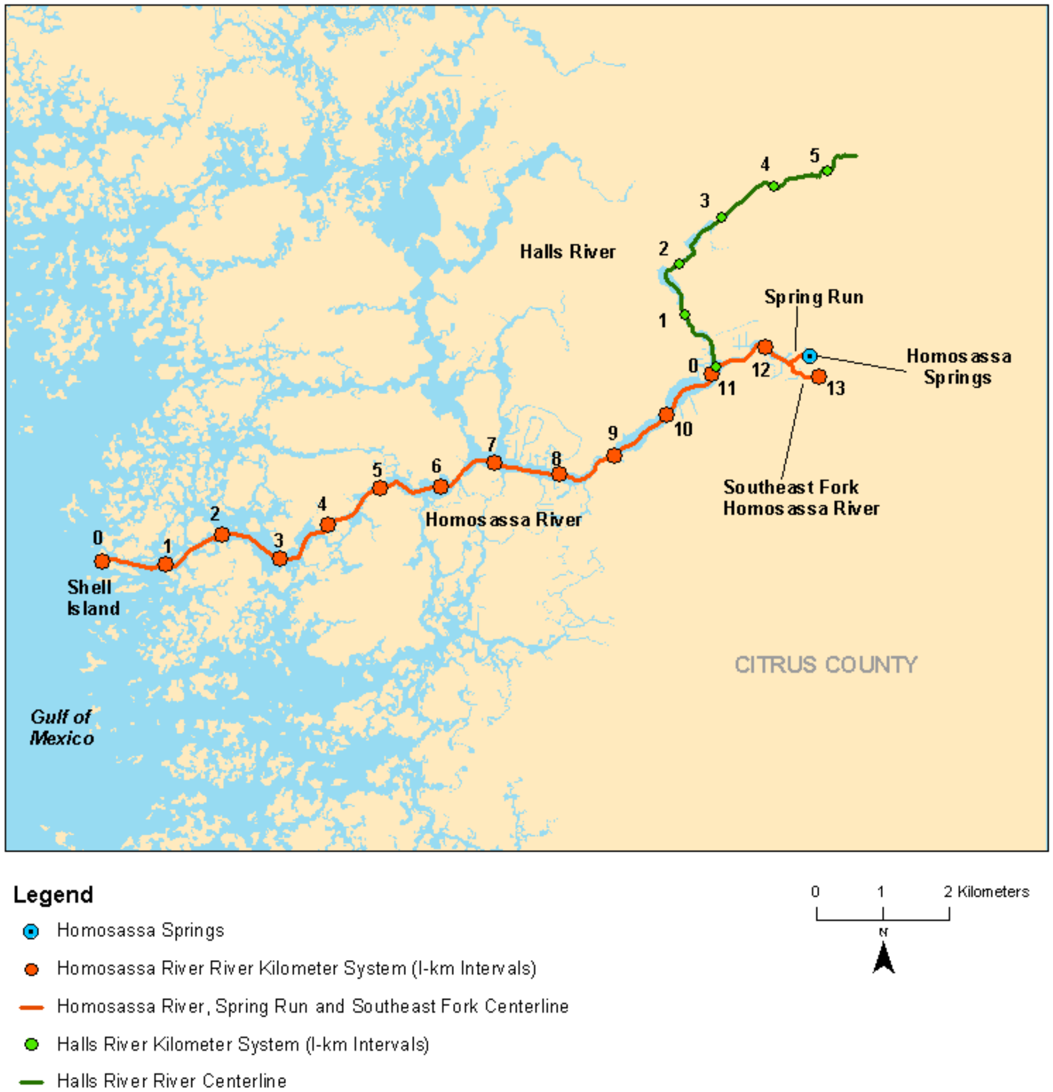


Figure 1-2. **Homosassa River (including the spring run and Southeast Fork) and Hall's River in Citrus County, Florida, with river centerlines and labeled river kilometers.**

Figure 1-3. The Homosassa River looking northeast from the bridge at West Fishbowl Drive towards the mouth of the spring run.

For this report, the Southeast Fork of the Homosassa River is the approximate 0.4 RKM portion of the river upstream from the bridge at West Fishbowl Drive (Figure 1-2). The shoreline is dotted with residences (Figure 1-4). This reach contributes, on average, ~69 cfs from at least six springs:

- Abdoney
- Belcher
- Trotter Main and Trotter #1
- McClain
- Pumphouse (Champion and Starks, 2001)

Champion and Starks (2001) observed that water chemistry of the springs in the Southeast Fork proper does not appear to be affected by the tidal cycle. They recorded a conductivity of 359 $\mu S\ cm^{-1}$ at Pumphouse Spring and 420 $\mu S\ cm^{-1}$ at Trotter Main Spring.

Tidal influences are, however, evident at U.S.G.S. gage 02310688 (U.S.G.S., 2008a), located on the West Fishbowl Drive bridge that crosses the Southeast Fork of the Homosassa River. Tidal influences are seen not only in conductivity (ranging from 1,080 to 3,840 $\mu S\ cm^{-1}$ during 12-14 May 2008; U.S.G.S. 2008a) and discharge (lower on flood tides), but also in water temperature (higher on flood tides).

Figure 1-4. The Southeast Fork of the Homosassa River looking south-southeast from the West Fishbowl Drive bridge.

The Homosassa River ranges in width from about 60-m (upstream) to 300-m near the Gulf. Water depths range from ~1.5-m upstream to ~6-m near the Gulf (Yobbi and Knocnemus, 1989).

Salinity in the spring run (Figure 1-2), is typically >2.5 ppt (>5000 $\mu S\ cm^{-1}$). Conductivity measurements also indicate that the spring run is tidal (*cf*. Yobbi and Knochenmus, 1989; U.S.G.S., 2008b). Within the downstream portion of the river, salinities are least variable upstream of RKM 8 and vary most from the Gulf to RKM 6.4 (Yobbi and Knochenmus, 1989).

The sediments of the spring run are described as including "large patches of bare sand" (Yobbi and Knocnemus, 1989). Sediments in the remainder of the river are predominantly muds (>50% of the observations; Frazer *et al*., 2001).

Yobbi and Knochenmus (1989) report little vegetation in the spring run, a consequence of manatee feeding. The Long River Bridge, located in the run, includes a submarine barrier to help segregate "captive" manatees in the run from the wild manatees in the river. Within the river, Frazer *et al*. (2001) reported highest macrophyte and macroalgal biomass upstream of the marsh system during 1998-2000. *Najas* and *Myriophyllum* were the most frequently occurring macrophytes and *Lyngbya* and *Chaetomorpha* were the most common macroalgae.

The river supports a recreational fishery for redfish and seatrout. There is commercial fishing for blue crabs, and boats based on the Homosassa fish for stone crabs in the Gulf (Figure 1-5).

Figure 1-5. Stone crab boat docked along the Homosassa River.

The Halls River (Figures 1-2 and 1-6) extends northward ~4 RKM from its nexus with the Homosassa River at ~RKM 11. The river is difficult to navigate because it is shallow, very narrow in places, and has areas of dense macroalgal coverage. The river is tidal for its entire length (Champion and Starks, 2001). Although the number of springs and seeps that contribute to its average discharge of ~162 cfs is unknown (Champion and Starks, 2001), there are two well-defined springs. These are the Halls River Head Spring and Halls River #1 (Figure 1-2). The conductivity of the headspring was 3,260 $\mu S\ cm^{-1}$ in January 1999 (Champion and Starks, 2001). In this survey only the lower 2.6 RKMs is considered.

Figure 1-6. The lower Halls River looking north from the Halls River bridge.

2.0 METHODS

A total of 114 benthic samples were collected from the Homosassa and Halls rivers during 12-14 May 2008. Samples were collected at 104 stations in the Homosassa River (Figure 2-1), including ten stations in the Southeast Fork and five stations in the spring run (Figure 2-2). Ten stations were sampled in the lower Halls River (Figures 2-1 and 2-2). This Section summarizes the study design, field methods, laboratory procedures, and the data analysis approaches used in this characterization of the benthic assemblages of these two rivers.

2.1 Study Design

Benthic samples were collected at a total of 22 transects in the Homosassa River, and at single transects at the mouth of the spring run and in the Southeast Fork. Samples were also collected at five transects in the lower segment of Halls River. In addition to the samples collected at the transect sites, a total of eight haphazardly selected sites were sampled, including single sites within the Homosassa River and spring run and six sites within the Southeast Fork.

The transects established in the Homosassa River system were located from River Kilometer (RKM) 0 near Shell Island - upstream to the mouth of the spring run at RKM 12.5 and into the Southeast Fork near RKM 12.6 (Figure 2-1). Six of the transects were established ~1 RKM apart from RKM 0 to a point near RKM 5.2 , where salinities are typically mesohaline to polyhaline (Yobbi and Knochenmus, 1989). Thirteen transects were established ~0.5 RKM apart between RKM 5.6 and RKM 11, which is just downstream from the confluence of the Halls and Homosassa rivers. Five transects were established upstream of the junction of the two rivers.

Four benthic samples were collected at each transect in the Homosassa River, spring run and Southeast Fork. At all transects, two samples were collected in shallow areas near each shoreline and two samples were collected in or near the deeper channel. An effort was also made to equally distribute sampling at each transect between areas with submersed aquatic vegetation and/or filamentous algae and unvegetated areas. Benthic samples were also collected from six haphazardly (see U.S.E.P.A 2008 for method) selected stations in the Southeast Fork and single stations in the spring run and Homosassa River (Figure 2-2).

Five transects were sampled in the Lower Halls River between RKMs 0 to 2.6. At each transect, single benthic sample were collected in deep and shallow areas, yielding a total of two samples per transect.

2.2 Field Methods

At each sampling location the following measurements and observations were recorded:

- sample depth;
- latitude and longitude;
- measurements of water temperature, salinity/conductivity, dissolved oxygen and pH were made at relative near-surface and near-bottom depths; and
- field notes on habitat characteristics, including the presence/absence of submersed aquatic vegetation (SAV) and macroalgae.

Each benthic sample was then collected. Initially a grab sample of sediment was collected with a 0.04 m^2 Young-modified Van Veen sampler. Then, a 7.62 cm diameter (3") (area= 45.6 cm^2) aluminum pipe was inserted into the Young sampler to extract the actual benthic sample.

The core sample was bagged with an internal label. Magnesium sulfate solution was added to relax the organisms and then the samples were stored on ice. Samples were sieved through a 0.5 mm mesh to remove finer-grained particles of sediment and meiofauna. Samples were then fixed in a 10% solution of buffered formalin and Rose Bengal stain.

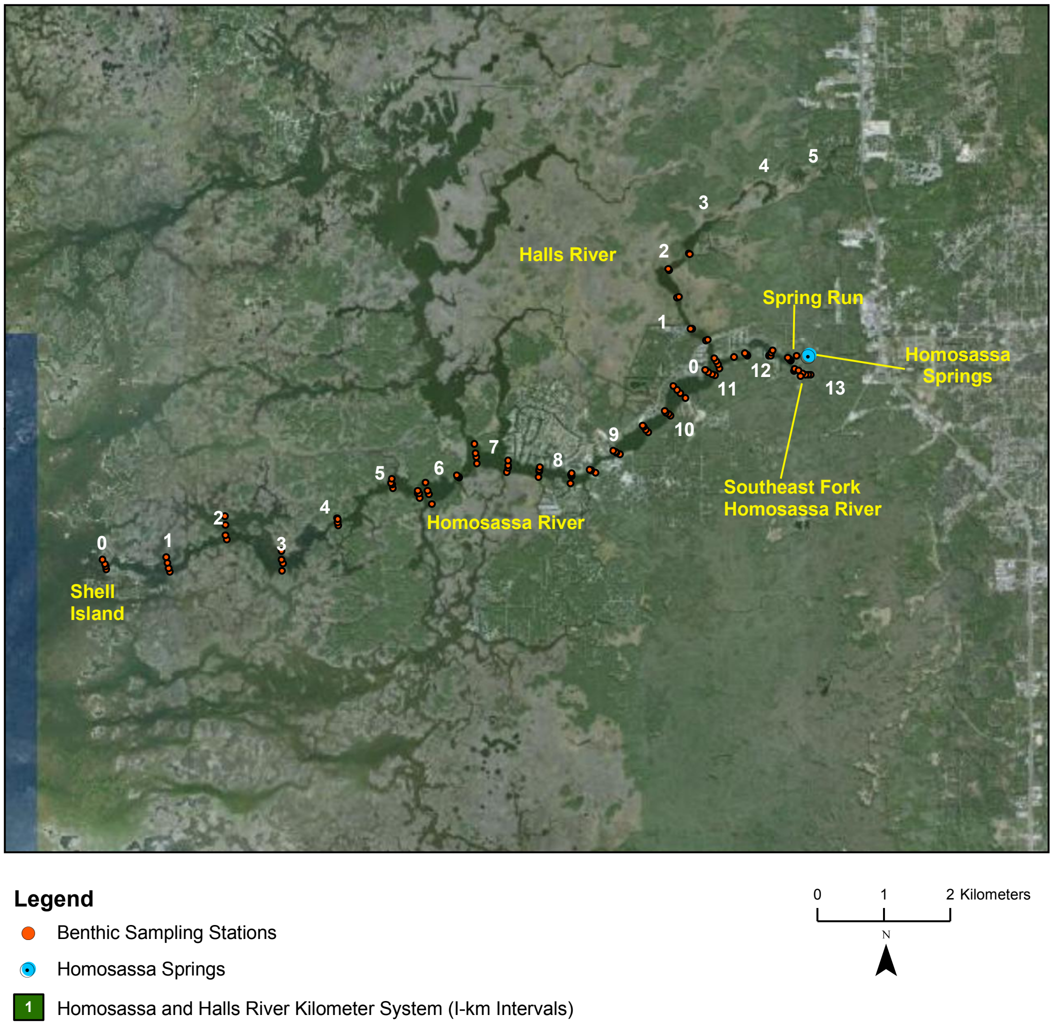


Figure 2-1. Location of benthic sampling stations in the Homosassa River (including the spring run and Southeast Fork), and the lower Halls River (Map provided by SWFWMD).

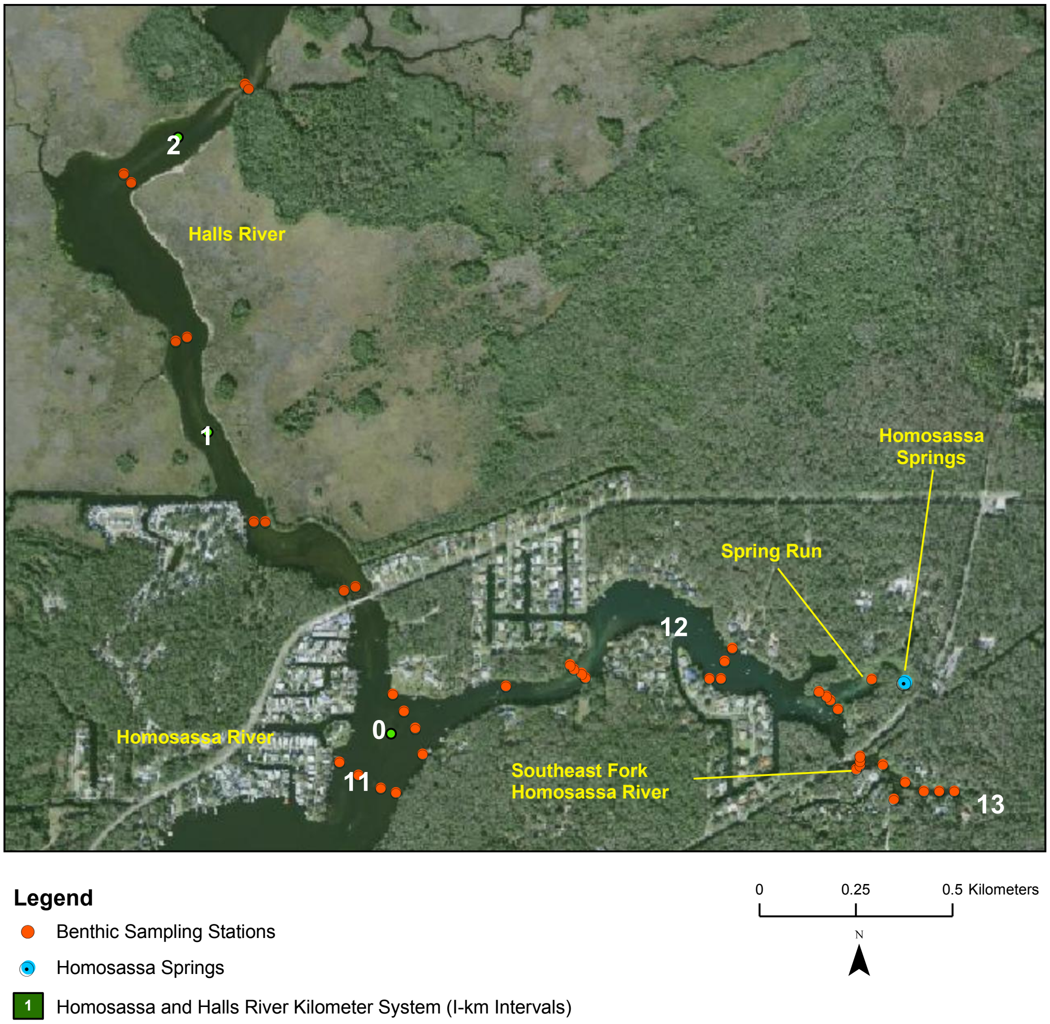


Figure 2-2. **Location of benthic sampling stations in the upper (≥RKM 11) Homosassa River(including the spring run and Southeast Fork) and the lower Halls River, May 2008 (Map provided by SWFWMD).**

2.3 Laboratory Methods

Macroinvertebrate samples were fixed in the formalin solution for at least 12 days, after which the samples were transferred to a preservative (a solution of 50% to 70% isopropanol or ethanol). All organisms were sorted from the samples, to at least 90% recovery, under a dissecting microscope. Macroinvertebrates were identified to the lowest practical identification level—typically genus or species. If an animal was a member of one of the "minor" taxonomic groups, such as the Nemertea, identifications might only be to that higher taxonomic level. Additionally, if an organism was damaged or a juvenile, identifications to the genus or species level could not always be made.

2.4 Data Analysis Approach

Four generic approaches to analyzing the benthic data were used, including:

- univariate biotic metrics;
- univariate tests (analyses of variance) to determine whether means of biotic and abiotic variables differed by depth strata and river kilometer;
- regression (linear and logistic) techniques were used to explore associations between biotic and abiotic variables; and
- multivariate analyses were used to explore how the benthos assemblage as a whole was organized.

2.4.1 Univariate Biotic Metrics

Three univariate metrics were calculated for the Homosassa and Halls River benthos as outlined below.

- Dominant taxa were identified for each river. Dominance was calculated as the geometric mean of the frequency of occurrence (a measure of the distribution in the river) and relative abundance (a measure of a taxon's contribution to the river's standing crop); for the 50 Dominant taxa the following metrics were also calculated:
  - mean numbers m^{-2};
  - mean salinity at capture; and
  - mean center of abundance (as RKM).
- Species (taxa) richness is the number of distinct species (taxa) identifiable in a sample. Species or taxa richness is the simplest representation of "diversity".
- Shannon-Weiner diversity is a metric that incorporates both numbers of taxa and evenness (the distribution of each species. For example if in a series of 10 samples and a total of 10 organisms, evenness is lower if the 10 organisms are only found in one or the samples and is higher if one is found in each sample).
- Total abundance (numbers of individuals m^{-2}) is an indicator of the standing crop of the benthic community. Extremely high or extremely low abundance can be indicative of a perturbed environment.

2.4.2 Univariate Tests

Analysis of Variance (ANOVA) was used to test for differences in mean values for the abiotic variables, numbers of taxa and, diversity, and total abundance among river kilometer groupings and depth strata (deep *vs*. shallow). All variables were natural log - transformed prior to analysis to normalize the data (Sokal and Rohlf, 1981). Where significant (p<0.05) differences in means were found by RKM, the Bonferroni comparison (Neter *et al.*, 1985) was used to test for differences between RKM pairs.

2.4.3 Regression Analyses

Forward stepwise multiple linear regression, using a *p* value of 0.05 for entry to the equation, was applied to quantify relationships between taxa richness and abundance in the Homosassa River and the measured environmental variables. The environmental variables (all measured at the time of collection) considered included:

- river kilometer;
- bottom depth;
- water temperature;
- salinity;
- pH;
- dissolved oxygen;
- sample depth; and
- temperature.

The resultant relationships and equations may be used to predict expected responses of the univariate community metrics to a "best fit" combination of abiotic variables.

Janicki Environmental, Inc. (2007a) employed univariate logistic regression (Peeters and Gardiniers, 1998, Ysebaert *et al.*, 2002) to estimate the probability of occurrence as a function of salinity for selected taxa from 12 Gulf Coast tidal rivers. The "optimum" or "preferred" salinity for each taxon was that with the highest probability of occurrence. An "optimal habitat range" was then calculated as the salinity $\pm$75% of the optimum (Peeters and Gardiniers, 1998). The taxa considered for this analysis were those with the highest dominance scores.

2.4.4. Multivariate Community Analysis

The spatial structure of the benthos of the Homosassa River and the lower Halls Rivers was examined using MDS and the ANOSIM test that compares the similarities of *a priori* defined "groups" (*e.g.,* RKM groups; RKM Group 0 $\leq$RKM 0.4; RKM Group 1=RKM 0.5$\leq$1.4,…) (Clarke and Warwick, 2001). MDS is an ordination technique in which rank similarities of a large number of variables are expressed as a two-dimensional map. The greater the distance between points (samples) on the MDS plot, the greater the difference between the samples. Samples with more similar benthic communities will be more closely aggregated in the MDS plot. For the survey of these two rivers, the interest is in comparing how similar or different the benthic communities of adjacent RKM groups were.

Abundance was 4th root transformed for all multivariate community analyses. The 4th root transformation in multivariate analyses permits a greater number of taxa to influence the results (Clarke and Warwick, 2001). The use of untransformed data yields results strongly influenced by the most abundant taxa. Cao *et al.* (1998) argue that "rare" taxa may be more sensitive to environmental perturbation than common species. Therefore, an analytical approach that is more responsive to the "community" rather than to only a few, numerically abundant taxa, was desirable. Thorne *et al.* (1999) demonstrated that the 4th root transformation is preferred in multivariate community analyses because it represents a "good compromise between untransformed and binary data". Therefore, the 4th root transformation was employed in the multivariate analyses.

Two MDS analyses are presented. The first presents each sample as an individual data point. The second analysis uses the mean abundances for each RKM group and presents a clearer picture of the spatial relationships.

3.0 RESULTS

This section presents a characterization of the hydrologic and physico-chemical characteristics of the Homosassa and lower Halls rivers, a description of the spatial characteristics of the benthic macroinvertebrate community, and the relationships between the benthic community structure and several abiotic variables.

3.1 Abiotic Characteristics

This section describes streamflow characteristics, salinity, and other physicochemical conditions measured during the May 2008 survey.

3.1.1 Streamflow

Historical flows from both the Homosassa main springs cluster (U.S.G.S. gage 02310678; U.S.G.S., 2008b) and the smaller springs in the Southeast Fork (U.S.G.S. gage 02310688; U.S.G.S., 2008a) indicated that the Southeast Fork contributed about two-thirds of the flow of the main springs (Table 3-1). Flows from the Southeast Fork were slightly more variable than those of Homosassa Springs. There was a seasonal cycle with a May-June minimum and a winter maximum (Figure 3-1). Flow data were not available for the U.S.G.S. gage in the Halls River.

The flows on the dates the benthic samples were collected, as well as over the preceding 30 and 60 days, were slightly lower than the long-term averages (Table 3-1; Figure 3-1). Tidal influences were also evident.

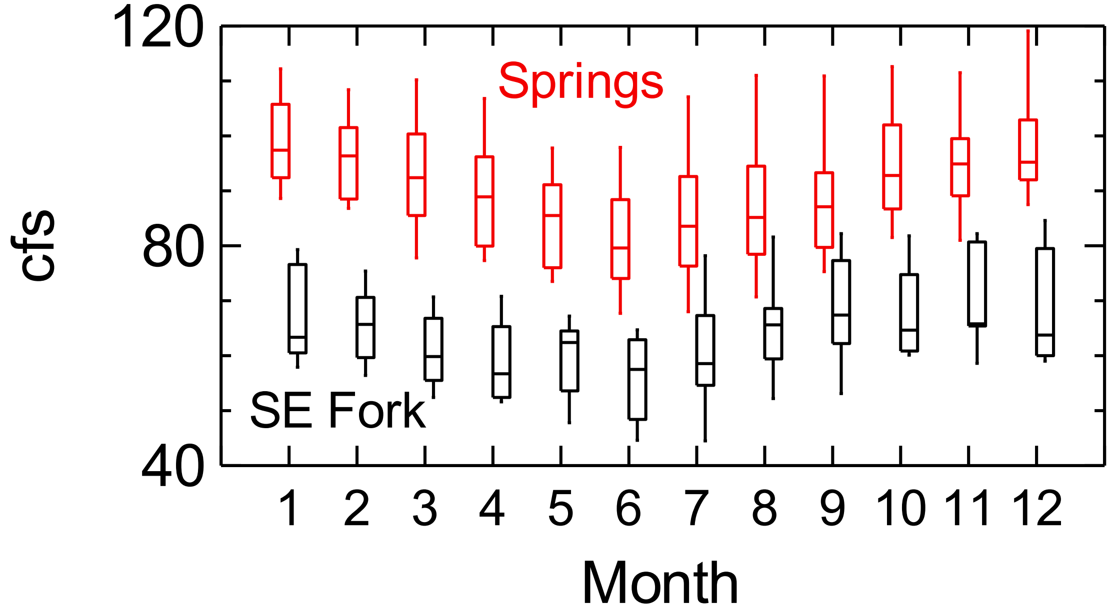
Table 3-1. Summary of mean streamflow (cfs) for the Homosassa Springs (02310678) and Homosassa Southeast Fork (02310688) U.S.G.S. gages.

Time Period	Homosassa Springs[a]	Southeast Fork[b]
1997-14 May 2008[c]	91	63
Sample Collection Period	78	54
30 Days Preceding Sample Collection	75	48
60 Days Preceding Sample Collection	80	52

[a]PERIOD OF RECORD (from USGS, 2008b): 1931-33, 1936, 1956, 1961, 1963-65 (misc. discharge measurements); August 1965 to September 1978, June 1988 to March 1989; October 1995 to present.

[b] PERIOD OF RECORD (from USGS, 2008a): 1932, 1933, 1936, 1946, 1956, 1963-65, 1976-86, 1997-2000; October 2000 to present.

[c]data from 1997 through 14 May 2008 were summarized since these represent the most recent period of continuous discharge measurements.



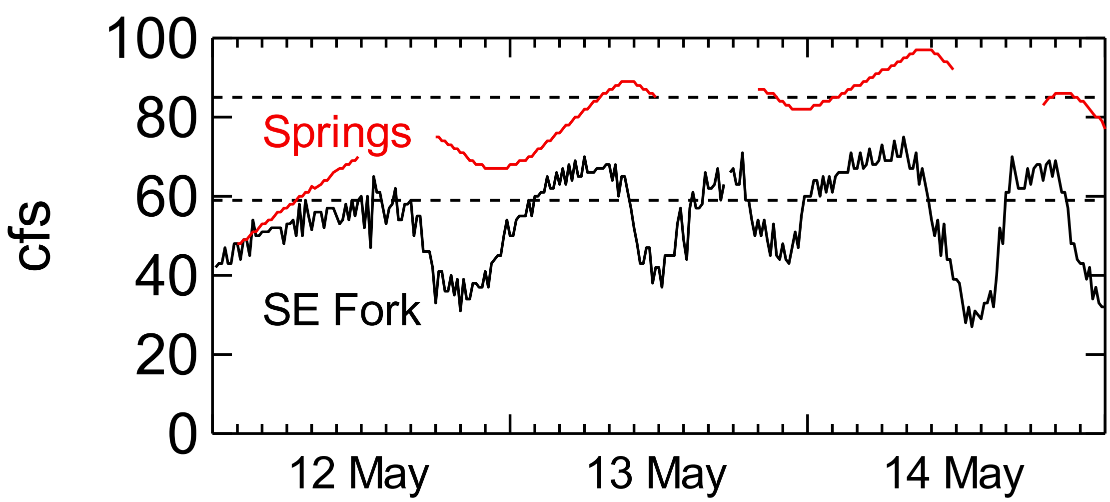


Figure 3-1. Box plot of monthly flows (cfs) (top) and flows every 15 minutes during 12-14 May 2008 (bottom) at the Homosassa Springs gage (USGS gage 02310678) and the Southeast Fork of the Homosassa River (USGS Gage 02310688). 12-14 May graph: lower horizontal line=Southeast Fork mean (2000-2007); upper horizontal line=Homosassa Springs mean (1996-2007) (modified from U.S.G.S. 2008a and 2008b).

3.1.2 Hydrographic and Sediment Characteristics

Water depths at sampled stations in the Homosassa River ranged up to 4.6 m and averaged 1.4 m (Table 3-2). Water depths in the Halls River and Southeast Fork were shallower than those of the Homosassa River (Figure 3-2).

Table 3-2. Summary of mean (range) near-bottom environmental variables measured at the time of benthic sample collection in the Homosassa River, spring run, Southeast Fork, and the Lower Halls River, 12-14 May 2008.

Variable	Homosassa River	Lower Halls River	Spring Run	Southeast Fork
Sample Depth (m)	1.4 (0.2-4.6)	0.5 (0.3-1.0)	1.1 (0.6-1.4)	0.5 (0.1-0.8)
Temperature (°C)	26.1 (24.1-28.6)	23.8 (23.4-24.1)	24.1 (23.6-24.6)	24.4 (23.4-25.4)
Salinity (ppt)	10.8 (1.1-24.1)	3.3 (2.7-5.4)	2 (1.1-3.0)	0.5 (0.5-0.6)
pH	7.69 (7.64-8.32)	7.46 (7.24-7.46)	7.86 (7.64-8.32)	7.96 (7.58-8.58)
Dissolved Oxygen (mg L^{-1})	6.7 (3.1-15.0)	2.9 (2.5-3.5)	6.7 (4.8-10.0)	7.6 (4.8-12.2)

Near-bottom water temperatures were warmest in the Homosassa and coolest in the Halls River (Table 3-2; Figure 3-3; Appendix 3-A1). Mean Homosassa River water temperatures were lower in RKM 0-1 than the rest of the Homosassa River (Figure 3-3; Appendix 3-A1).

Near-bottom salinities declined upstream in the Homosassa River (Figure 3-4) and were lowest in RKM 12, which includes the spring run and the Southeast Fork. Mean salinities in the Homosassa River, excluding RKM 12, were lower than those of the Halls River (Figure 3-4; Appendix 3-A2). Salinities in RKM 0-1 were similar to those of RKM 2-3 and those of RKM 2-3 were similar to those of RKM 4-9 (Appendix 3-A2). The mean salinities in the Halls River and RKM 12 of the Homosassa were similar (Figure 3-4; Appendix 3-A2).

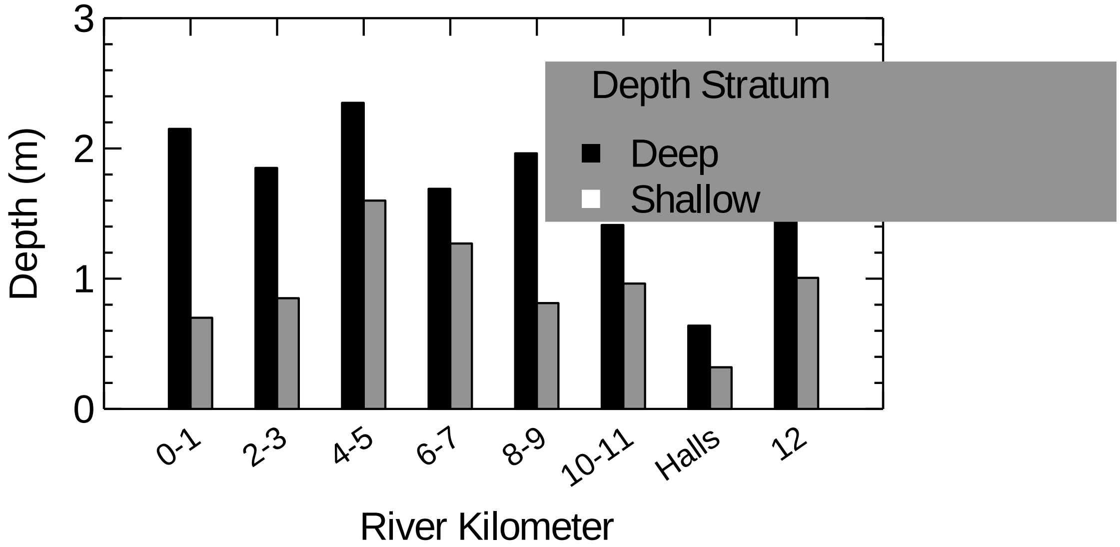


Figure 3-2. Bar plot of bottom depths by "deep" *vs.* "shallow" samples in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.

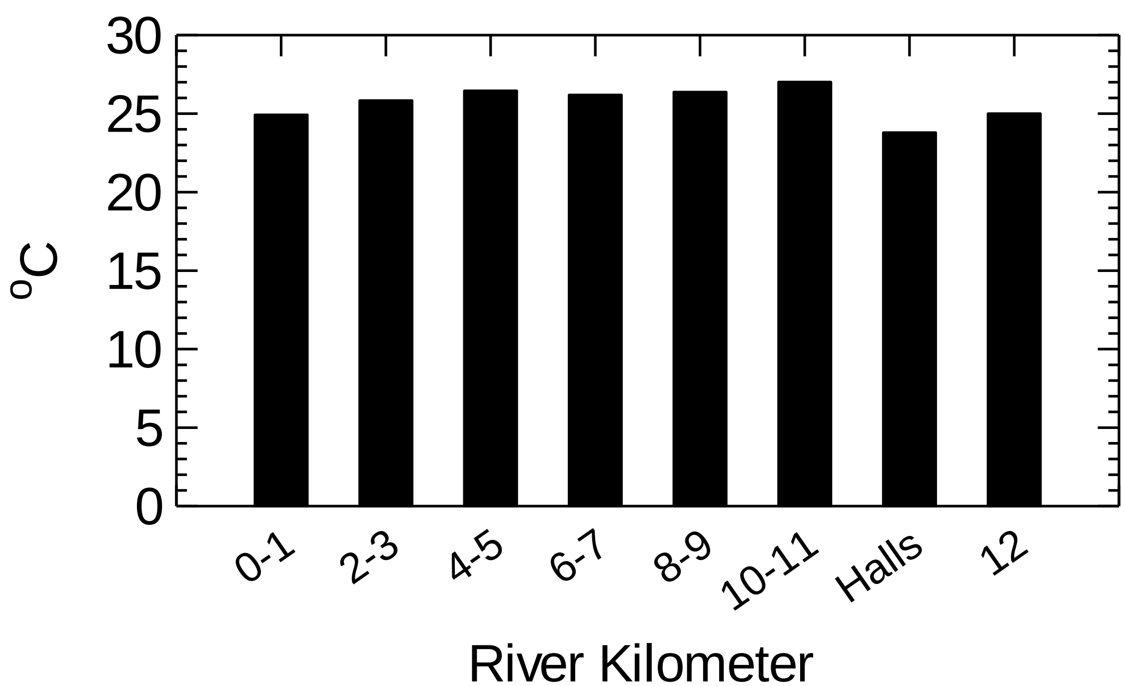


Figure 3-3. Bar plot of near-bottom water temperatures in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.

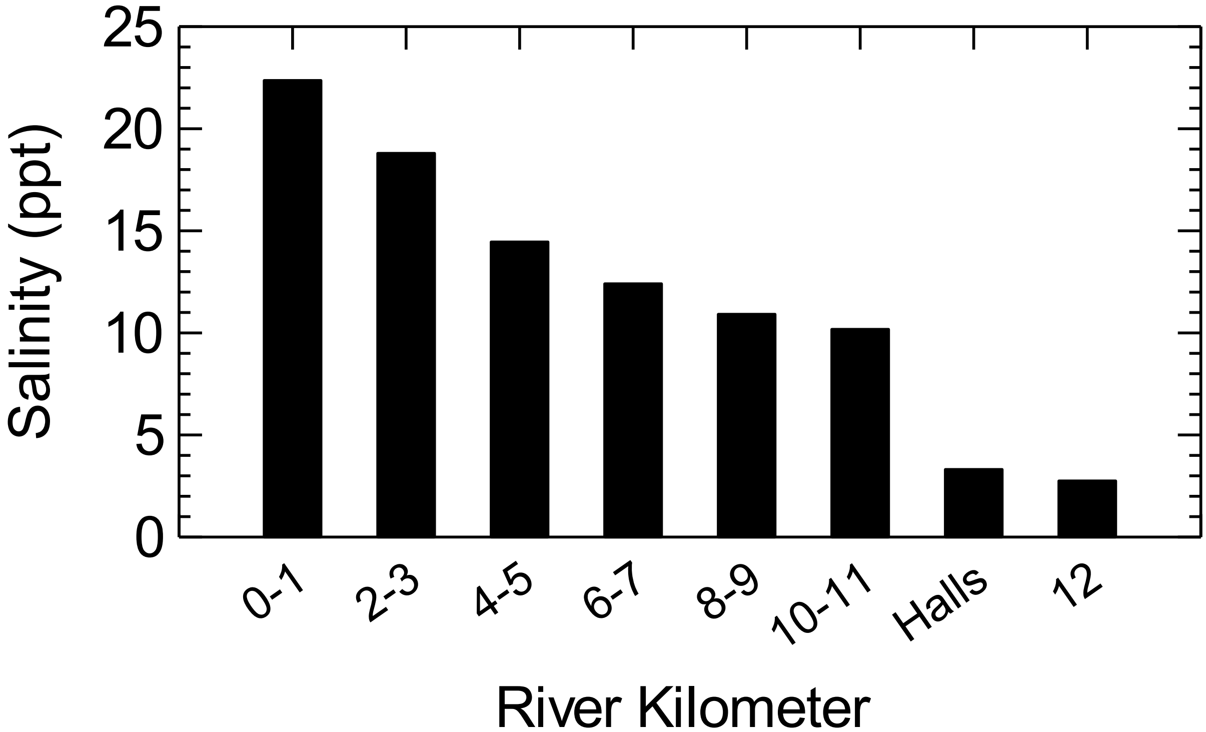


Figure 3-4. Bar plot of near-bottom salinity in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.

Near-bottom pH differed by RKM (Figure 3-5; Appendix 3-A3). Mean pH in RKM 0-1 was less than that of RKMs 4-5, 8-9, and the Halls River (Appendix 3-A3). Mean pH within RKM 12 as less than that of RKM 2-3 and the Halls River (Figure 3-5; Appendix 3-A3).

Near-bottom dissolved oxygen (DO) concentrations were generally greater in the Homosassa than in the lower Halls River (Figure 3-6; Appendix 3-A4). Mean DO was similar between shallow and deep depth strata (Appendix 3-A4).

Sediments were characterized qualitatively by the field crew (Appendix 3-B). Shell hash was typical of the two most downstream transects. The remainder of the river bottom was made up of mainly mud-sized sediments (silts, clays, and "muck"). Submersed aquatic vegetation was observed in 7.9% of the Homosassa River samples, 100% of the spring run samples, and 60% of the samples from the Southeast Fork (cf. Appendix 3-B). Macroalgae was found at 11.2% of the Homosassa River samples, none of the spring run samples, and 70% of the samples from the Southeast fork. Nine of the 10 Halls River samples had submersed aquatic vegetation but only one had macroalgae (Appendix 3-B).

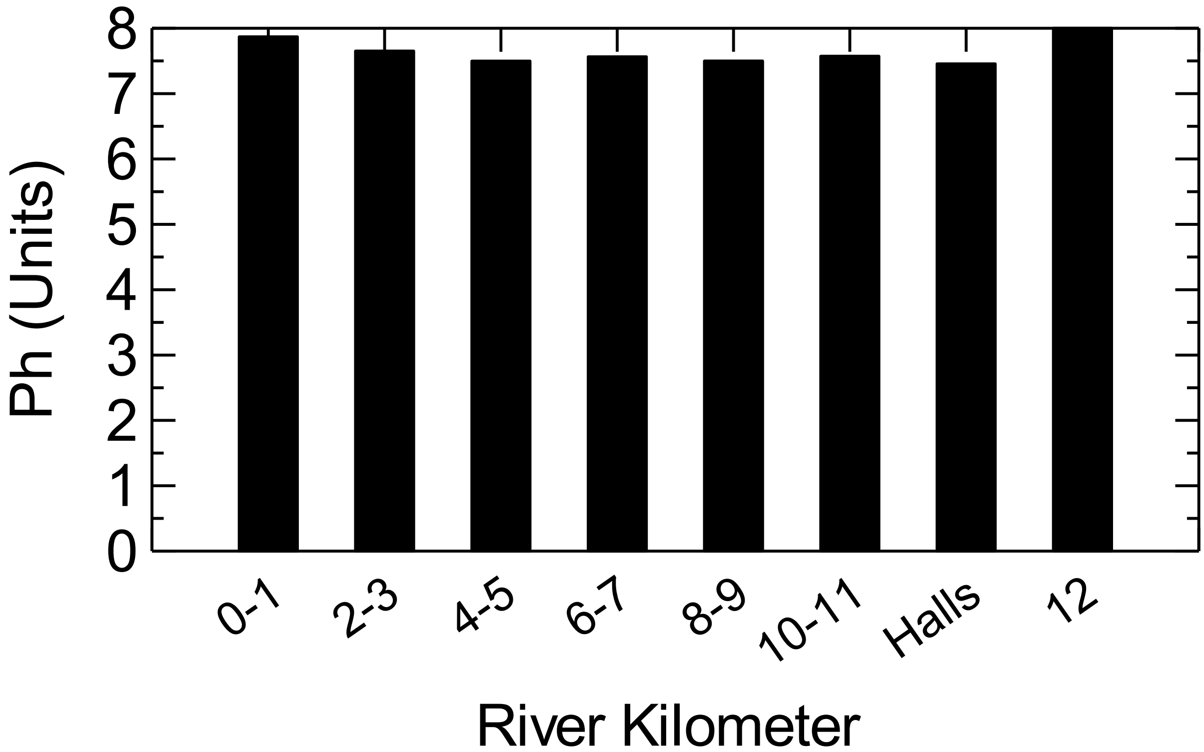


Figure 3-5. Bar plot of near-bottom pH values in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.

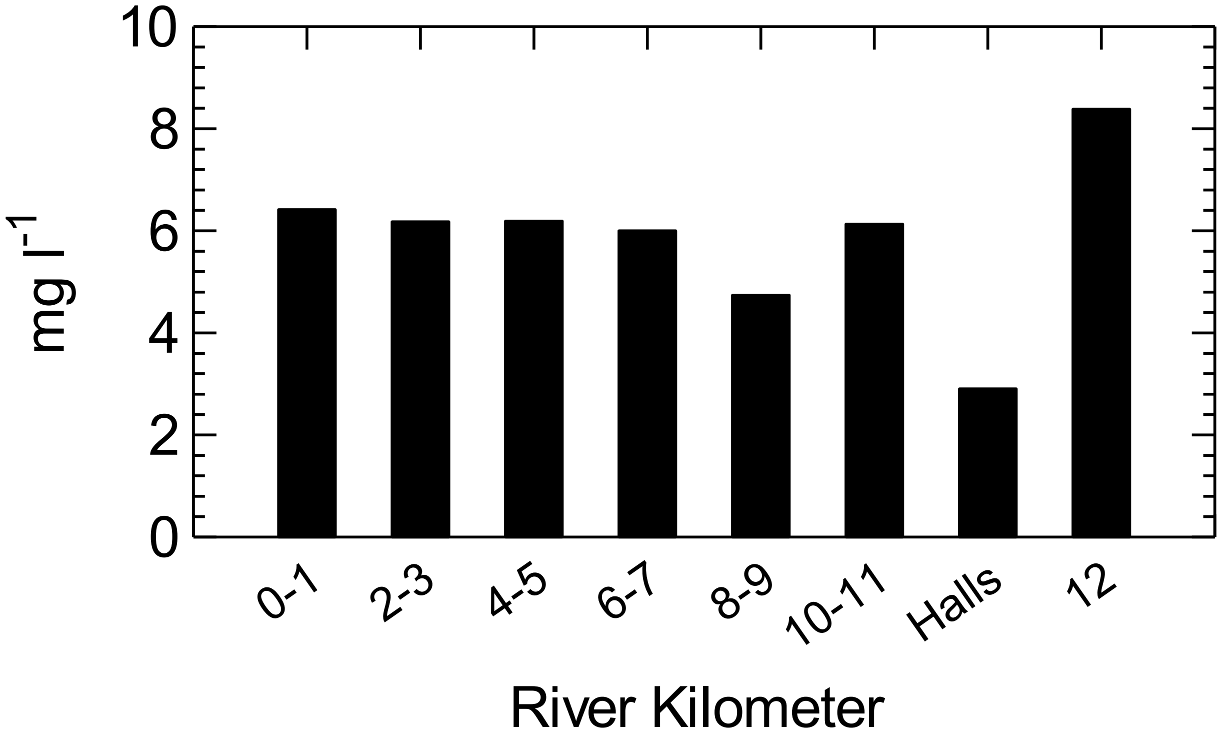


Figure 3-6. Bar plot of near-bottom dissolved oxygen concentrations in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.

3.2 Biota

Species characteristic of the Homosassa and Halls River are identified and compared by location within the river. Spatial patterns in the benthic community as a whole were investigated using MDS.

3.2.1 Dominant Taxa of the Homosassa and Halls Rivers

Species characteristic of these two rivers are identified by their Dominance score or value and compared. Additionally, the mean numbers of individuals per m^{-2}, the Center of Abundance (COA), as RKM, and the mean salinity where the taxa were collected were determined for the Homosassa River dominants. Data for taxa with the 50 highest Dominance scores are presented (these 50 taxa represent >91% of the mean total numbers of individuals).

The amphipods *Grandidierella bonnieroides* and *Ampelisca sp.,* along with the polychaete worm *Mediomastus* sp., were the highest ranked taxa (in terms of Dominance scores) in the Homosassa River, spring run and Southeast Fork (Table

3-3). Three amphipods *(Gammarus mucronatus, Cerapus benthophilus,* and *Grandidierella bonnieroides*), were also the top-ranked dominants in the Halls River of those taxa identified at least to Genus (Table 3-4). Twelve of the 50 dominants had COA in RKM 4-5 and 10 of the dominants had COA in RKMs 6-7 (Table 3-3).

Table 3-3. 50 Dominant benthic taxa, mean abundance, mean center of abundance (as RKM), and mean salinity at capture in the Homosassa River, spring run and Southeast Fork, May 2008.

Taxa	Mean numbers m^{-2}	Dominance	Center of Abundance (RKM)	Mean Salinity at Capture (ppt)
Actiniaria-Genera undet.	274	3.4	3.8	17.9
Nemertea-Genera undet.	118	2.3	3.8	17.0
Platyhelminthes-Genera undet.	322	2.6	11.9	1.3
Annelida				
Polychaeta				
Amphicteis gunneri	158	3.0	6.1	13.1
Apomatus sp.	310	1.9	7.1	13.7
Aricidea philbinae	518	5.4	2.2	19.6
Brania sp.	126	1.8	2.7	18.2
Capitella capitata complex	110	2.0	5.3	15.2
Cirrophorus sp.	320	2.3	0.3	22.6
Fabriciola sp.	598	4.9	3.3	17.5
Leitoscoloplos sp.	173	3.0	4.1	15.9
Lysilla sp.	101	1.6	1.2	21.0
Mediomastus sp.	3573	18.7	6.7	13.1
Parandalia tricuspis	335	4.9	7.3	11.9
Streblospio gynobranchiata	680	6.5	7.5	12.5
Typosyllis alosae	1004	4.6	0.4	22.1
Oligochaeta-Genera undet.	2156	14.9	10.6	3.4
Mollusca				
Bivalvia				
Angulus versicolor	152	2.9	6.1	13.9
Branchiodontes exustus	2318	6.9	6.4	12.9
Crepidula sp.	457	3.3	0.7	21.6
Parastarte triquetra	331	3.3	4.3	16.2
Gastropoda				
Acteocina canaliculata	76	1.6	5.6	13.5
Hydrobioidea-Genera undet.	440	4.4	8.4	11.0

Taxa	Mean numbers m^{-2}	Dominance	Center of Abundance (RKM)	Mean Salinity at Capture (ppt)
<u>Crustacea</u>				
Cumacea				
Cyclaspis varians	82	1.8	4.1	15.9
Isopoda				
Cassidinidea ovalis	535	4.8	3.1	17.2
Cyathura polita	625	6.5	9.3	3.7
Valvifera-Genera undet.	213	3.3	10.7	4.9
Xenanthura brevitelson	467	5.7	5.1	14.4
Tanaidacea				
Halmyrapseudes cf. Cubensis	1685	9.6	4.0	16.0
Hargeria/Letochelia sp.complex	461	5.3	6.3	12.4
Kalliapseudes macsweenyi	1186	3.3	0.3	22.7
Amphipoda				
Americorophium ellisi	457	4.3	10.2	10.6
Ampelisca sp.	5848	23.7	6.0	13.4
Amphipoda-Genera undet.	1504	9.8	7.9	8.3
Aoridae-Genera undet.	937	4.6	11.4	1.7
Cerapus benthophilus	204	2.8	2.8	5.2
Corophiidae-Genera undet.	474	3.7	4.5	10.6
Elasmopus sp.	1154	3.6	0.1	22.6
Gammarus mucronatus	903	8.2	5.9	3.9
Grandidierella bonnieroides	5208	25.6	10.4	4.3
Hourstonius laguna	598	4.4	5.5	14.0
Hyalella sp. C	2453	8.0	12.0	0.7
Melitidae-Genera undet.	383	7.4	5.6	13.2
Caprellidae-Genera undet.	211	2.0	0.6	21.9
Decapoda				
Panopeidae-Genera undet.	259	3.8	5.3	12.1

Taxa	**Mean numbers m^{-2}**	**Dominance**	**Center of Abundance (RKM)**	**Mean Salinity at Capture (ppt)**
<u>Insecta</u>				
Diptera				
Chironomidae sp. -Genera undet.	898	6.7	11.4	2.1
Chironomus sp.	230	2.5	10.9	8.4
Dicrotendipes sp.	758	5.3	11.8	1.3
Procladius sp.	128	2.1	9.2	3.7
Pseudochironomus sp.	246	1.9	11.9	0.5

Table 3-4. 50 Dominant benthic taxa and their mean abundance in the lower Halls River, May 2008.		
Taxa	**Mean numbers m^{-2}**	**Dominance**
Nemertea-Genera undet.	22	0.8
Annelida		
Polychaeta		
Amphicteis gunneri	66	2.5
Laeonereis culveri	175	5.2
Polydora socialis	22	0.8
Streblospio gynobranchiata	22	0.8
Oligochaeta-Genera undet.	1621	18.6
Hirudinea-Genera undet.	22	0.8
Mollusca		
Bivalvia		
Branchiodontes exustus	22	0.8
Polymesoda caroliniana	1643	17.4
Gastropoda		
Hydrobioidea-Genera undet.	482	8.6
Crustacea		
Isopoda		
Cyathura polita	1029	16.8
Tanaidacea		
Hargeria/Letochelia sp. Complex	44	1.2
Amphipoda		
Amphipoda-Genera undet.	1029	13.7
Cerapus benthophilus	7118	33.0
Corophiidae-Genera undet.	2256	23.5
Gammarus mucronatus	11388	49.4
Grandidierella bonnieroides	4271	32.3
Decapoda		
Panopeidae-Gen. Undet.	460	9.2

Taxa	Mean numbers m^{-2}	Dominance
<u>Insecta</u>		
Ephemeroptera-*Stenonema* sp. + Genera undet.	22	0.8
Diptera		
Chironomidae-Genera undet.	285	8.3
Chironomus sp.	22	0.8
Cryptochironomus sp.	66	2.5
Dicrotendipes sp.	66	1.4
Polypedilum halterale Group	131	2.8
Procladius sp.	416	8.7
Pseudochironomus sp.	22	0.8

Overall, the benthos of the Homosassa River system is a diverse assemblage comprised of taxa generally similar to those of other Springs Coast tidal rivers (Janicki Environmental, Inc., 2007a). The proportionately high numbers of crustaceans in the benthos in particular, is similar to the relative abundances observed for this group in the Anclote River (Janicki Environmental, 2007b).

3.2.2. Spatial Patterns in Univariate Community Metrics

Three univariate metrics of community structure were selected for analysis of their longitudinal distribution. The metrics are:

- numbers of taxa;
- Shannon-Wiener diversity; and
- total abundance (as numbers of individuals m^{-2}).

Both numbers of taxa and diversity decreased upstream to RKM 10-11 in the Homosassa River and then increased in both the lower Halls River and in RKM 12, which includes the spring run and Southeast Fork (Figures 3-7 and 3-8). The largest decline in numbers of taxa occurred between RKMs 0-1 and 2-3 (Figure 3-8). The numbers of taxa in RKMs 10-11 was less than any other portion of the Homosassa River, although it was similar to that of the lower Halls River (Figure 3-7; Appendix 3-C1).

The longitudinal decrease in diversity was more gradual (Figure 3-9). Diversity was lowest in RKMs 10-11 of the Homosassa River (Figure 3-8; Appendix 3-C2), although diversity in the lower Halls River, RKMs 8-9 and 12 was similar to that of RKM 10-11 (Appendix 3-C2).

Total abundance was highest within RKM 0-1, although there were no significant differences in abundance between RKM 01 and RKMs 4-7 and RKM 12 (Appendix

3-C3). Abundance was lowest within RKMs 10-11 (Figure 3-9). The station at RKM 0.3 had >220,000 organisms m^{-2}. The total abundance values near the mouth of the Homosassa River are among the highest of the Gulf Coast tidal rivers evaluated by Janicki Environmental, Inc. (2007a). The two most abundant taxa at this site were the tanaid *Kalliapseudes macsweeneyi* (>77,000 m^{-2}) and the amphipod *Elasmopus* sp. (>26,000 m^{-2}).

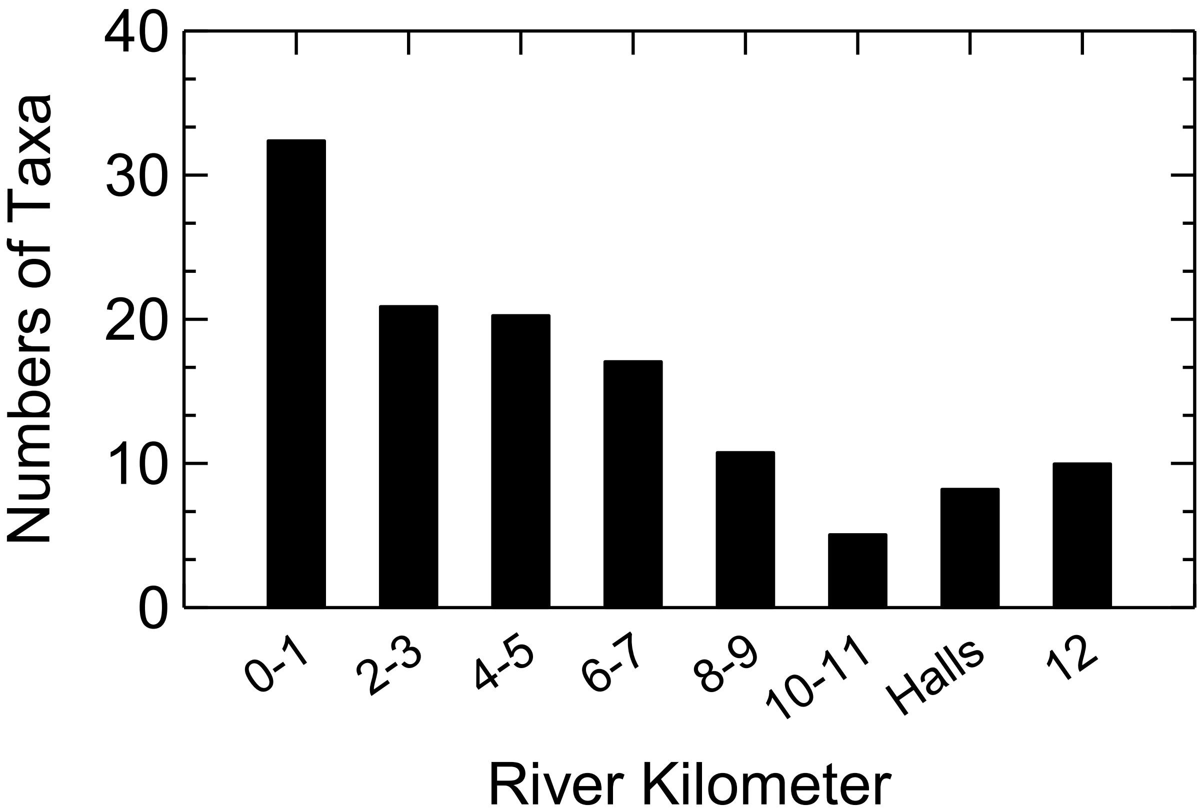


Figure 3-7. Bar plot of mean numbers of taxa in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.

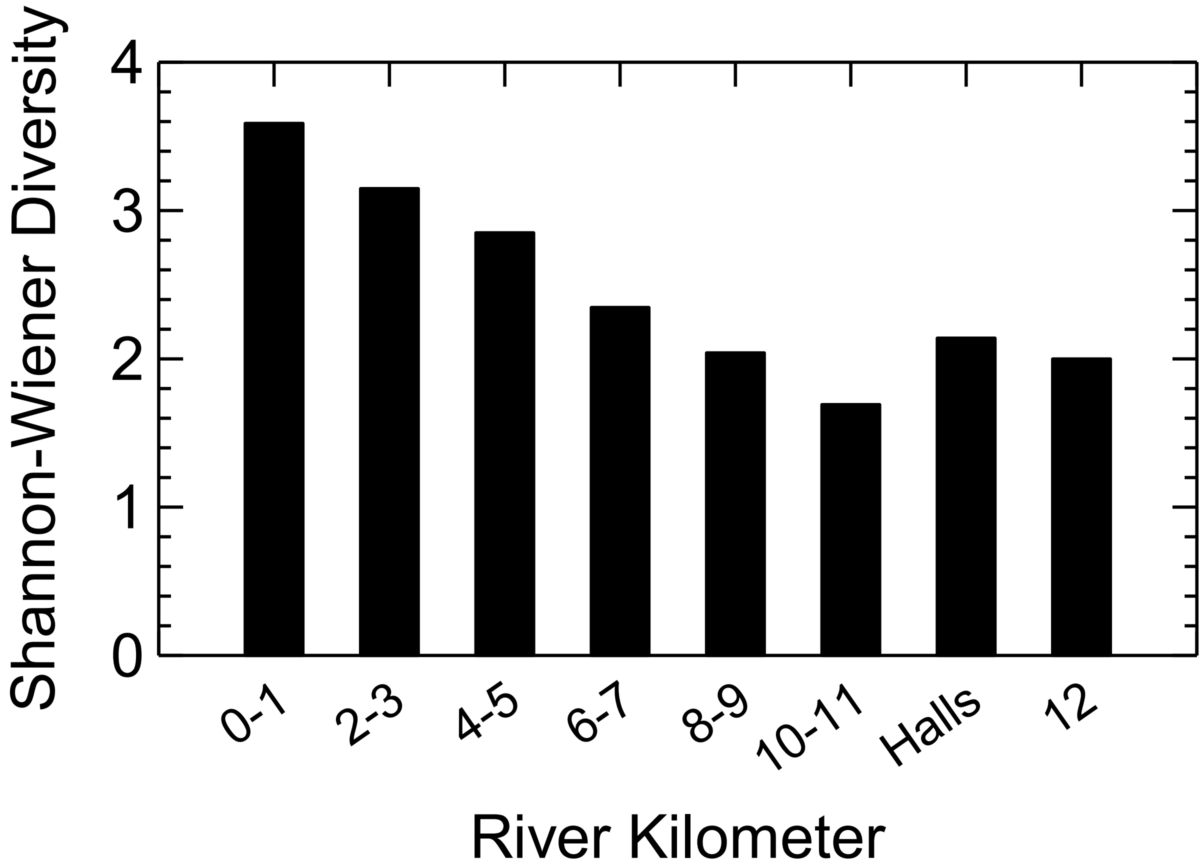


Figure 3-8. **Bar plot of Shannon-Wiener diversity (H') in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.**

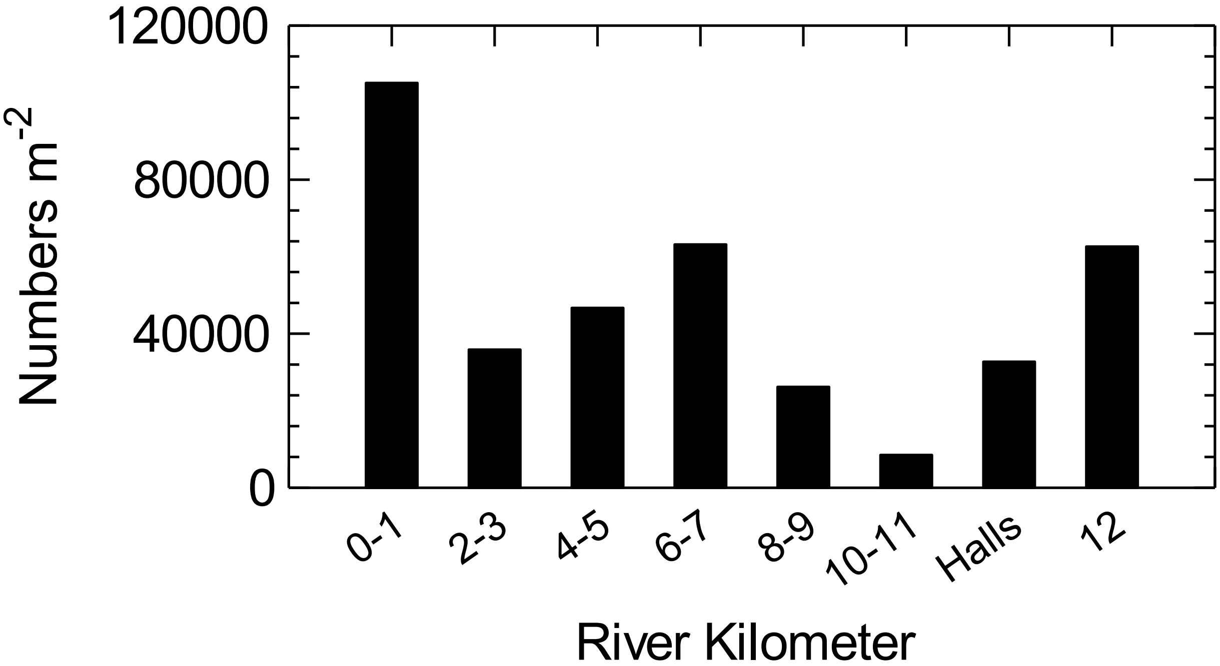


Figure 3-9. **Bar plot of mean numbers of individuals m^{-2} in the Homosassa River (including the spring run and Southeast Fork) by river kilometer and in the lower Halls River, 12-14 May 2008.**

3.2.3 Relationships of Univariate Community Metrics with Abiotic Variables

The association of numbers of taxa, diversity, and mean abundance with abiotic variables were explored using forward stepwise linear regression analysis (Appendix 3-D). Statistically significant relationships were found for each of the univariate community metrics and some combination of the abiotic variables (Table 3-5).

Both numbers of taxa and diversity increased with salinity and dissolved oxygen concentration and decreased at higher water temperatures (Table 3-5). Diversity also declined moving upstream (increasing RKM). The measured abiotic variables explained very little of the variability in total abundance (adjusted multiple R^2= 0.19).

Table 3-5. Results of forward stepwise multiple regression analyses that examine the relationship between numbers of taxa, Shannon Diversity, and abundance and abiotic variables in the Homosassa River. Variables selected must have $p<0.05$ to be included.	
	Adjusted multiple R^2
Numbers of Taxa	
Y=93.25 + (1.18*Salinity) – (3.80*Temperature) + (0.99*DO)	0.60
Shannon Diversity	
Y=7.21 – (0.05*RKM) + (0.07*Salinity) – (0.22*Temperature) + (0.08*DO)	0.40
Numbers m^{-2}	
Y=489940 +(2365*Salinity) –(19020*Temperature) + (3588*DO)	0.19

3.2.4 Multivariate Community Structure

The spatial structure of the benthos of the Homosassa River (including the spring run and Southeast Fork) and the lower Halls Rivers was examined using MDS. The ANOSIM test was used to compares the similarities of the *a priori* defined 'groups" (assemblages within RKMs groups).

The plots (Figure 3-10) showed that there were longitudinal differences in benthic community structure in the study area. The ANOSIM tests Table 3-6) showed that adjacent RKM groups generally supported different benthic assemblages. Generally polychaetes and gastropods decreased in abundance upriver, and were virtually absent upstream of RKM 8-9 (Table 3-7), where the mean salinity was ~12 ppt (Figure 3-4). Bivalves and crustaceans showed more species-specific longitudinal changes (Table 3-7). For example, among the bivalves, *Polymesoda caroliniana* was only found in the low salinity waters of the lower Halls River whereas *Crepidula* was most abundant in RKMs 0-1 (Table 3-7). There were also differences among isopods. *Cassidinidea ovalis* was most abundant at RKM 0-1, whereas *Xenanthura brevitelson* was most abundant within RKMs 4-7, where salinities were in the low teens (Figure 3-4), and *Cyathura polita* was most abundant in the lowest salinity waters (RKM 12 and the Halls River) (Table 3-7).

The assemblages in RKMs 4-5 and 6-7, where salinities were in the low to mid teens (Figure 3-4) were, however, similar (Table 3-6; Figure 3-10). The plot based upon the mean abundances of the different taxa within each RKM group shows that the greatest variability (as distance) in community structure occurred moving upriver from RKMs 0-1 to 2-3 (Figure 3-10).

Table 3-7 summarizes the mean abundance of the most common taxa by RKM group.

The fauna of RKMs 0-1 and 2-3 differed mainly in the abundances of:

- *Cirrophorus* sp. (Polychaeta)- more abundant RKM 0-1;
- *Filograna huxlei* (Polyhaeta)- more abundant RKM 0-1;
- *Typosyllis alosae* (Polychaeta)- more abundant RKM 0-1;
- *Lysianopsis alba* (Amphipoda)- more abundant RKM 0-1; and
- *Melita nitida* complex (Amphipoda)- more abundant RKM 2-3.

The fauna of RKMs 2-3 and 4-5 differed mainly in the abundances of:

- *Ampelisca sp.*-more abundant RKMs 4-5;
- *Aricidea philbinae* (Polychaeta)-more abundant RKMs 2-3; and
- *Typosyllis alosae*- more abundant RKMs 2-3.

Taxa with similar densities in RKMs 4-5 and 6-7 include:

- *Xenanthura brevitelson* (Isopoda);
- *Ampelisca* sp. ;
- *Hourstonius laguna* (Amphipoda); and
- *Melita nitida* complex.

The fauna of RKMs 6-7 and 8-9 differed mainly in the abundances of:

- *Brachidontes exustus* (Bivalvia)- more abundant RKM 6-7;
- *Ampelisca* sp.- more abundant RKM 6-7;
- *Halmyrapseudes cf. cubensis* (Tanaidacea)- more abundant RKM 6-7;
- *Streblospio gynobranchiata* (Polychaeta)- more abundant RKM 8-9.

The fauna of RKMs 8-9 and 10-11 differed mainly in the abundances of:

- *Ampelisca* sp.- more abundant RKM 8-9;
- *Americorophium ellisi* (Amphipoda)- more abundant RKM 10-11; and
- *Brachidontes exustus* (Bivalvia)- more abundant RKM 8-9.

The fauna of RKMs 10-11 and $\geq$12 differed mainly in the abundances of:

- *Cyathura polita* (Isopoda)-more abundant RKMs $\geq$12;
- *Americorophium ellisi* (Amphipoda)- more abundant RKM 10-11;
- *Dicrotendipes* sp. (Chironomidae)-more abundant RKM $\geq$12; and
- *Pseudochironomus* sp. (Chironomidae)-more abundant RKM $\geq$12

Within RKMs 12-13, there were also some differences among the river proper, the spring run, and the Southeast Fork (Appendix 3-E). Among the 25 ranked dominants, hydrobiid gastropods were particularly abundant within RKM 12—and less abundant in both the run and the Southeast Fork. Taxa that were more abundant in the spring run than either in the river or the Southeast Fork included:

- *Hargeria/Leptochelia* sp. complex (Tanaidacea);
- *Gammarus mucronatus* (Amphipoda); and
- *Grandidierella bonnieroides* (Amphipoda).

Taxa that flourished in the Southeast Fork included:
- *Cyathura polita* (Isopoda); and
- *Hyalella* sp. C (Amphipoda).

The spring run and Southeast Fork were similar in that:
- *Dicrotendipes* sp.;
- Oligochaetes (Genera undet.);
- chironomid larvae (Genera undet.); and
- amphipods (Genera undet.)

were each collected in relatively similar densities.

3.2.5 Relationship Among Salinity and the Occurrence of Selected Taxa

The effect of salinity on benthic community structure also depends upon how the distributions of individual taxa vary with changes in salinity. Logistic regression has been used to quantify the relationship between salinity and the probability of occurrence of estuarine biota (Peeters and Gardiniers, 1998; Ysebaert et al., 2002).

Janicki Environmental (2007a) employed univariate logistic regression to estimate the probability of occurrence as a function of salinity for selected taxa from 12 Southwest Florida tidal rivers. The "optimum" or "preferred" salinity was that with the highest probability of occurrence for that taxon. A "preferred habitat range" was calculated as the salinity range coincident with the 25th and 75th percent probability of occurrence (Peeters and Gardiniers, 1998).

Figure 3-11 presents a summary of the salinity preference data derived from the univariate logistic regressions for six taxa (identified to Genus or Species) that were among the Dominant taxa from the Homosassa and lower Halls rivers. These included taxa that were identified as preferred prey items of fishes (*e.g.*, amphipods such as *Grandidierella bonnieroides*) by Peebles (2005). The six taxa selected are:

- Polychaete: *Mediomastus* sp. (*Mediomastus ambiseta* was selected from the logistic regression analyses);
- Bivalvia: *Polymesoda caroliniana;* and
- Amphipoda: *Ampelisca* sp. (*Ampelisca abdita* was selected from the logistic regression analyses), *Cerapus benthophilus, Gammarus mucronatus*, and *Grandidierella bonnieroides*.

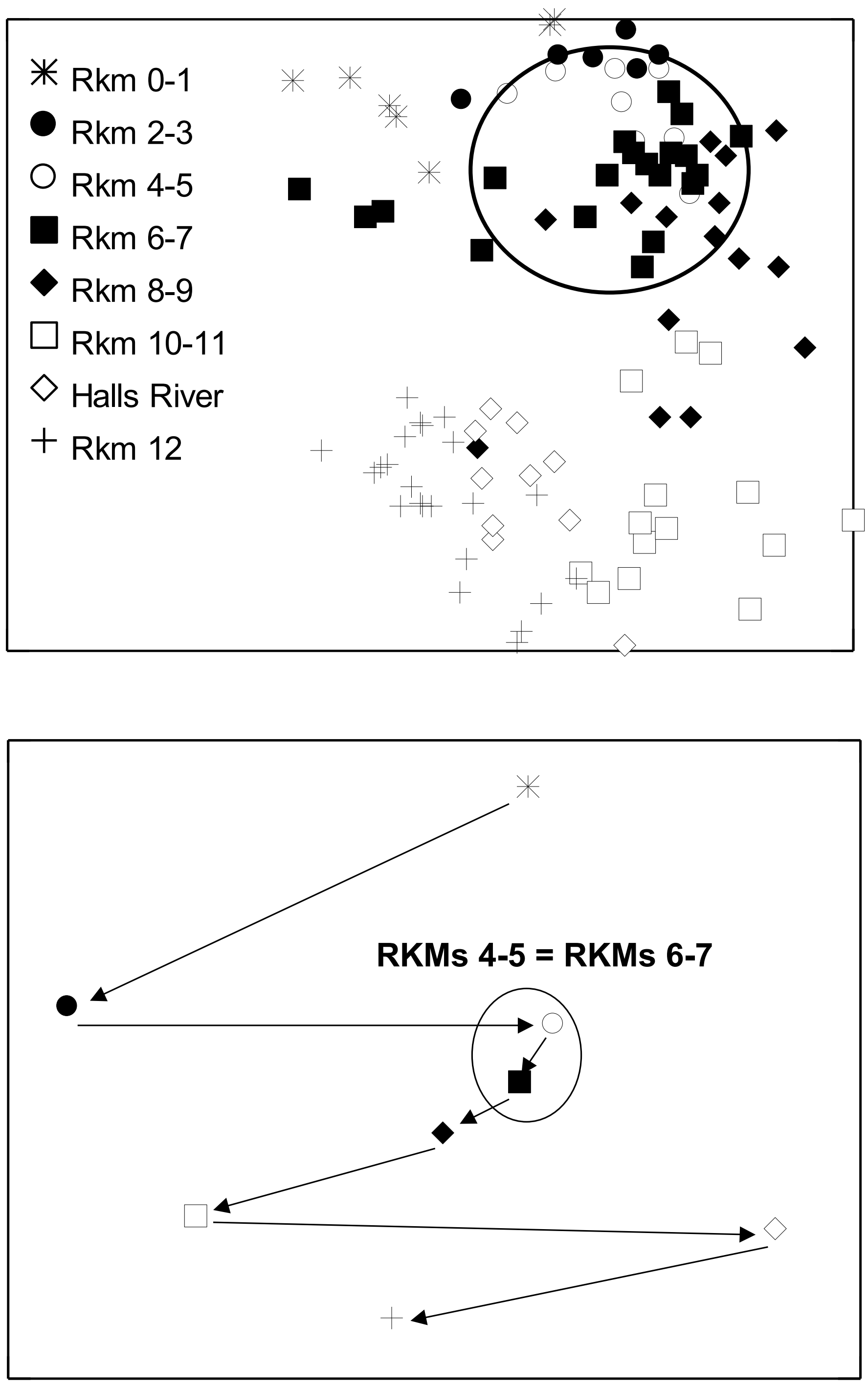


Figure 3-10. **MDS plots showing the similarity of the Homosassa River (including the spring run and Southeast Fork) and lower Halls rivers benthos, by River kilometer Group, May 2008. Top plot shows all samples; Bottom plot is based upon the mean abundance in each RKM group. All abundances 4th root (n+0.1) transformed. Stress in each MDS analysis <0.2. *ANOSIM tests showed that only the RKM 4-5 and RKM 6-7 groups (circled) had similar benthic assemblages* (*cf.* Table 3-6).**

Table 3-6. Summary of ANOSIM tests comparing the composition of the benthos (n+0.1 4th root transformed numbers m^{-2}) between pairs of adjoining RKM groups in the Homosassa (Including the spring run and Southeast Fork) and lower Halls River, May 2008. NS= $p \geq 0.05$; *= $p \leq 0.05$; ** = $p \leq 0.01$; ***= $p \leq 0.001$	
River Kilometer Comparisons	**R Statistic**
0-1 vs. 2-3	**0.5*** **
2-3 vs. 4-5	**0.3** **
4-5 vs. 6-7	<0.1 NS
4-5 vs. 8-9	**0.2***
6-7 vs. 8-9	**0.2** **
8-9 vs. 10-11	**0.4*** **
Halls vs. 10-11	**0.3** **
10-11 vs. ≥12	**0.6*** **

Janicki Environmental (2007a) showed that the benthos of several Springs Coast tidal rivers differed by salinity regime. Four salinity classes were identified for Springs Coast rivers based upon the distribution of the benthos using Principal Components Analysis:

- 0-16 ppt;
- 17-24 ppt;
- 24-30 ppt; and
- >30 ppt

Based upon salinity measured at the time the benthic samples were collected, 93 samples (82%) were in the 0-16 ppt class; 17 (14.9%) were in the 17-24 ppt group, and one sample (<1%) was in the 24-30 ppt class.

Among the six selected Dominant taxa, two species, *Polymesoda caroliniana* ("optimum" salinity ~9 ppt) (Figure 3-11) and *Grandidierella bonnieroides* ("optimum salinity" ~14ppt) (Figure 3-11) fell within the lowest salinity class. *Polymesoda caroliniana* was rare or absent in the Homosassa, but was a Dominant in the lower Halls River (Figure 3-12). *Grandidierella bonnieroides*, on the other hand, was found throughout the Homosassa and lower Halls rivers (Figure 3-13), although it attained maximum abundance in RKM 12 (particularly in the spring run; Appendix 3-E). In the Homosassa River, the COA, however, was at RKM 10.4, downstream from the location of maximum abundance (Table 3-3). The mean salinity at which *Grandidierella* was collected was 4.3 ppt (Table 3-3)—lower than that of RKM 12 (Figure 3-4).

The other four taxa attained their highest probability of occurrence in the 17-24 ppt salinity class (Figure 3-11). Both *Mediomastus* sp. (based upon the distribution of *Mediomastus ambiseta*; *cf*. Janicki Environmental, Inc., 2007a) (Figure 3-14) and *Cerapus benthophilus* (3-15) had slightly lower salinity "optima" than either *Gammarus mucronatus* (Figure 3-16) or *Ampelisca* sp. (as *Ampelisca abdita*) (Figure 3-17).

Mediomastus sp. was rare both in the lower and upper reaches of the Homosassa River and reached its greatest abundance in RKMs 4-9 (Figure 3-14). The COA for *Mediomastus* was RKM 6.7 and the mean salinity at which this taxon was collected was 13.1 ppt (Table 3-3). The mean salinity at which *Mediomastus* sp. was collected in this survey was markedly lower that at which logistic regression estimated it was most likely to occur: 13.1 ppt (Table 3-3) *vs.* ~22 ppt (Figure 3-14).

Table 3-7. Taxa identified to genus or species occurring in ≥5% of all samples and the location of their maximum abundance in the Homosassa River (including the spring run and Southeast Fork) and lower Halls River, May 2008.

TAXA	RKM 0-1	RKM 2-3	RKM 4-5	RKM 6-7	RKM 8-9	RKM 10-11	Halls	RKM≥ 12
ANNELIDA								
Polychaeta								
Amphicteis gunneri	0	192	82	548	178	22	66	0
Apomatus sp.	0	0	0	1303	383	0	0	0
Aricidea philbinae	1396	4490	520	120	14	0	0	0
Brania sp.	657	219	548	88	0	0	0	0
Capitella capitata	164	192	192	175	219	0	0	0
Cirrophorus sp.	3805	329	27	0	0	0	0	0
Demonax microphthalmus	82	0	0	0	0	0	0	0
Ehlersia cornuta	110	0	0	0	0	0	0	0
Exogone sp.	27	0	0	0	0	0	0	0
Filograna huxleyi	794	0	0	0	0	0	0	0
Heteromastus filiformis	246	110	0	0	0	0	0	0
Hyboscolex quadricincta	27	0	0	0	0	0	0	0
Kinbergonuphis simoni	82	0	0	0	0	0	0	0
Laeonereis culveri	55	0	0	0	82	0	175	219
Marphysa sanguinea	0	82	0	0	0	0	0	0
Melinna maculata	0	55	55	22	0	0	0	0
Neanthes succinea	0	0	0	0	14	0	0	0
Podarkeopsis levifuscina	27	27	0	0	0	0	0	0
Polydora socialis	27	0	0	175	123	0	22	9
Prionospio steenstrupi	0	137	0	0	0	0	0	0
Streblospio gynobranchiata	0	383	219	953	2779	110	22	9
Typosyllis alosae	11717	1259	27	22	0	0	0	0

Table 3-7. continued								
TAXA	**RKM 0-1**	**RKM 2-3**	**RKM 4-5**	**RKM 6-7**	**RKM 8-9**	**RKM 10-11**	**Halls**	**RKM≥ 12**
MOLLUSCA								
Gastropoda								
Acteocina canaliculata	55	110	164	241	27	0	0	0
Prunum apicinum	137	0	0	0	0	0	0	0
Vitrinella sp.	548	219	110	0	0	0	0	18
Bivalvia								
Angulus versicolor	27	192	356	339	219	44	0	0
Branchiodontes exustus	0	0	110	10873	1424	0	22	0
Corbicula fluminea	0	0	0	0	0	0	0	9
Crassostrea virginica	0	0	27	296	41	0	0	0
Crepidula sp.	4626	903	301	44	0	0	0	0
Merisca aequistriata	219	110	0	0	0	0	0	0
Polymesoda caroliniana	0	0	0	33	205	11	1643	9
Tagelus plebeius	0	27	110	44	27	0	0	0
CRUSTACEA								
Isopoda								
Cassidinidea ovalis	3148	794	329	909	55	0	0	100
Cyathura polita	630	246	301	33	0	77	1030	2227
Xenanthura brevitelson	657	520	1341	1270	192	0	0	0
Tanaidacea								
Halmyrapseudes cf. bahamaensis	0	0	0	0	0	0	0	9
Halmyrapseudes cf. cubensis	1615	7939	7337	2004	0	0	0	0
Hoplomachus propinquus	2081	0	0	0	0	0	0	0
Amphipoda								
Americorophium ellisi	0	55	82	66	27	2212	0	18
Ampelisca sp.	1068	4380	13852	19305	4188	22	0	9
Cerapus benthophilus	164	27	657	460	219	88	7118	0
Grandidierella bonnieroides								
Hourstonius laguna	602	110	1068	2256	178	0	0	0
Lysianopsis alba	1533	82	0	0	0	0	0	0
Melita nitida	0	1834	931	1566	123	0	0	411
Paramicrodeutopus myersi	0	27	0	0	0	0	0	0
Decapoda								
Rhithropanopeus harrisii	110	137	55	230	68	44	372	0

Table 3-7. continued								
TAXA	**RKM 0-1**	**RKM 2-3**	**RKM 4-5**	**RKM 6-7**	**RKM 8-9**	**RKM 10-11**	**Halls**	**RKM≥ 12**
INSECTA								
Chironomidae								
Chironomus sp.	0	0	0	0	82	887	22	201
Cryptochironomus sp.	0	0	0	0	0	0	66	164
Dicrotendipes sp.	0	0	55	33	0	0	66	3239
Pseudochironomus sp.	0	0	0	0	0	0	22	1068

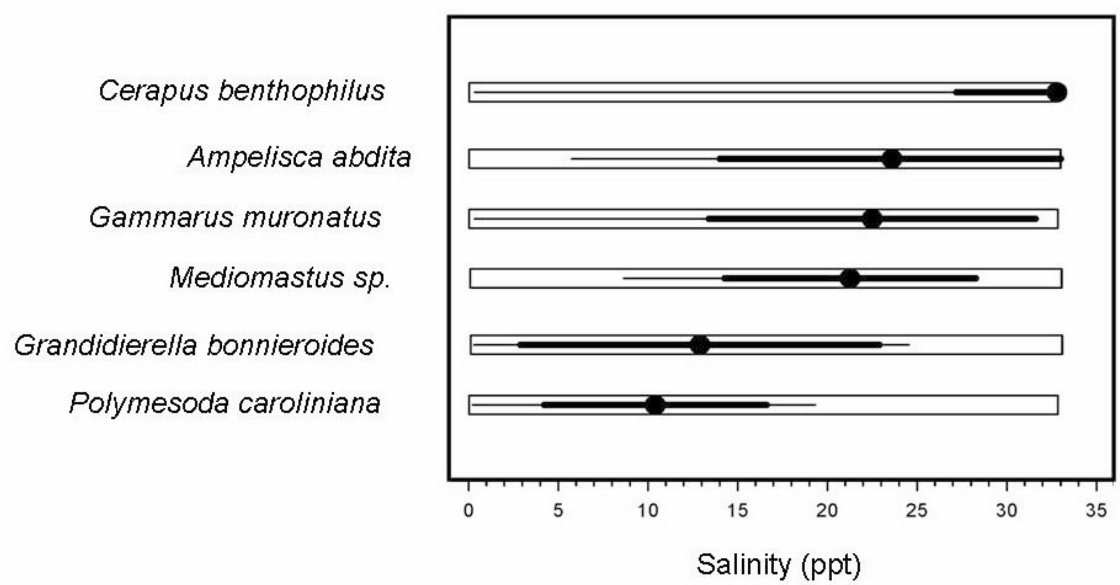


Figure 3-11. Summary of salinity optimum (circle), optimal habitat range (solid bar), 10th to 90th percentile probability of occurrence (thin line), and model domain (open bar) of salinity for six selected benthic taxa derived from Janicki Environmental, Inc.'s (2007a) analysis of benthic data from 12 southwest Florida tidal rivers.

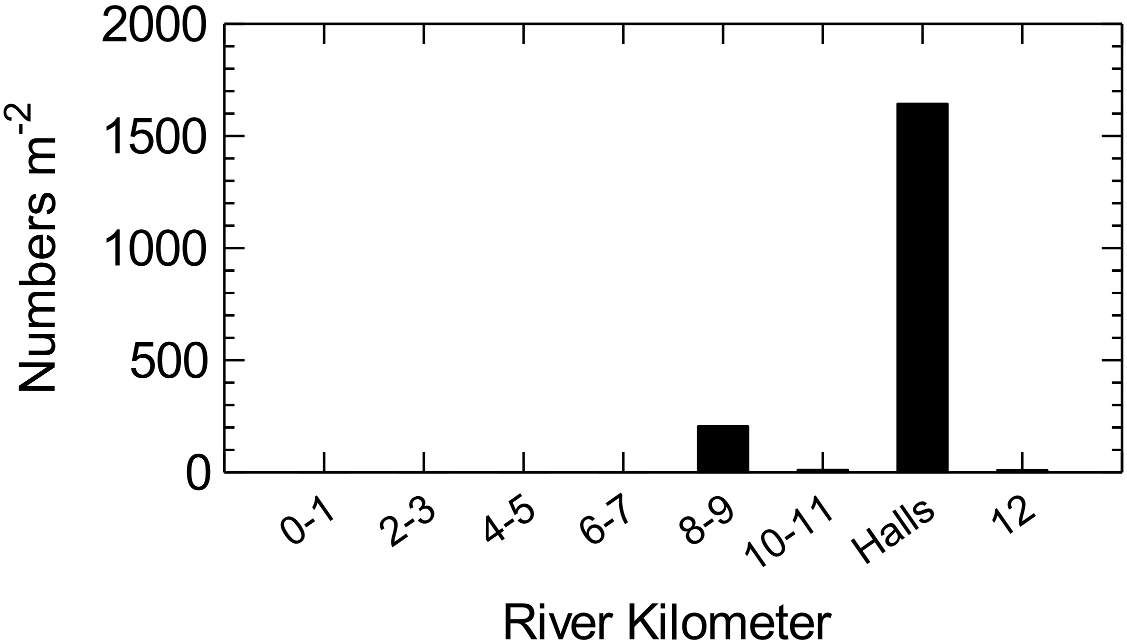


Figure 3-12. **Longitudinal distribution of *Polymesoda caroliniana* in the Homosassa River (Including the spring run and Southeast Fork) and lower Halls River, May 2008.**

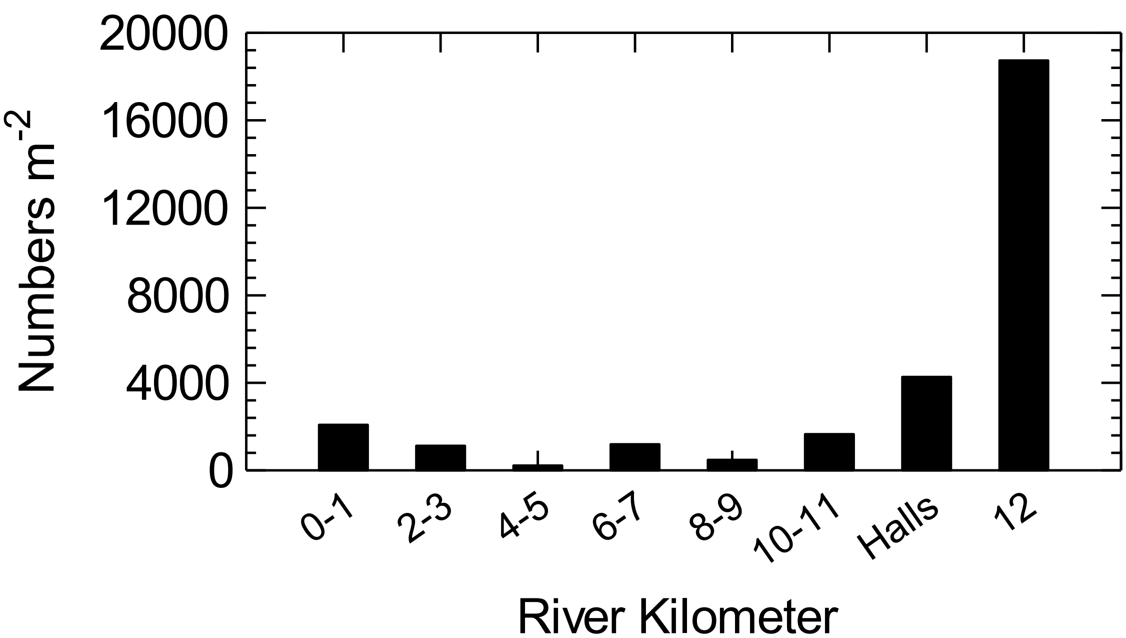


Figure 3-13. **Longitudinal distribution of *Grandidierella bonnieroides* in the Homosassa River (including the spring run and Southeast Fork) and lower Halls River, May 2008.**

Cerapus benthophilus (Figure 3-15) was found throughout most of the Homosassa River, but reached maximum densities in the lower Halls River. Although this amphipod was relatively rare in the Homosassa River, the mean salinity at which it was collected was 5.2 ppt (Table 3-3), somewhat higher than the salinities in the lower Halls River (Figure 3-4).

Gammarus mucronatus was also collected at low concentrations throughout much of the Homosassa River, but reached maximum abundance in the lower Halls River (Figure 3-16) and the spring run (Appendix 3-E). The mean salinity at which this amphipod was collected in the Homosassa River was 3.9 ppt (Table 3-3).

Ampelisca sp. was found in the Homosassa River from RKM 0 to RKM 9 (Figure 3-17); maximum densities occurred at RKM 6-7 (Figure 3-17) and the mean salinity at which it was collected was at 13.4 ppt (Table 3-3). *Ampelisca abdita* is the most likely of the *Ampelisca* species to tolerate salinities in the teens (Janicki Environmental, Inc., 2007a). On a regional basis (Springs Coast south to Charlotte Harbor area tidal rivers), *Ampelisca abdita* was most likely to be collected at ~18 ppt in other Springs Coast rivers and at ~19 ppt in Charlotte Harbor area rivers (Janicki Environmental, Inc., 2007a).

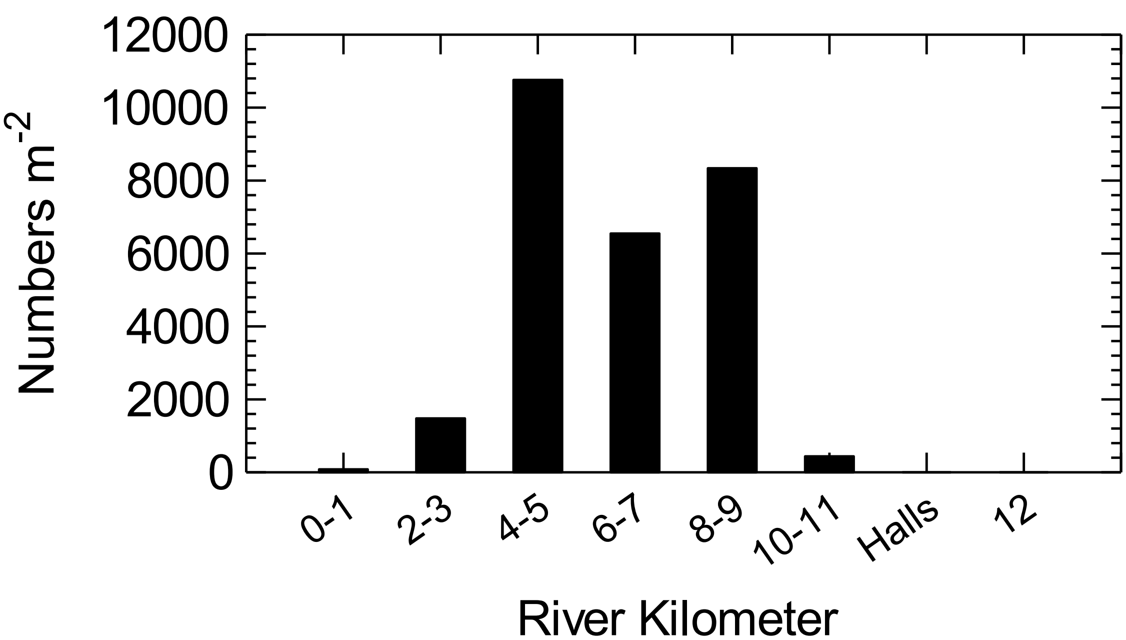


Figure 3-14. Longitudinal distribution of *Mediomastus* spp. in the Homosassa (including the spring run and Southeast Fork) and lower Halls River, May 2008.

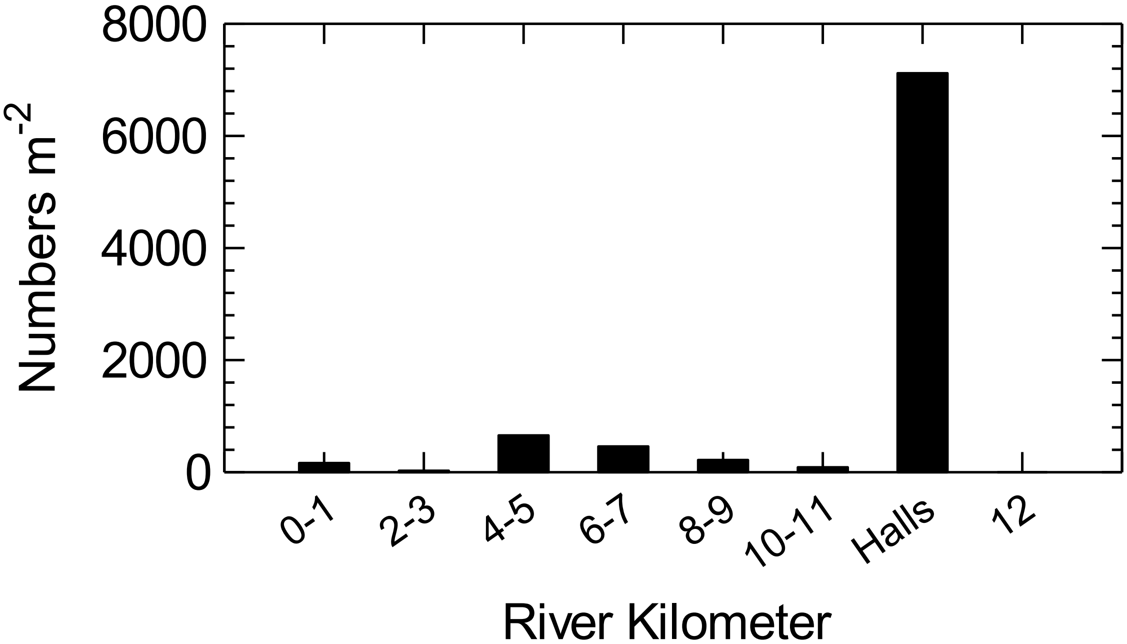


Figure 3-15. **Longitudinal distribution of *Cerapus benthophilus* in the Homosassa River (including the spring run and Southeast Fork) and lower Halls River, May 2008.**

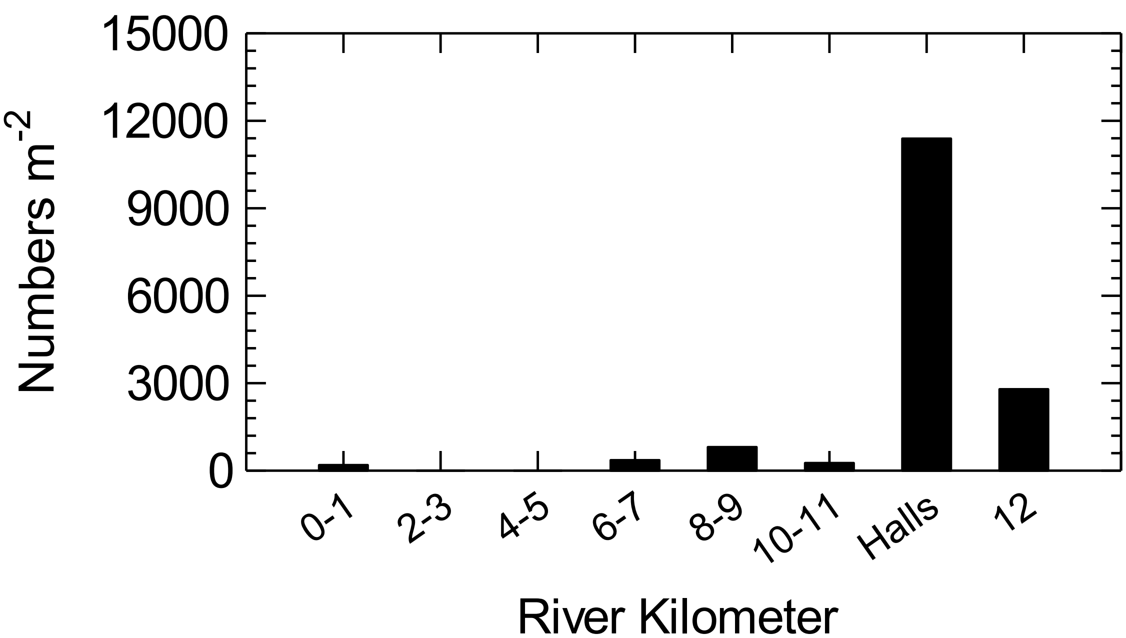


Figure 3-16. **Longitudinal distribution of *Gammarus mucronatus* in the Homosassa River (including the spring run and Southeast Fork) and lower Halls River, May 2008.**

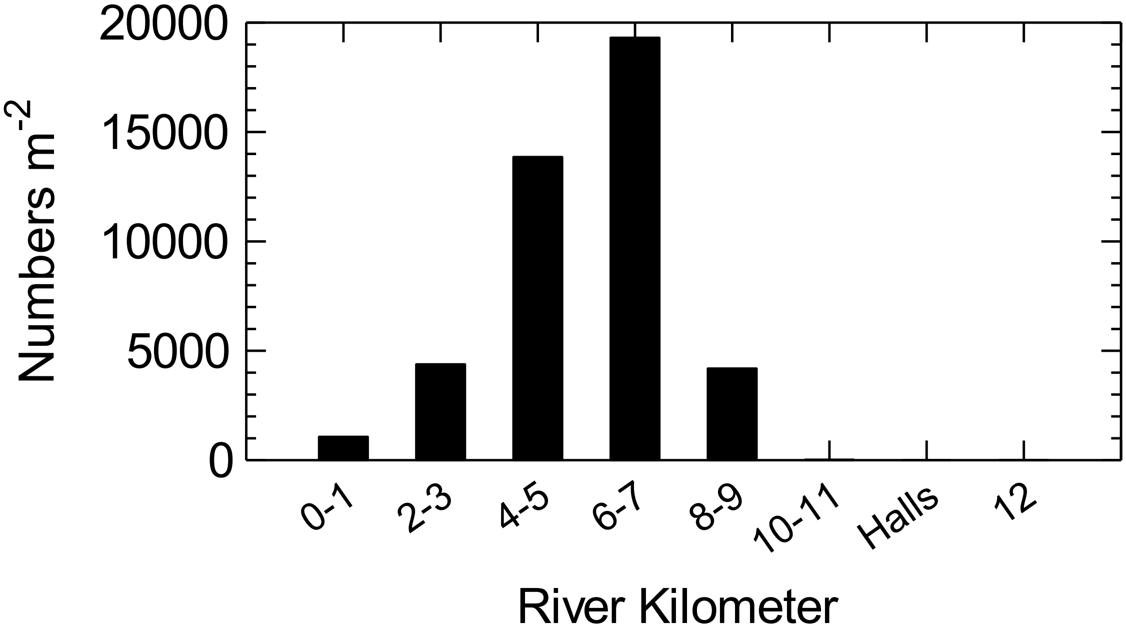


Figure 3-17. **Longitudinal distribution of *Ampelisca* spp. in the Homosassa River (including the spring run and Southeast Fork) and lower Halls River, May 2008.**

4.0 CONCLUSIONS

The following conclusions can be drawn from the May 2008 survey of benthic macroinvertebrates in the Homosassa River (including the spring run and Southeast Fork) and the lower segment of Halls River:

- Salinity varied widely (23.6 ppt) along the longitudinal axis of the Homosassa River over the three-day survey ; in the lower Halls River, salinity ranged from 2.2-5.4 ppt;
- The benthos of both the Homosassa River and the lower Halls River was dominated by amphipod crustaceans (*e.g., Ampelisca* sp., *Grandidierella bonnieroides* and *Gammarus mucronatus*); the polychaete *Mediomastus* sp. was a subdominant in the Homosassa River;
- Dominant taxa were generally dissimilar between the Homosassa and Halls rivers because of differences in the ranges of salinity encountered;
- The spring run fauna was dominated by *Hargeria/Leptochelia* sp. Complex tanaids and the amphipods *Gammarus mucronatus* and *Grandidierella bonnieroides*;
- The Southeast Fork dominants included the isopod *Cyathura polita* and the amphipod *Hyalella* sp. C;
- Both numbers of taxa and Shannon-Wiener diversity generally declined upstream;
- Abundance of benthic macroinvertebrates did not show any consistent longitudinal trend;
- Statistically significant relationships between the number of taxa, diversity, and total abundance and a number of abotic variables were found:
    - ♦ Both numbers of taxa and diversity had a positive association with both salinity and dissolved oxygen and a negative association with water temperature; and
    - ♦ Total abundance had a much weaker, although statistically significant, relationship to abiotic variables than did both numbers of taxa and diversity;
- Multivariate community structure varied longitudinally in the Homosassa River:
    - ♦ Adjacent River Kilometer groups (2-RKMs in length starting at RKM 0) generally differed from one another; and
    - ♦ RKMs 4-5 and 6-7 supported similar benthic assemblages; salinities were generally in the low to mid-teens in these groups.

Were spring flows to be reduced such that saline waters were able to intrude further upriver:

- Both numbers of taxa and diversity should increase as salinity increases;
- Habitat for Chironomidae larvae could decease; and
- *Ampelisca* sp., the tanaid *Kalliapseudes macsweeneyi*, polychaetes and gastropods could penetrate further upriver.

5.0 REFERENCES

Bate, G.C., A.K. Whitfield, J.B. Adams, P. Huizinga and T.H. Wooldridge. 2002. The importance of the river-estuary interface (REI) zone in estuaries. *Water SA* 28: 271-279.

Boesch, D. F. and R. Rosenberg. 1981. Response to stress in marine benthic communities. Pages 179-200. In: G.W. Barrett and R. Rosenberg (Eds.), *Stress Effects on Natural Ecosystems*. Wiley-Interscience, New York.

Boyton, W. R. and W. M. Kemp. 2001. Influence of river flow and nutrient loads on selected ecosystem processes: a synthesis of Chesapeake Bay data. Pages 269-298. In: J.E. Hobbie (Ed.). *Estuarine Science: A Synthetic Approach to Research and Practice*. Island Press, Washington DC.

Browder, J.A. and D. Moore. 1981. A new approach to determining the quantitative relationship between fishery production and the flow of freshwater to estuaries. Pages 403-430 In: R. Cross and D. Williams (Eds.) *Proceedings of the National Symposium on Freshwater Inflow to Estuaries*. FWS/OBS-81/4. USFWS.

Cao, Y., D.D. Williams, and N.E. Williams. 1998. How important are rare species in aquatic habitat bioassessment? *Bulletin of the North American Benthological Society* 15: 109.

Champion and R. Starks. 2001. *The Hydrology and Water Quality of Springs in West-Central Florida.* Water Quality Monitoring Program, Southwest Florida Water Management District. Brooksville, Florida.

Clarke, K.R. and R.M. Warwick. 2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation*. 2nd Ed. PRIMER-E Ltd. Plymouth Marine Laboratory, United Kingdom.

FDER (Florida Department of Environmental Regulation). 1985. *Limnology of the Suwannee River, Florida.* Biology Section, Division of Environmental Programs. Tallahassee, FL.

Flannery, M.S., E. P. Peebles and R. T. Montgomery. 2002. A percent-of-flow approach for managing reductions to freshwater inflows from unimpounded rivers to southwest Florida estuaries. Estuaries 25:1318-1332.

Florida Geological Society. 2008. Springs of Florida. http://www.dep.state.fl.us/geology/geologictopics/springs/bulletin66.htm

Frazer, T.K., M.V. Hoyer, S.K. Notestein, J.A. Hale and D.E. Canfield, Jr. 2001. *Final Report. Physical, Chemical and Vegetative Characteristics of Five Gulf Coast Rivers.* University of Florida, Institute of Food and Agricultural Sciences.

Gainesville, FL. Submitted to Southwest Florida Water Management District. Brooksville, FL.

Gillanders, B.M. and M.J. Kingsford. 2002. Impact of changes in flow of freshwater on estuarine and open coastal habitats and the associated organisms. *Oceanography and Marine Biology Annual Review* 40: 233-309.

Grabe, S.A. 1989. *Surface Water Quality Monitoring Network Report: 1979-1988.* Collier County Pollution Control Department, Naples, FL. Prepared for Big Cypress Basin Board, South Florida Water Management District. Naples, FL.

Janicki Environmental, Inc. 2007a. *Development of Analytical Tools for the Establishment of Minimum Flows Based Upon Macroinvertebrate Communities of Southwest Florida Tidal Rivers*. Prepared for Southwest Florida Water Management District. Brooksville, FL.

Janicki Environmental, Inc. 2007b. *Analysis of Benthic Community Structure and its Relationship to Freshwater Inflows in the Anclote River*. Prepared for Southwest Florida Water Management District. Brooksville, FL.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J.R. Schubel, and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. *Ecological Applications* 51: 272-289.

Jones, G.W., S.B. Upchurch, K.M. Champion and D.J. Dewitt. 1997. Water Quality and Hydrology of the Homosassa, Chassahowitzka, Weeki Wachee, and Aripeka Spring Complexes, Citrus and Hernando Counties, Florida – Origin of Increasing Nitrate Concentrations. Southwest Florida Water Management District. Brookville, FL.

Kalke, R.D. and P.A. Montagna. 1989. *Report to the Texas Water Development Board.* Marine Science Institute, University of Texas at Austin. Port Aransas, TX.

Kelly, B.J., Jr. and W.D. Burback. 1976. Responses of embryonic *Cyathura polita* (Stimpson) (Isopoda: Anthuridea) to varying salinity. *Chesapeake Science* 17: 159-167.

Neter, J., W. Wasserman and M.H. Kutner. 1985. *Applied Linear Statistical Models*. 2nd Ed. Irwin Publ. Boston, MA.

Peebles, E. 2005. Review of feeding habits of juvenile estuarine dependent fishes and blue crabs: identification of important prey. Prepared for Southwest Florida Water Management District. Brooksville, FL.

Peeters, E.T.H.M. and Gardeniers, J.J.P. 1998. Logistic regression as a tool for defining habitat requirements of two common gammarids. *Freshwater Biology* 39: 605-615.

Peterson, D.H. and J.F. Festa. 1984. Numerical simulation of phytoplankton productivity in partially mixed estuaries. *Estuarine, Coastal and Shelf Science* 19: 563-589.

Seidemann, D.E. 1991. Metal pollution in sediments of Jamaica Bay, New York, USA—an urban estuary. *Environmental Management* 15: 73-81.

Sokal, R.R. and F.J. Rohlf. 1981. *Biometry*. 2nd Ed. W.H. Freeman Publ. New York.

SWFWMD (Southwest Florida Water Management District). 2007. *The Determination of Minimum Flows for the Lower Alafia River Estuary.* Technical report of the Southwest Florida Water Management District. Brooksville, FL.

SWFWMD (Southwest Florida Water Management District). 2001. 2001 Regional Water Supply Plan. Brooksville, FL.

Thorne, R.St.J., W.P. Williams, and Y. Cao. 1999. The influence of data transformations on biological monitoring studies using macroinvertebrates. *Water Research* 33: 343-350.

U.S.E.P.A. (United States Environmental Protection Agency). 2008. *Biological Indicators of Watershed Health*. Uniform Resource Locator: http://www.epa.gov/bioindicators/html/llstr4.html.

U.S.E.P.A. (United States Environmental Protection Agency). 1999. *Ecological Condition of Estuaries in the Gulf of Mexico*. EPA 620-R-98-004. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division. Gulf Breeze, FL.

U.S.G.S. (United States Geological Survey). 2008a. Uniform Resource Locator: http://waterdata.usgs.gov/usa/nwis/uv?site_no=02310688

U.S.G.S. (United States Geological Survey). 2008b. Uniform Resource Locator: http://waterdata.usgs.gov/usa/nwis/uv?site_no=02310678

Yobbi, D. K. & L. A. Knochenmus. 1989. *Salinity and Flow Relations and Effects of Reduced Flow in the Chassahowitzka River and Homosassa River Estuaries, Southwest Florida.* U.S. Geological Survey. WRI 88–404. Tallahassee, FL.

Ysebaert,T., P. Meire, P.M.J. Herman, and H. Verbeek. 2002. Macrobenthic species responses along estuarine gradients: prediction by logistic regression. *Marine Ecology Progress Series* 225: 79-85.

APPENDIX 3-A

Analysis of Variance: Abiotic Variables
Depth Stratum, River Kilometer and Depth Stratum*River Kilometer &
Bonferroni *a posteriori* paired comparisons tests

3-A1

Dependent Variable: Temperature **N: 92 Multiple R^2: 0.4**					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	0	1	0	0.0	0.908
RKM	36	6	6	7.9	0.000
DEPTH*RKM	4	6	1	0.9	0.523
Error	59	78	1		

Bonferroni Adjustment

RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

1	1	2	3	4	5	6	7	8
2	0.000	1.000						
3	1.000	0.000	1.000					
4	0.924	0.032	0.474	1.000				
5	0.012	1.000	0.001	1.000	1.000			
6	0.014	0.075	0.000	1.000	1.000	1.000		
7	0.004	0.719	0.000	1.000	1.000	1.000	1.000	
8	0.152	0.000	0.006	0.000	0.000	0.000	0.000	1.000

3-A2

Dependent Variable: Salinity N: 92 Multiple R^2: 0.8					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	49	1	49	5.7	0.019
RKM	2429	6	405	46.7	0.000
DEPTH*RKM	28	6	5	0.5	0.773
Error	676	78	9		

Bonferroni Adjustment

RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

	1	2	3	4	5	6	7	8
1	1.000							
2	0.000	1.000						
3	0.000	0.000	1.000					
4	0.497	0.000	0.000	1.000				
5	0.000	0.022	0.000	0.119	1.000			
6	0.000	0.532	0.000	0.000	1.000	1.000		
7	0.000	1.000	0.000	0.000	0.191	1.000	1.000	
8	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000

3-A3

Dependent Variable: pH N: 92 **Multiple R^2: 0.5**					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	0	1	0	0.8	0.373
RKM	4	6	1	13.5	0.000
DEPTH*RKM	0	6	0	0.7	0.662
Error	4	78	0		

Bonferroni Adjustment

RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

	1	2	3	4	5	6	7	8
1	1.000							
2	0.070	1.000						
3	1.000	0.000	1.000					
4	1.000	1.000	0.009	1.000				
5	0.043	1.000	0.000	1.000	1.000			
6	0.053	1.000	0.000	1.000	1.000	1.000		
7	0.009	1.000	0.000	1.000	1.000	1.000	1.000	
8	0.007	1.000	0.000	1.000	1.000	1.000	1.000	1.000

3-A4

Dependent Variable: Dissolved Oxygen N: 92 Multiple R^2: 0.4					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	5	1	5	1.1	0.291
RKM	194	6	32	8.0	0.000
DEPTH*RKM	11	6	2	0.4	0.850
Error	313	78	4		

Bonferroni Adjustment

RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

	1	2	3	4	5	6	7	8
1	1.000							
2	1.000	1.000						
3	0.444	0.007	1.000					
4	1.000	1.000	0.197	1.000				
5	1.000	1.000	0.207	1.000	1.000			
6	1.000	1.000	0.003	1.000	1.000	1.000		
7	1.000	1.000	0.000	1.000	1.000	1.000	1.000	
8	0.008	0.001	0.000	0.018	0.018	0.003	0.632	1.000

APPENDIX 3-B

Summary of field observations of sediment types and the presence of SAV and macroalgae. Key: SAV/Macroalgae present=1; absent=0.

Homosassa River, Spring Run & Southeast Fork				
Transect & Station	**River Kilometer**	**Sediments**	**SAV**	**Macro-algae**
08HOM001	0.0	shell hash	0	0
08HOM002	0.0	shell hash	0	0
08HOM003	0.0	shell hash	0	0
08HOM004	0.0	shell hash	1	0
08HOM011	1.0	shell hash	1	0
08HOM012	1.0	shell hash	0	0
08HOM013	1.0	sand muck	0	0
08HOM014	1.0	sand muck	0	0
08HOM021	2.0	shell silt	0	0
08HOM022	2.0	muck sand	0	0
08HOM023	2.1	muck sand	0	0
08HOM024	2.1	salty muck	0	0
08HOM031	3.0	sand muck	1	0
08HOM032	3.0	muck; shell hash	0	0
08HOM033	3.0	Muck; silt	0	0
08HOM034	2.9	sand muck	0	0
08HOM041	4.1	muck; shell hash	0	0
08HOM042	4.1	shell hash	0	0
08HOM043	4.2	No Data	0	0
08HOM044	4.2	sand shell	0	0
08HOM051	5.2	muck sand	0	0
08HOM052	5.2	muck sand	0	0
08HOM053	5.2	muck sand	0	0
08HOM054	5.2	muck sand	0	0
08HOM061	5.6	muck sand	0	0
08HOM062	5.6	muck sand	0	0
08HOM063	5.6	muck sand	0	0
08HOM064	5.6	muck sand	0	0
08HOM071	5.8	muck sand	1	1

Homosassa River, Spring Run & Southeast Fork				
Transect & Station	**River Kilometer**	**Sediments**	**SAV**	**Macro-algae**
08HOM072	5.8	muck sand	0	1
08HOM073	5.8	muck sand	0	0
08HOM074	5.8	muck sand	0	0
08HOM081	6.4	shell hash	0	0
08HOM082	6.4	shell hash	0	0
08HOM083	6.4	shell hash; oyster bar	0	0
08HOM084	6.4	oyster hash	0	0
08HOM091	6.7	sand muck	0	0
08HOM092	6.7	shell hash muck	0	0
08HOM093	6.7	muck sand	0	0
08HOM094	6.7	silty muck	0	0
08HOM101	7.2	muck sand	0	0
08HOM102	7.2	muck sand	0	0
08HOM103	7.2	muck sand	0	0
08HOM104	7.2	muck sand; shell hash	0	0
08HOM111	7.7	muck sand	0	0
08HOM112	7.7	muck sand	0	0
08HOM113	7.7	muck sand	0	0
08HOM114	7.7	muck sand	0	0
08HOM121	8.2	muck sand	0	0
08HOM122	8.2	silt hard bottom	0	0
08HOM123	8.2	muck sand	0	0
08HOM124	8.2	silt muck	0	0
08HOM131	8.6	sand muck	0	0
08HOM132	8.5	sand muck	0	0
08HOM133	8.5	sand muck	0	0
08HOM134	8.5	muck sand	0	0
08HOM141	9.1	muck sand	0	0
08HOM142	9.0	muck sand shell	0	0
08HOM143	9.0	muck shell hash	0	0
08HOM144	9.0	muck sand	0	1
08HOM151	9.6	muck sand	0	0
08HOM152	9.6	sand muck	0	0
08HOM153	9.6	sand muck	1	1
08HOM154	9.6	muck silt	0	0

Homosassa River, Spring Run & Southeast Fork				
Transect & Station	**River Kilometer**	**Sediments**	**SAV**	**Macro-algae**
08HOM161	10.0	sand muck	0	0
08HOM162	10.0	muck sand	0	0
08HOM163	10.0	silt	0	0
08HOM164	10.0	sand muck	0	0
08HOM171	10.4	sand muck	0	0
08HOM172	10.4	silty sand	0	0
08HOM173	10.4	sand muck	0	0
08HOM174	10.4	sand muck	0	0
08HOMSUP3	11.0	muck sand	0	0
08HOMSUP4	11.0	sand muck	0	0
08HOMSUP5	11.0	silt muck	0	0
08HOMSUP6	11.0	muck sand	0	0
08HOM181	11.2	silt	0	0
08HOM182	11.2	sand muck	0	0
08HOM183	11.2	silt	0	1
08HOM184	11.2	sand muck	0	0
08HOMSUP2	11.4	muck sand	0	0
08HOM191	11.6	sand muck	0	1
08HOM192	11.6	sand muck	1	0
08HOM193	11.6	sand muck	0	1
08HOM194	11.6	muck sand	0	1
08HOM201	12.2	muck sand	1	1
08HOM202	12.2	muck clay	0	0
08HOM203	12.2	silt muck	0	0
08HOM204	12.2	silt detritus	0	1
08HOM211	12.5 (RUN)	sand muck	1	0
08HOM212	12.5 (RUN)	sand	1	0
08HOM213	12.5 (RUN)	sand muck	1	0
08HOM214	12.5 (RUN)	sand muck	1	0
08HOMSUP1	12.6 (RUN)	sand	1	0
08HOM221	12.9 (SEF)	silt	1	1
08HOM222	12.9 (SEF)	sand muck	1	0
08HOM223	12.9 (SEF)	sand muck	1	0
08HOM224	12.9 (SEF)	sand muck	0	1
08HOMF1	13.0 (SEF)	No Data	1	1
08HOMF2	13.0 (SEF)	muck sand	0	1
08HOMF3	13.0 (SEF)	sand muck	1	1

Homosassa River, Spring Run & Southeast Fork				
Transect & Station	**River Kilometer**	**Sediments**	**SAV**	**Macro-algae**
08HOMF4	13.0 (SEF)	muck sand	0	1
08HOMF5	13.0 (SEF)	sand muck	1	1
08HOMF6	13.0 (SEF)	sand muck	0	0
Halls River				
Transect & Station	**River Kilometer**	**Sediments**	**SAV**	**Macro-algae**
08HAL11	0.4	sand muck	1	0
08HAL12	0.4	sand muck	1	0
08HAL21	0.7	sand muck	0	0
08HAL22	0.7	sand muck	1	0
08HAL31	1.3	sand muck	1	0
08HAL32	1.3	sand muck	1	0
08HAL41	1.8	silty muck	1	1
08HAL42	1.8	sand muck	1	0
08HAL51	2.2	sand	1	0
08HAL52	2.2	sand	1	0

APPENDIX 3-C

Analysis of Variance: Univariate Community Metrics (Numbers of Taxa, Shannon-Wiener Diversity, and Total Numbers of Individuals m^{-2});

Factors: Depth Stratum (Shallow vs. Deep), River Kilometer, and Depth Stratum*River Kilometer;

Bonferroni *a posteriori* paired comparisons tests

3-C1 NUMBERS OF TAXA

Dependent Variable: Numbers of Taxa **N: 92 Multiple R^2: 0.7**					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	55	1	55	1.6	0.204
RKM	5188	6	865	25.7	**0.000**
DEPTH*RKM	68	6	11	0.3	0.916
Error	2620	78	34		

Bonferroni Adjustment

ROW RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

	1	2	3	4	5	6	7	8
1	1.000							
2	0.000	1.000						
3	0.000	0.009	1.000					
4	0.000	0.000	0.001	1.000				
5	0.000	0.000	0.003	1.000	1.000			
6	0.000	0.000	0.014	1.000	1.000	1.000		
7	0.000	0.045	1.000	0.002	0.005	0.030	1.000	
8	0.000	0.530	1.000	0.002	0.005	0.033	1.000	1.000

3-C2 SHANNON-WIENER DIVERSITY

Dependent Variable: Shannon Diversity **N: 92 Multiple R^2: 0.4**					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	0	1	0	0.2	0.691
RKM	25	6	4	8.6	**0.000**
DEPTH*RKM	2	6	0	0.5	0.777
Error	38	78	0		

Bonferroni Adjustment

ROW RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

	1	2	3	4	5	6	7	8
1	1.000							
2	0.000	1.000						
3	0.000	1.000	1.000					
4	1.000	0.000	0.009	1.000				
5	0.440	0.002	0.271	1.000	1.000			
6	0.000	0.062	1.000	0.167	1.000	1.000		
7	0.000	1.000	1.000	0.014	0.328	1.000	1.000	
8	0.003	0.272	1.000	0.490	1.000	1.000	1.000	1.000

3-C3 TOTAL NUMBERS OF INDIVIDUALS m^{-2}

Dependent Variable: Total Numbers m^{-2} N: 92 Multiple R^2: 0.4					
Source	**Sum-of-Squares**	**df**	**Mean Square**	**F**	***p***
DEPTH	7326050000	1	7326050000	5.2	**0.026**
RKM	63682300000	6	10613700000	7.5	**0.000**
DEPTH*RKM	6676170000	6	1112690000	0.8	0.585
Error	110692000000	78	1419120000		

Bonferroni Adjustment

RKM$
1 0-1
2 10-11
3 12
4 2-3
5 4-5
6 6-7
7 8-9
8 Halls

Matrix of pairwise comparison probabilities:

	1	2	3	4	5	6	7	8
1	1.000							
2	0.000	1.000						
3	0.385	0.001	1.000					
4	0.033	1.000	1.000	1.000				
5	0.164	0.841	1.000	1.000	1.000			
6	0.489	0.002	1.000	1.000	1.000	1.000		
7	0.001	1.000	0.214	1.000	1.000	0.257	1.000	
8	0.010	1.000	1.000	1.000	1.000	1.000	1.000	1.000

APPENDIX 3-D
Forward Step-wise Linear Regression Analyses

3-D1 NUMBERS OF TAXA

Step # 0 R = 0.791 R-Square = 0.626

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	-0.408	0.214	-0.183	0.37781	1	3.627	0.060
3	SAL	0.978	0.142	0.714	0.32502	1	47.411	0.000
4	TEMP	-3.400	0.716	-0.480	0.34200	1	22.545	0.000
5	PH	-2.190	4.473	-0.074	0.15478	1	0.240	0.625
6	DO	1.372	0.530	0.375	0.16650	1	6.697	0.011
7	BOTDEP	0.561	0.683	0.058	0.69837	1	0.676	0.413
Out		Part. Corr.						
	none							

Dependent Variable NUMBERS OF TAXA
Minimum tolerance for entry into model = 0.000000

Backward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050
Step # 1 R = 0.791 R-Square = 0.625
Term removed: PH

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	-0.433	0.208	-0.194	0.39910	1	4.331	0.040
3	SAL	0.961	0.137	0.702	0.34546	1	49.010	0.000
4	TEMP	-3.187	0.567	-0.450	0.54258	1	31.645	0.000
6	DO	1.140	0.237	0.312	0.82507	1	23.077	0.000
7	BOTDEP	0.615	0.672	0.064	0.71652	1	0.837	0.362
Out		Part. Corr.						
5	PH	-0.047	.	.	0.15478	1	0.240	0.625

Step # 2 R = 0.789 R-Square = 0.622
Term removed: BOTDEP

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	-0.383	0.201	-0.172	0.42768	1	3.652	0.059
3	SAL	1.011	0.126	0.739	0.41139	1	64.726	0.000
4	TEMP	-3.177	0.566	-0.449	0.54279	1	31.502	0.000
6	DO	1.097	0.232	0.300	0.85860	1	22.275	0.000
Out		Part. Corr.						
5	PH	-0.060	.	.	0.15881	1	0.396	0.530
7	BOTDEP	0.088	.	.	0.71652	1	0.837	0.362

Step # 3 R = 0.781 R-Square = 0.609
Term removed: RKM

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
3	SAL	1.176	0.092	0.859	0.78101	1	162.402	0.000
4	TEMP	-3.800	0.468	-0.537	0.81212	1	65.841	0.000
6	DO	0.992	0.228	0.271	0.90978	1	18.833	0.000
Out		Part. Corr.						
2	RKM	-0.180	.	.	0.42768	1	3.652	0.059
5	PH	-0.094	.	.	0.16516	1	0.964	0.328
7	BOTDEP	0.037	.	.	0.76783	1	0.148	0.702

Dep Var: NUMBERS OF TAXA   N: 114   Multiple R: 0.781   Squared multiple R: 0.609

Adjusted squared multiple R: 0.599   Standard error of estimate: 5.629

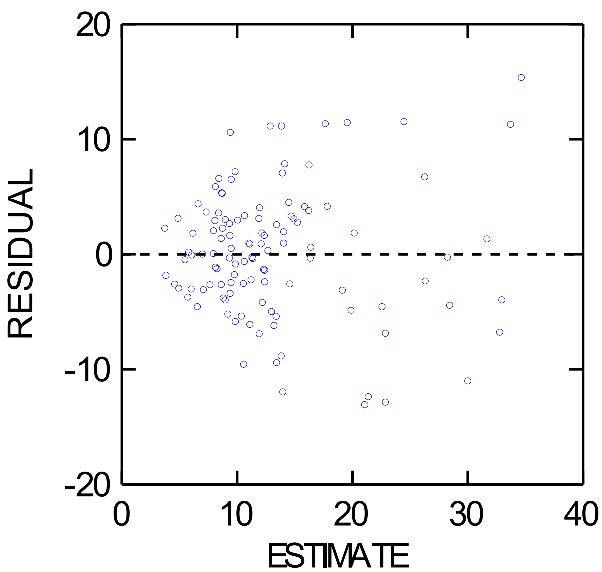
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	93.246	11.536	0.000	.	8.083	0.000
SAL	1.176	0.092	0.859	0.781	12.744	0.000
TEMP	-3.800	0.468	-0.537	0.812	-8.114	0.000
DO	0.992	0.228	0.271	0.910	4.340	0.000

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	54 38.390	3	18 12.797	57 .205	0. 000
Residual	34 85.864	11 0	31 .690		

Durbin-Watson D Statistic 1.436
First Order Autocorrelation 0.280

Plot of residuals against predicted values




```
Step # 0 R =  0.659 R-Square =  0.434
```

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	-0.040	0.025	-0.193	0.37781	1	2.666	0.105
3	SAL	0.076	0.016	0.595	0.32502	1	21.759	0.000
4	TEMP	-0.230	0.082	-0.347	0.34200	1	7.782	0.006
5	PH	-0.106	0.515	-0.038	0.15478	1	0.042	0.838
6	DO	0.081	0.061	0.236	0.16650	1	1.759	0.188
7	BOTDEP	-0.121	0.079	-0.134	0.69837	1	2.355	0.128
Out		Part. Corr.						
	none							

Dependent Variable SHANNON DIVERSITY
Minimum tolerance for entry into model = 0.000000

Backward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050
Step # 1 R = 0.659 R-Square = 0.434
Term removed: PH

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	- 0.041	0.024	-0.199	0.3991 0	1	3.00 9	0. 086
3	SAL	0.07 5	0.016	0.589	0.3454 6	1	22.8 38	0. 000
4	TEMP	- 0.220	0.065	-0.331	0.5425 8	1	11.3 67	0. 001
6	DO	0.07 0	0.027	0.204	0.8250 7	1	6.53 1	0. 012
7	BOTDEP	- 0.118	0.077	-0.131	0.7165 2	1	2.33 5	0. 129
Out		Part. Corr.						
5	PH	- 0.020	.	.	0.1547 8	1	0.04 2	0. 838

Step # 2 R = 0.649 R-Square = 0.422
Term removed: BOTDEP

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	- 0.051	0.023	-0.244	0.4276 8	1	4.80 1	0. 031
3	SAL	0.06 6	0.015	0.513	0.4113 9	1	20.4 28	0. 000
4	TEMP	- 0.222	0.066	-0.334	0.5427 9	1	11.4 36	0. 001
6	DO	0.07 8	0.027	0.228	0.8586 0	1	8.39 5	0. 005
Out		Part. Corr.						
5	PH	0.00 4	.	.	0.1588 1	1	0.00 2	0. 969
7	BOTDEP	- 0.145	.	.	0.7165 2	1	2.33 5	0. 129

Dep Var: SHANNON DIVERSITY N: 114 Multiple R: 0.649 Squared multiple R: 0.422

Adjusted squared multiple R: 0.401 Standard error of estimate: 0.644

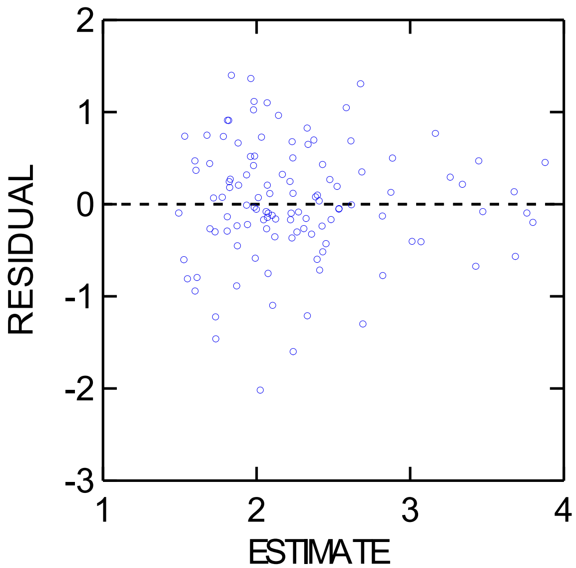
Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	7.212	1.512	0.000	.	4.768	0.000
RKM	-0.051	0.023	-0.244	0.428	-2.191	0.031
SAL	0.066	0.015	0.513	0.411	4.520	0.000
TEMP	-0.222	0.066	-0.334	0.543	-3.382	0.001
DO	0.078	0.027	0.228	0.859	2.897	0.005

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	32.952	4	8.238	19.874	0.000
Residual	45.182	109	0.415		

Durbin-Watson D Statistic 2.033
First Order Autocorrelation -0.033

Plot of residuals against predicted values



3-D3 TOTAL ABUNDANCE

Step # 0 R = 0.494 R-Square = 0.244

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	1478.903	1645.246	0.123	0.37781	1	0.808	0.371
3	SAL	2688.268	1089.482	0.364	0.32502	1	6.088	0.015
4	TEMP	-23999.375	5495.611	-0.628	0.34200	1	19.071	0.000
5	PH	-18116.488	34329.907	-0.113	0.15478	1	0.278	0.599
6	DO	5525.886	4067.721	0.280	0.16650	1	1.845	0.177
7	BOTDEP	7332.314	5242.067	0.141	0.69837	1	1.956	0.165
Out		Part. Corr.						
	none							

Dependent Variable TOTAL ABUNDANCE
Minimum tolerance for entry into model = 0.000000

Backward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050
Step # 1 R = 0.492 R-Square = 0.242
Term removed: PH

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
2	RKM	1278.376	1595.407	0.106	0.39910	1	0.642	0.425
3	SAL	2548.422	1053.225	0.345	0.34546	1	5.855	0.017
4	TEMP	-22236.095	4348.567	-0.582	0.54258	1	26.147	0.000
6	DO	3608.060	1821.181	0.183	0.82507	1	3.925	0.050
7	BOTDEP	7772.643	5157.917	0.149	0.71652	1	2.271	0.135
Out		Part. Corr.						
5	PH	-0.051	.	.	0.15478	1	0.278	0.599

Step # 2 R = 0.487 R-Square = 0.237
Term removed: RKM

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
3	SAL	1947.150	737.843	0.264	0.70159	1	6.964	0.010
4	TEMP	-20315.832	3622.663	-0.531	0.77924	1	31.449	0.000
6	DO	4010.358	1747.732	0.203	0.89294	1	5.265	0.024
7	BOTDEP	8841.036	4974.410	0.170	0.76783	1	3.159	0.078
Out		Part. Corr.						
2	RKM	0.077	.	.	0.39910	1	0.642	0.425
5	PH	-0.032	.	.	0.16350	1	0.108	0.743

Step # 3 R = 0.464 R-Square = 0.215
Term removed: BOTDEP

	Effect	Coefficient	Std Error	Std Coef	Tol.	df	F	'P'
In								
1	Constant							
3	SAL	2365.323	706.153	0.320	0.78101	1	11.220	0.001
4	TEMP	-19020.288	3583.221	-0.498	0.81212	1	28.177	0.000
6	DO	3587.718	1748.387	0.182	0.90978	1	4.211	0.043
Out		Part. Corr.						
2	RKM	0.117	.	.	0.42768	1	1.502	0.223
5	PH	-0.048	.	.	0.16516	1	0.250	0.618
7	BOTDEP	0.168	.	.	0.76783	1	3.159	0.078

Dep Var: TOTAL ABUNDANCE   N: 114   Multiple R: 0.464   Squared multiple R: 0.215

Adjusted squared multiple R: 0.194   Standard error of estimate: 43075.843

Effect	Coefficient	Std Error	Std Coef	Tolerance	t	P(2 Tail)
CONSTANT	489940 .871	88273. 830	0.000	.	5.550	0.000
SAL	2365.3 23	706.15 3	0.320	0.781	3.350	0.001
TEMP	- 19020.288	3583.2 21	-0.498	0.812	-5.308	0.000
DO	3587.7 18	1748.3 87	0.182	0.910	2.052	0.043

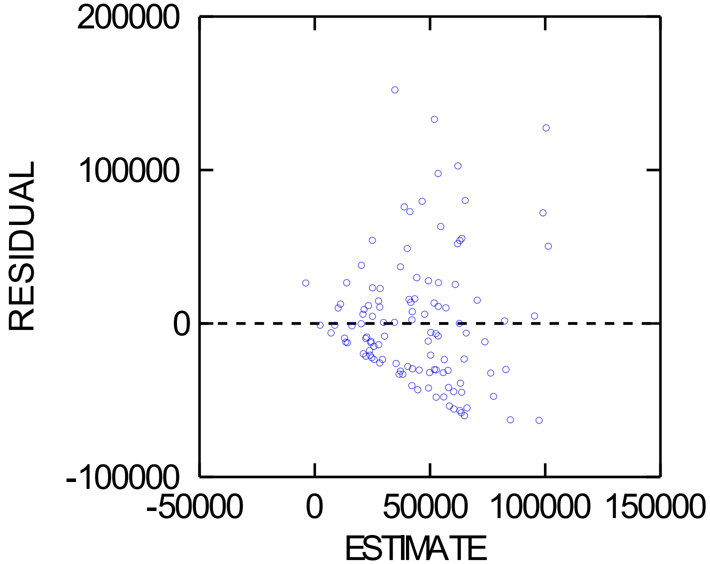
Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	5. 59684E+10	3	1. 86561E+10	10 .054	0. 000
Residual	2. 04108E+11	11 0	1. 85553E+09		

*** WARNING ***
Case 45 is an outlier (Studentized Residual = 3.745)

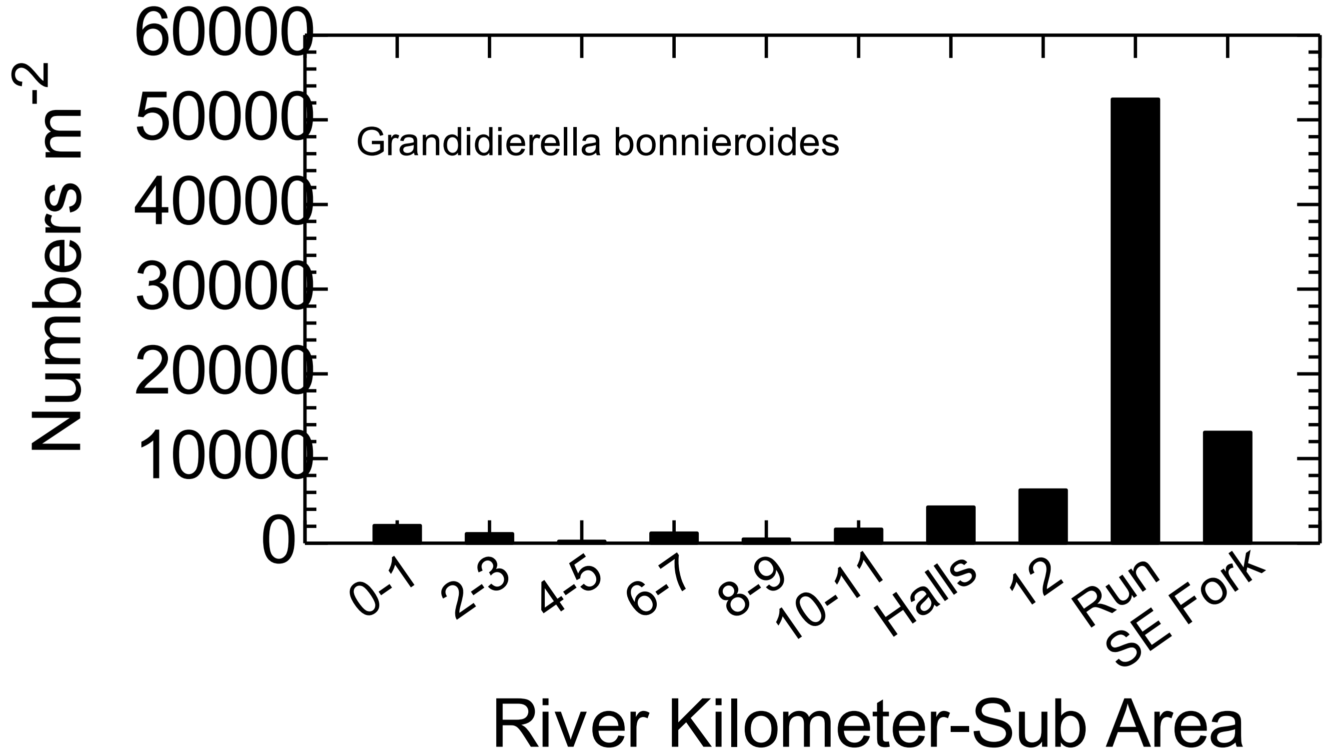
Durbin-Watson D Statistic 1.137
First Order Autocorrelation 0.429

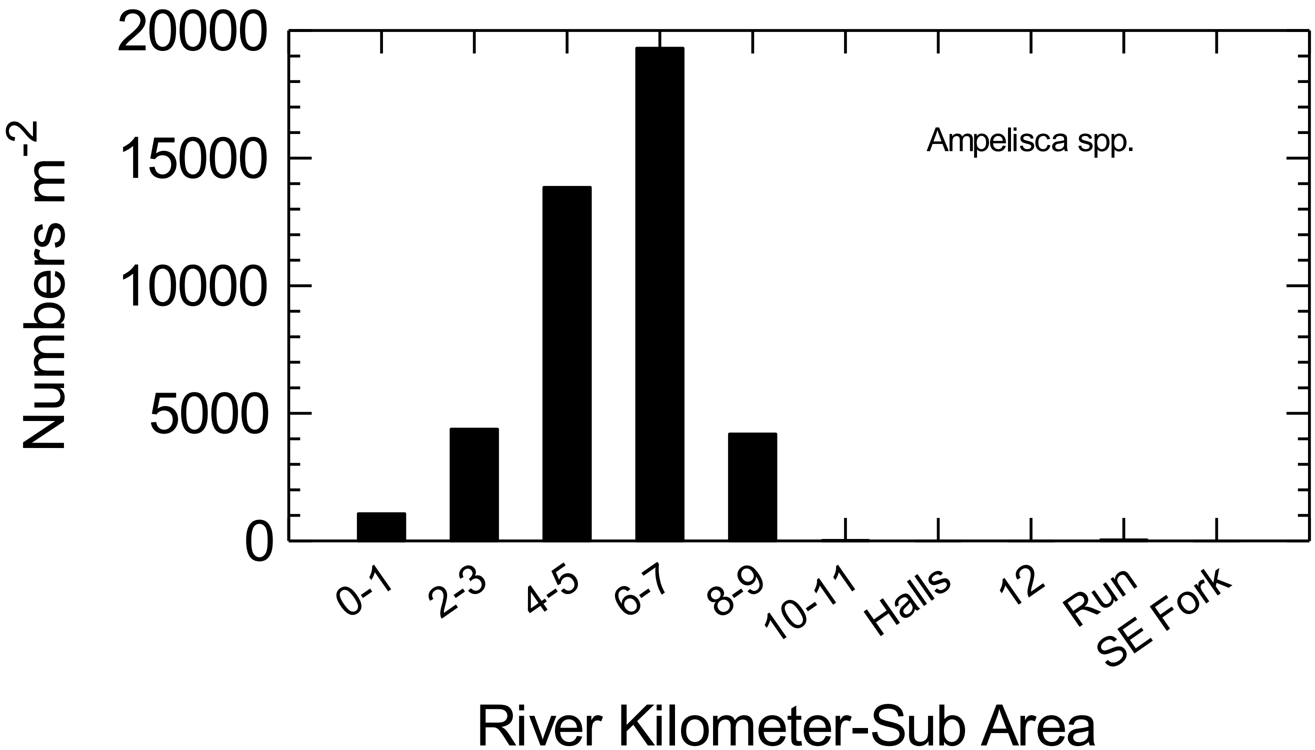
Plot of residuals against predicted values



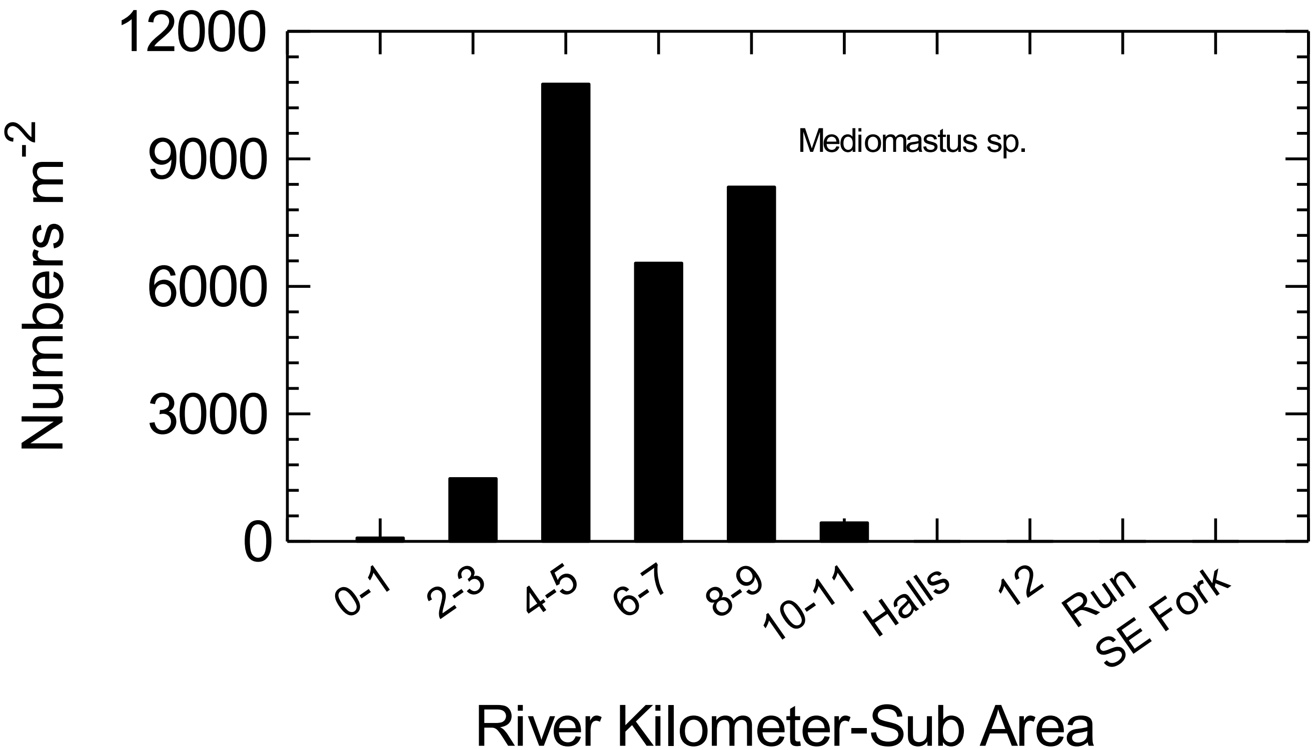
APPENDIX 3-E

Abundance vs. River Kilometer Plots of the 25 Highest Ranked Dominant Taxa, Homosassa River

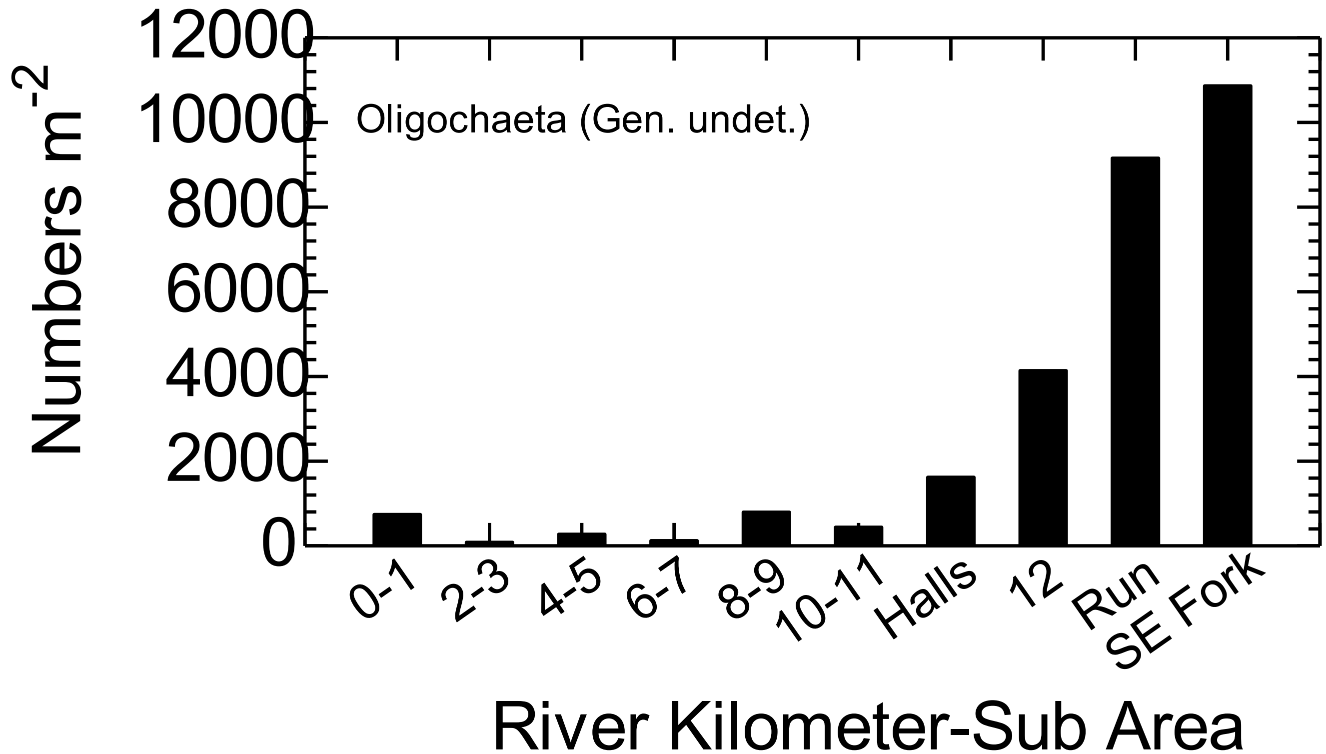


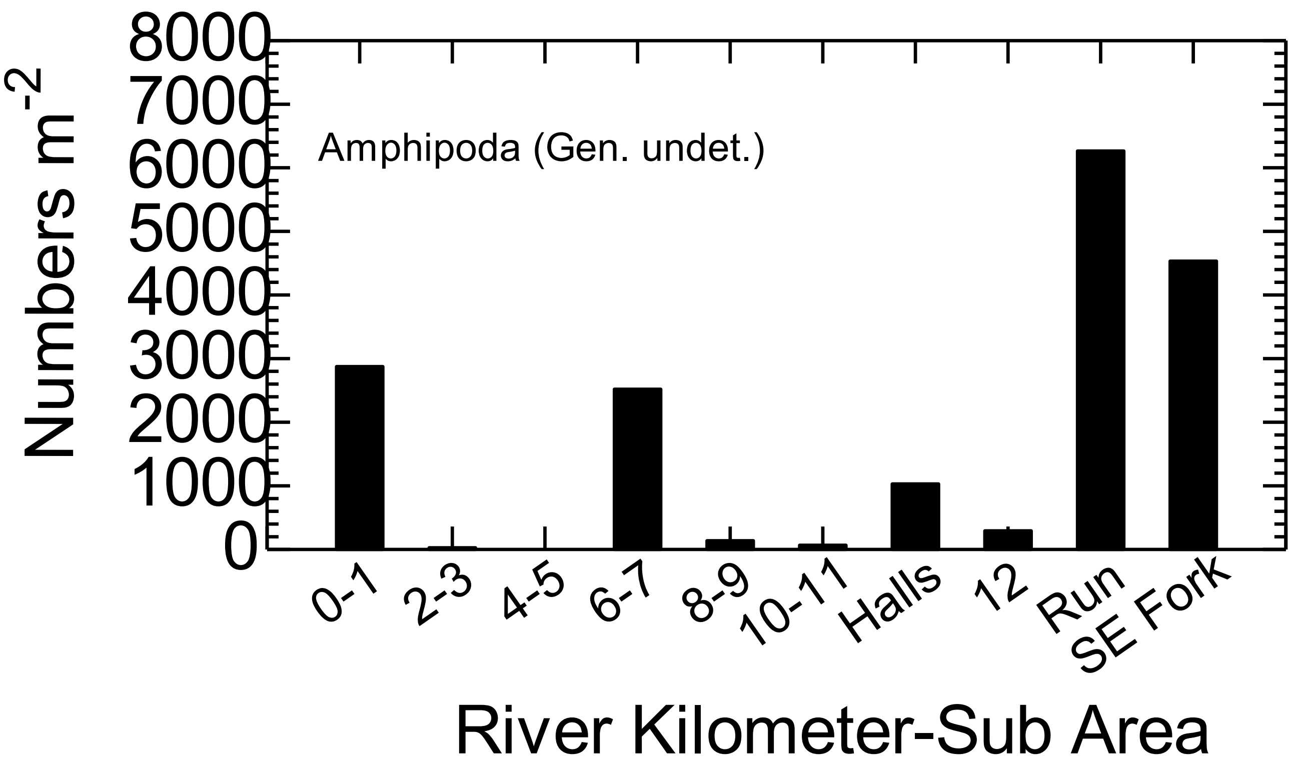


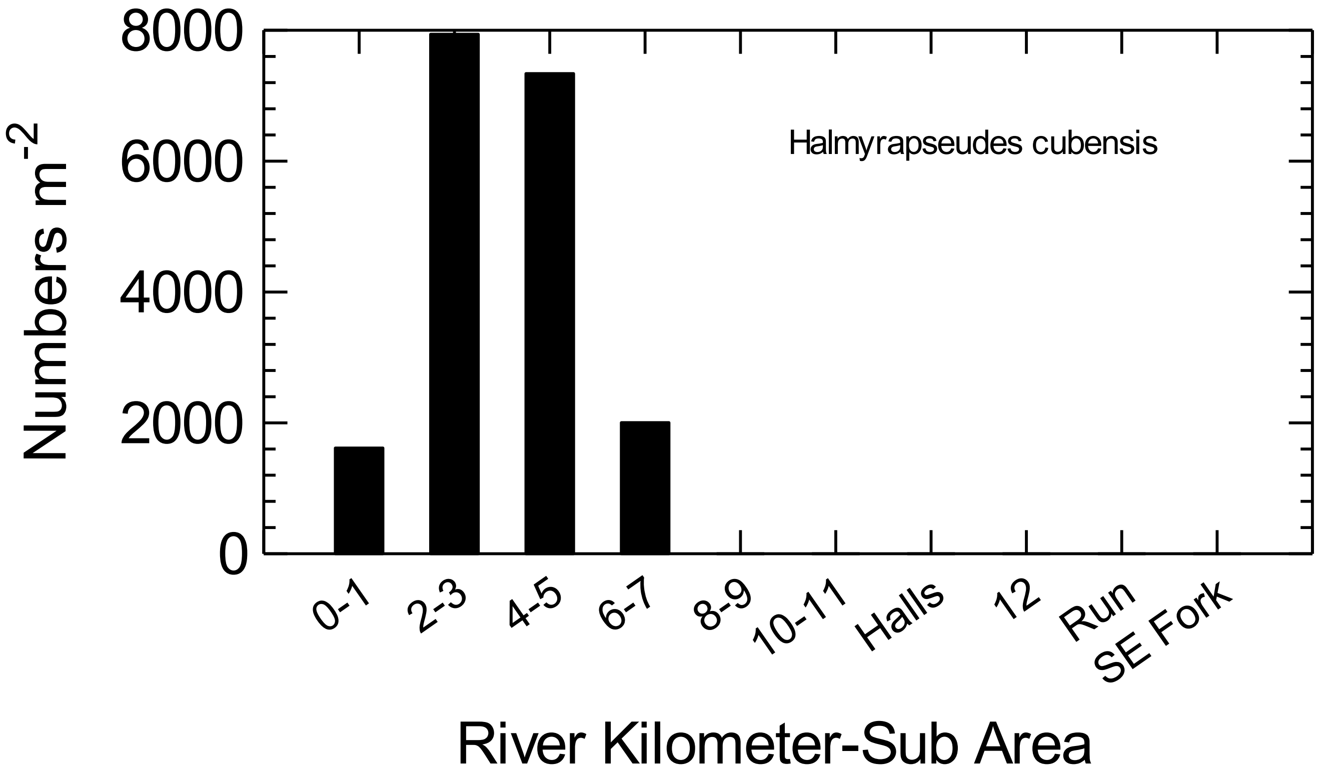
20000
15000
10000
5000
0
Numbers m-2
Ampelisca spp.
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

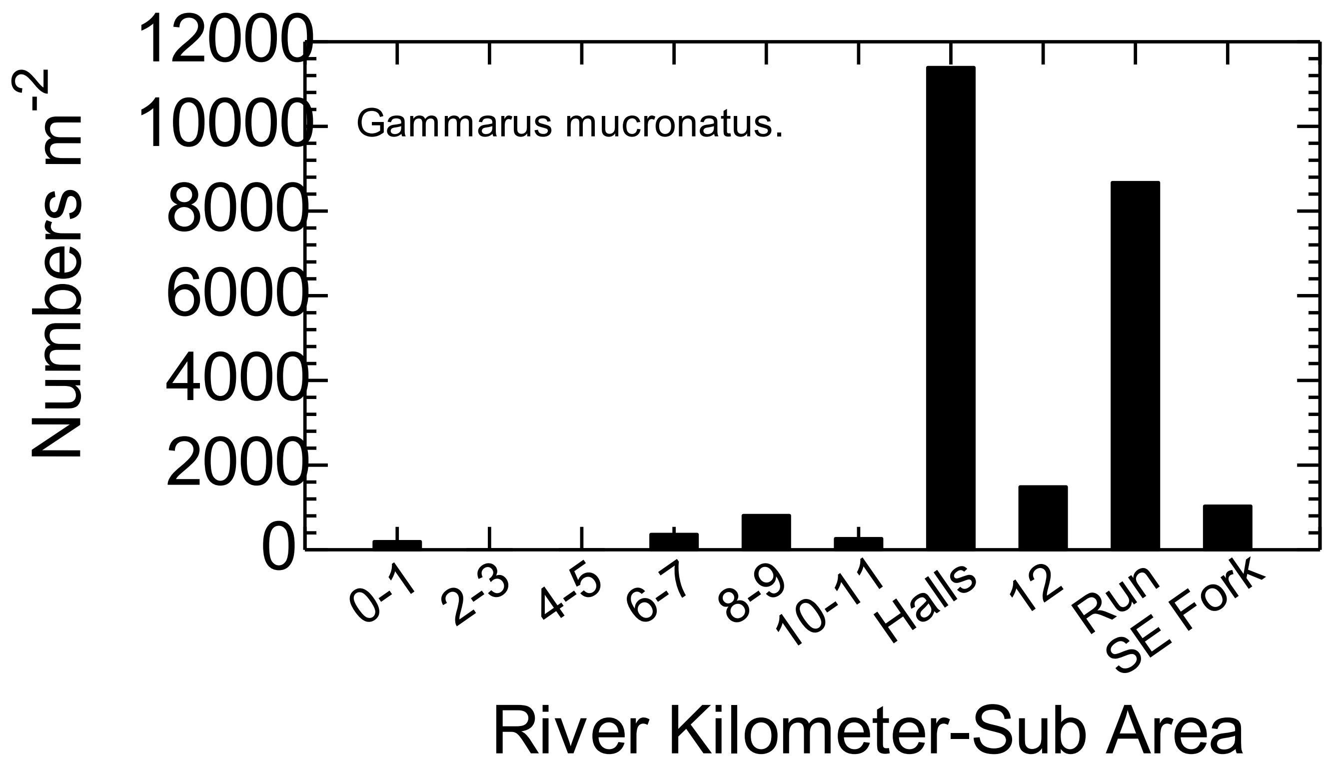


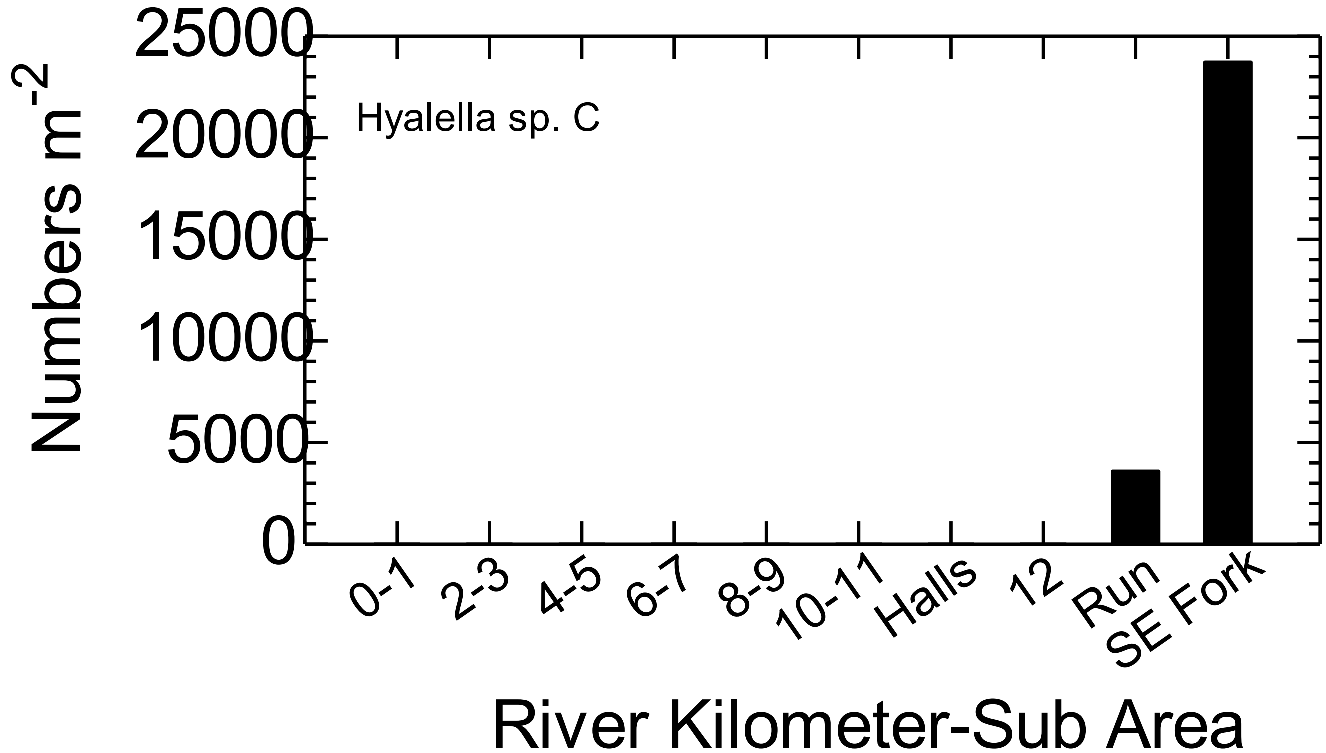
12000
9000
6000
3000
0
Numbers m-2
Mediomastus sp.
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

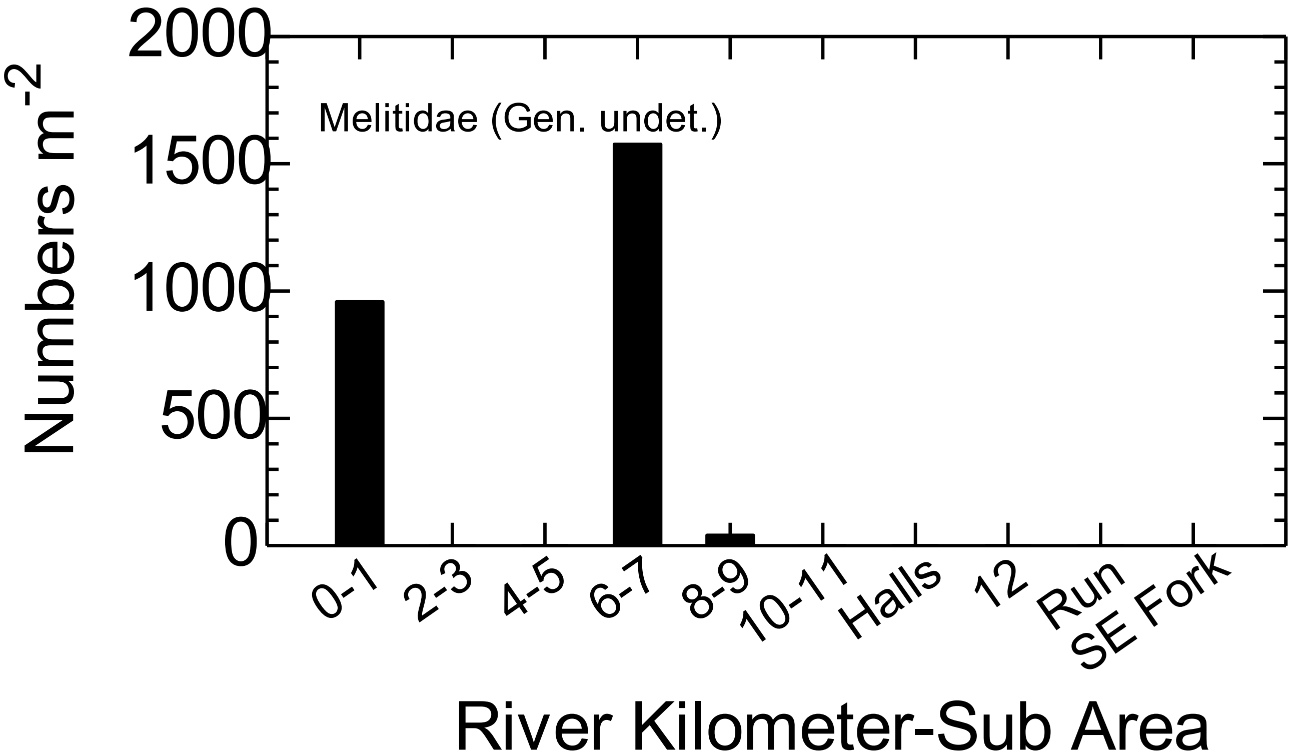

Numbers m-2
12000
10000
8000
6000
4000
2000
0
Oligochaeta (Gen. undet.)
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

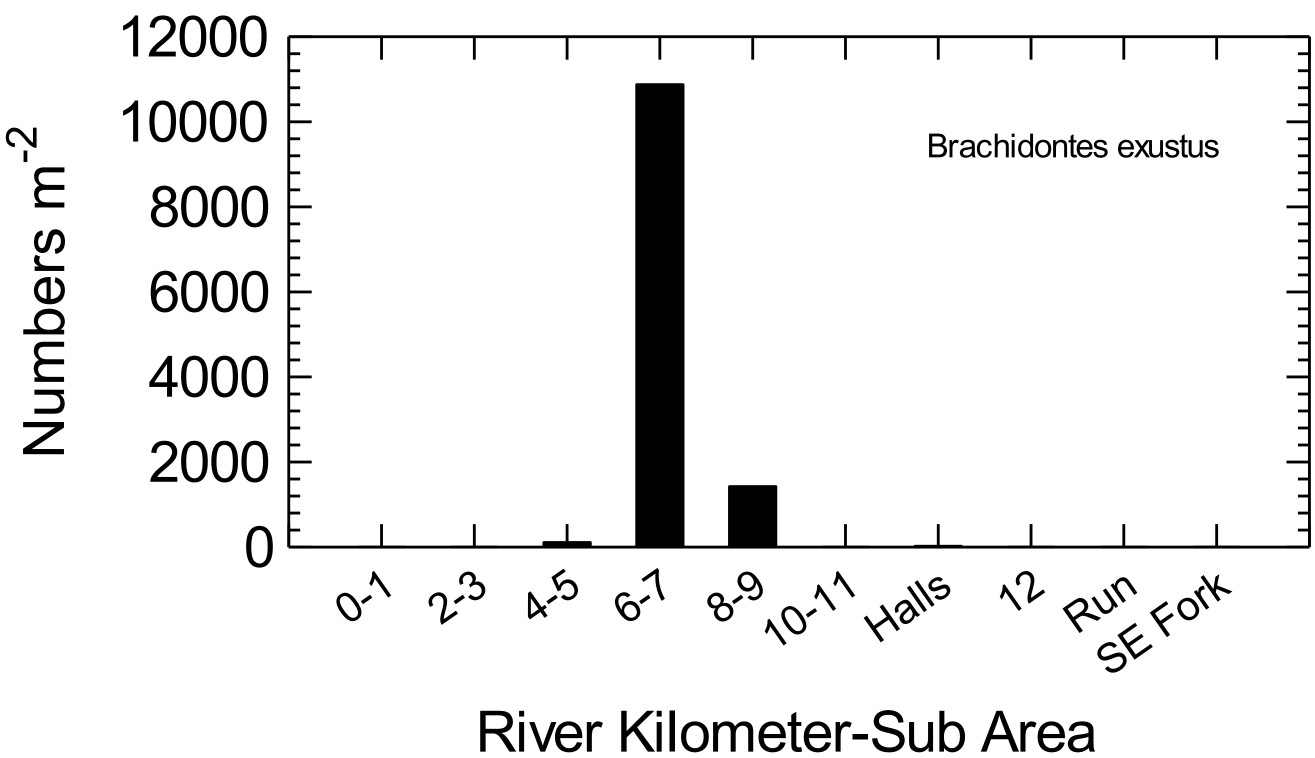

Amphipoda (Gen. undet.)
Numbers m-2
8000
7000
6000
5000
4000
3000
2000
1000
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

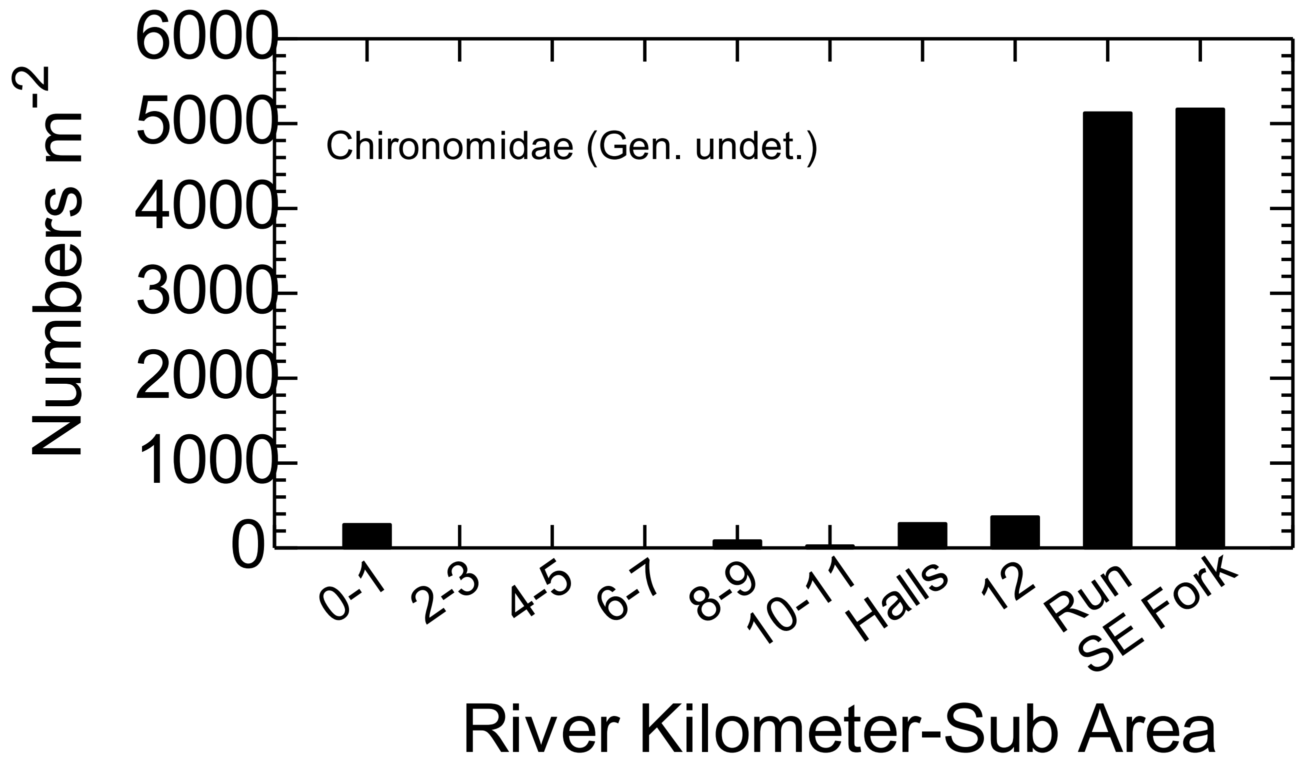

Halmyrapseudes cubensis
Numbers m-2
8000
6000
4000
2000
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

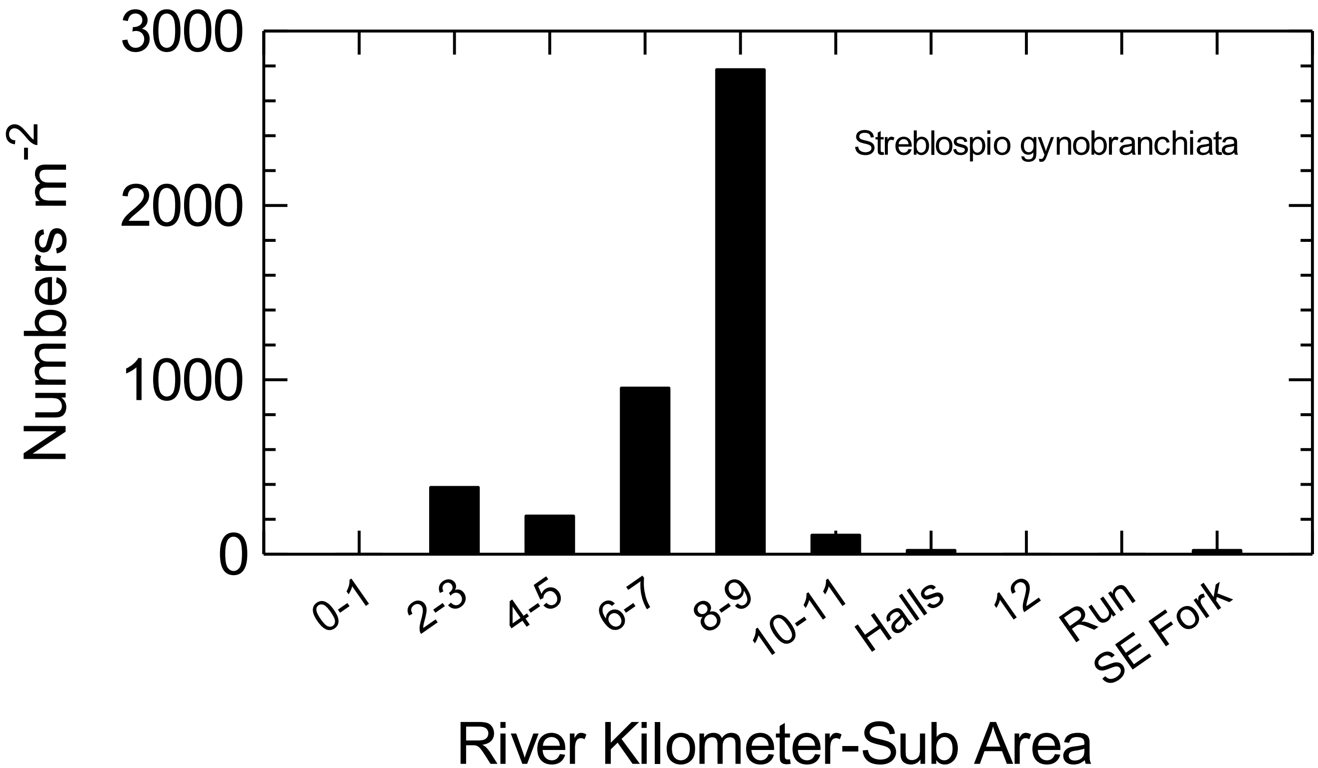

Gammarus mucronatus.
Numbers m-2
12000
10000
8000
6000
4000
2000
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area


Hyalella sp. C
Numbers m-2
25000
20000
15000
10000
5000
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

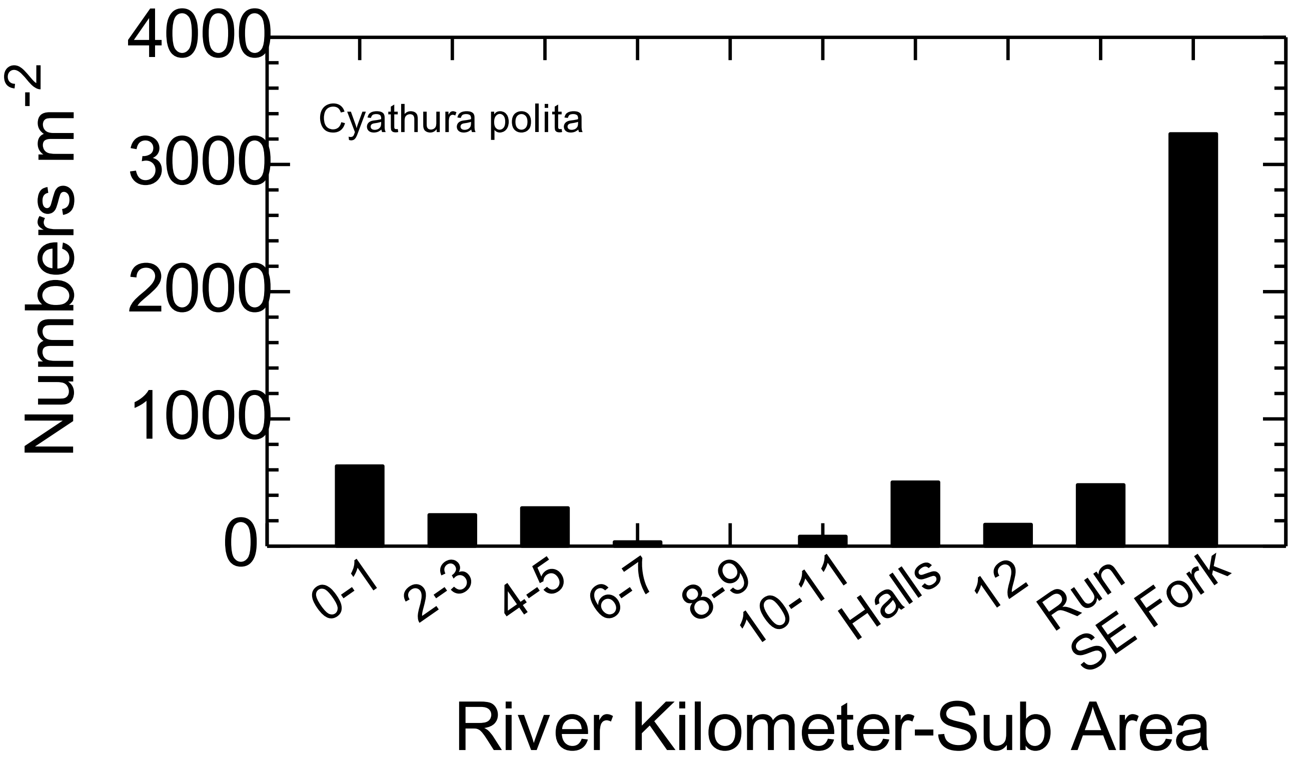

Numbers m-2
2000
1500
1000
500
0
Melitidae (Gen. undet.)
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

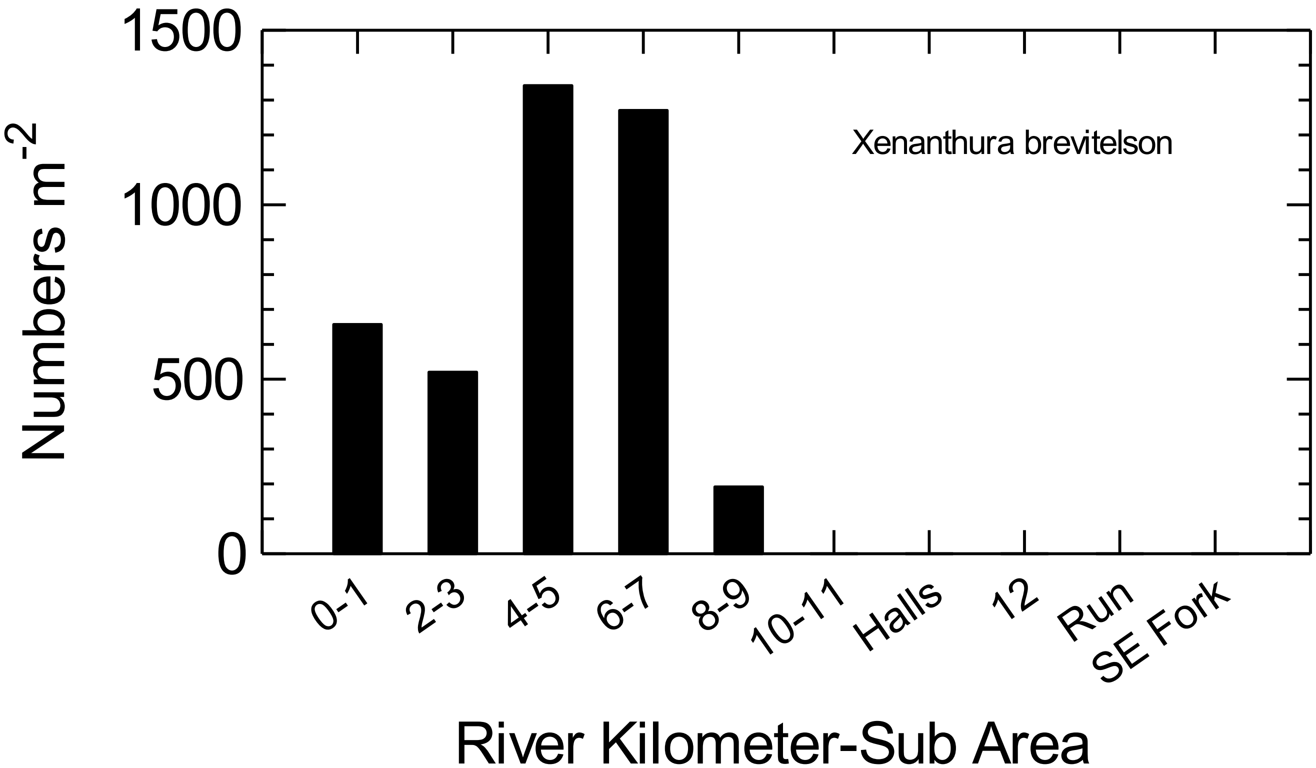

12000
10000
8000
6000
4000
2000
0
Numbers m-2
Brachidontes exustus
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area


Numbers m-2
6000
5000
4000
3000
2000
1000
0
Chironomidae (Gen. undet.)
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

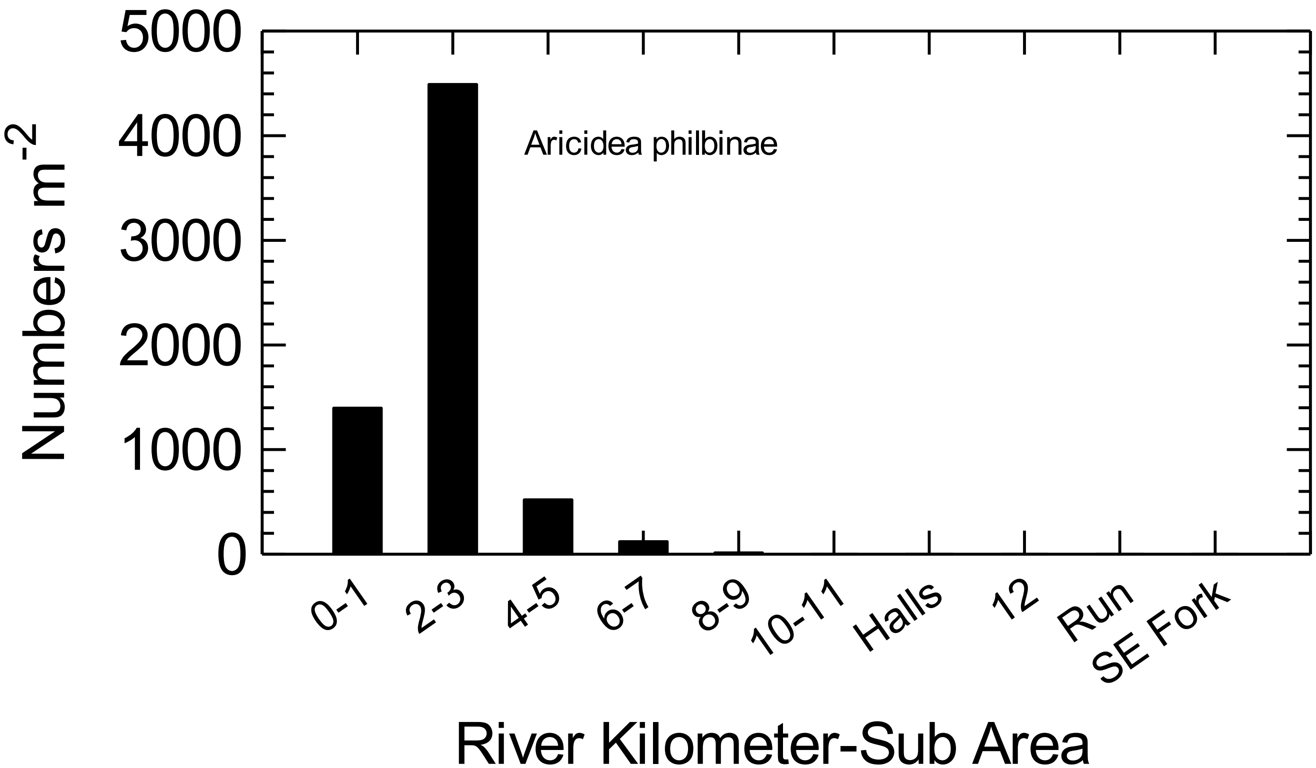


3000
2000
1000
0
Numbers m-2
Streblospio gynobranchiata
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

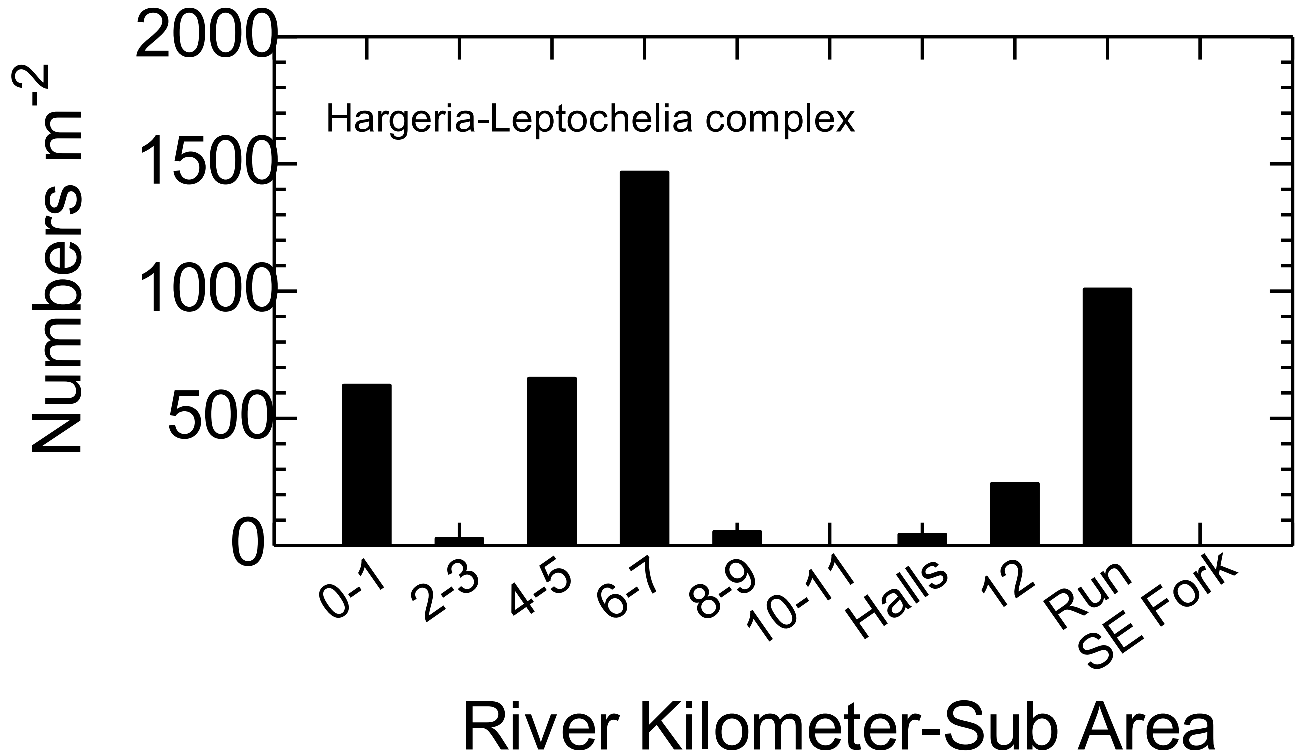

Cyathura polita
Numbers m-2
4000
3000
2000
1000
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area



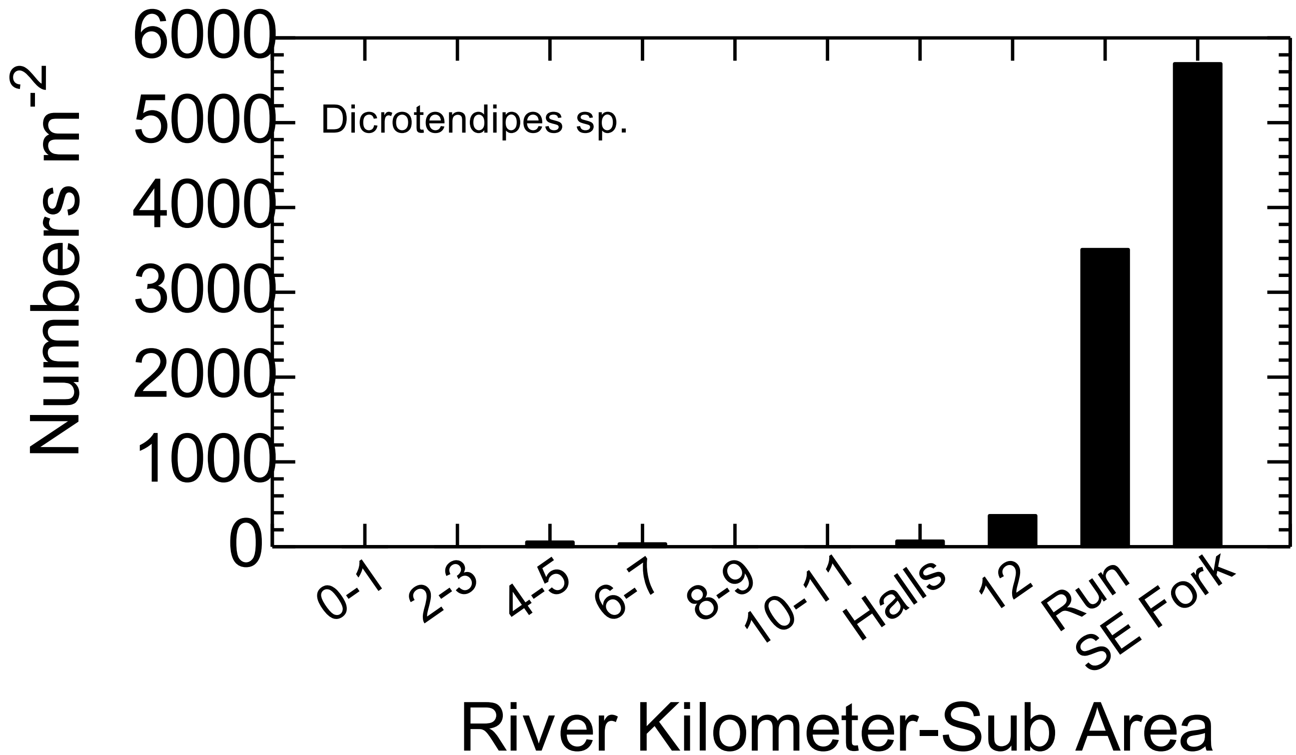
1500
1000
500
0
Numbers m-2
Xenanthura brevitelson
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area



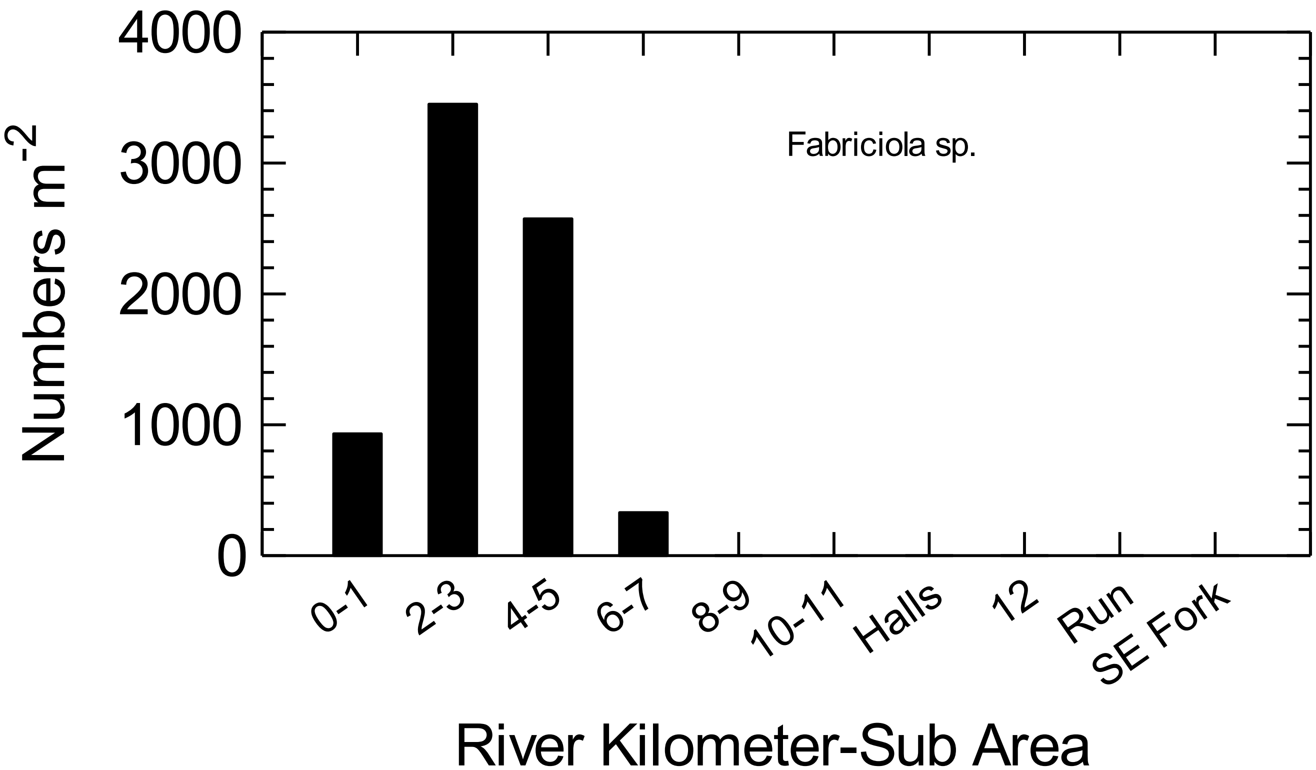
5000
4000
3000
2000
1000
0
Numbers m-2
Aricidea philbinae
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

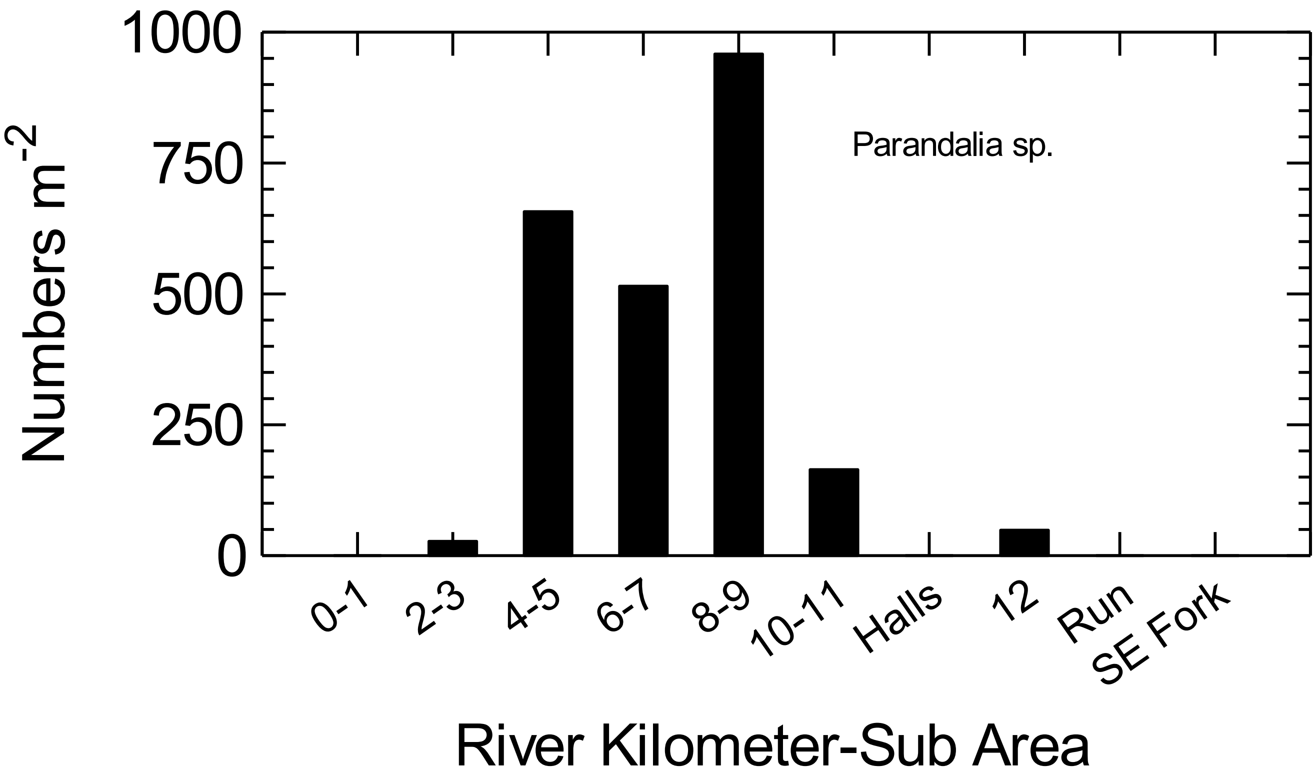


Hargeria-Leptochelia complex
Numbers m-2
2000
1500
1000
500
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

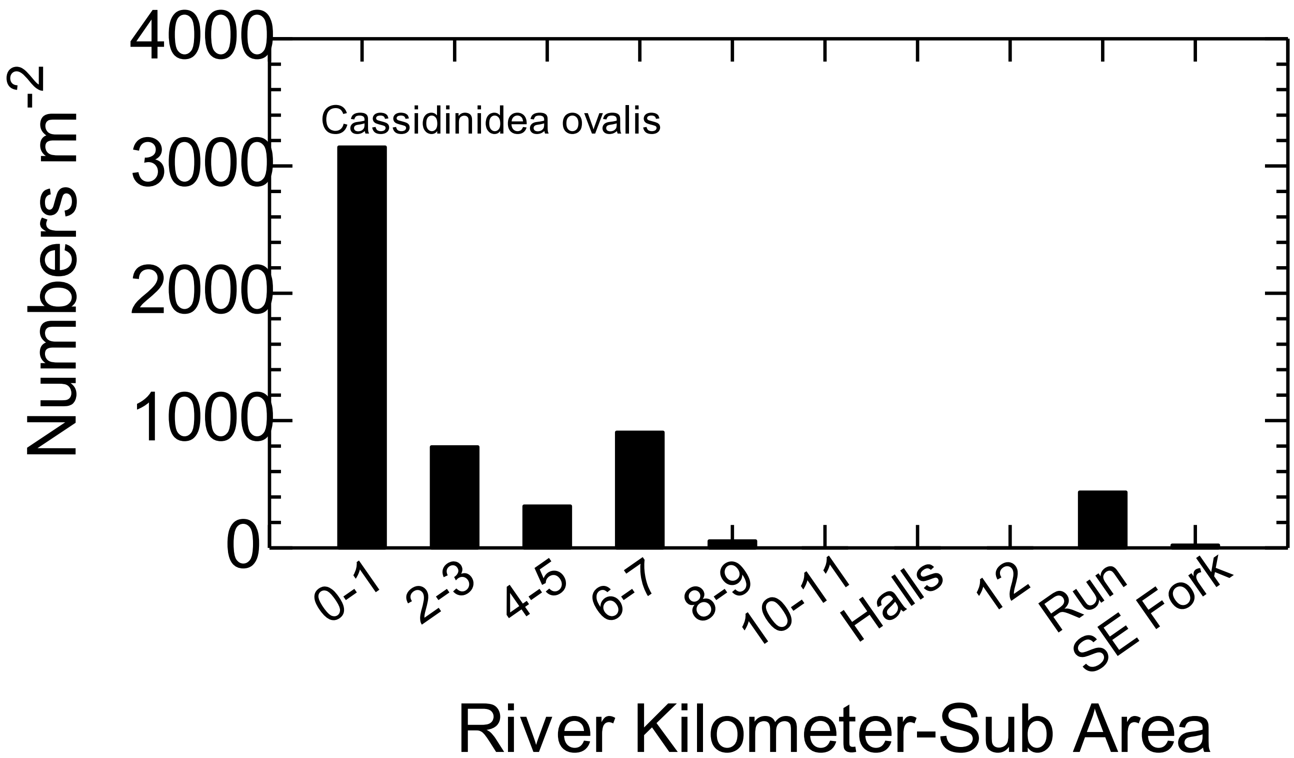


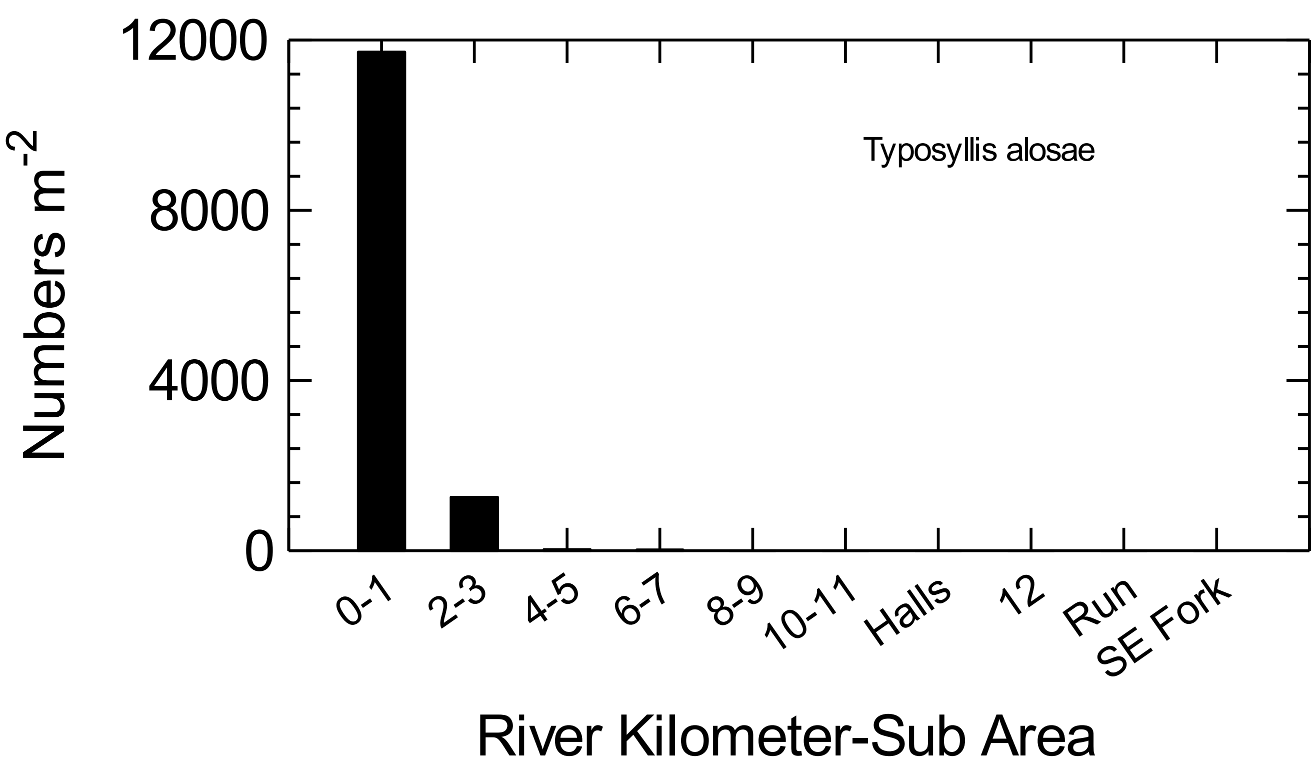
Numbers m-2
6000
5000
4000
3000
2000
1000
0
Dicrotendipes sp.
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

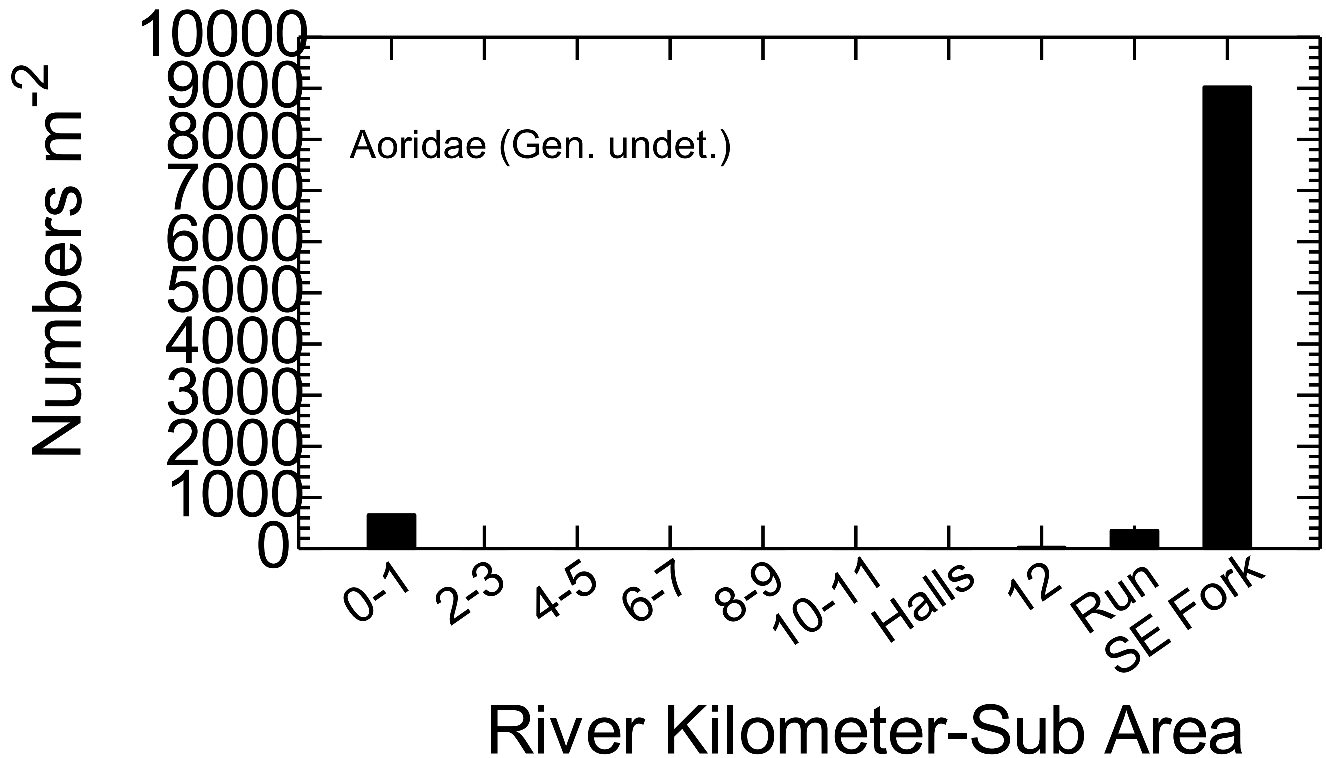

4000
3000
2000
1000
0
Numbers m-2
Fabriciola sp.
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area



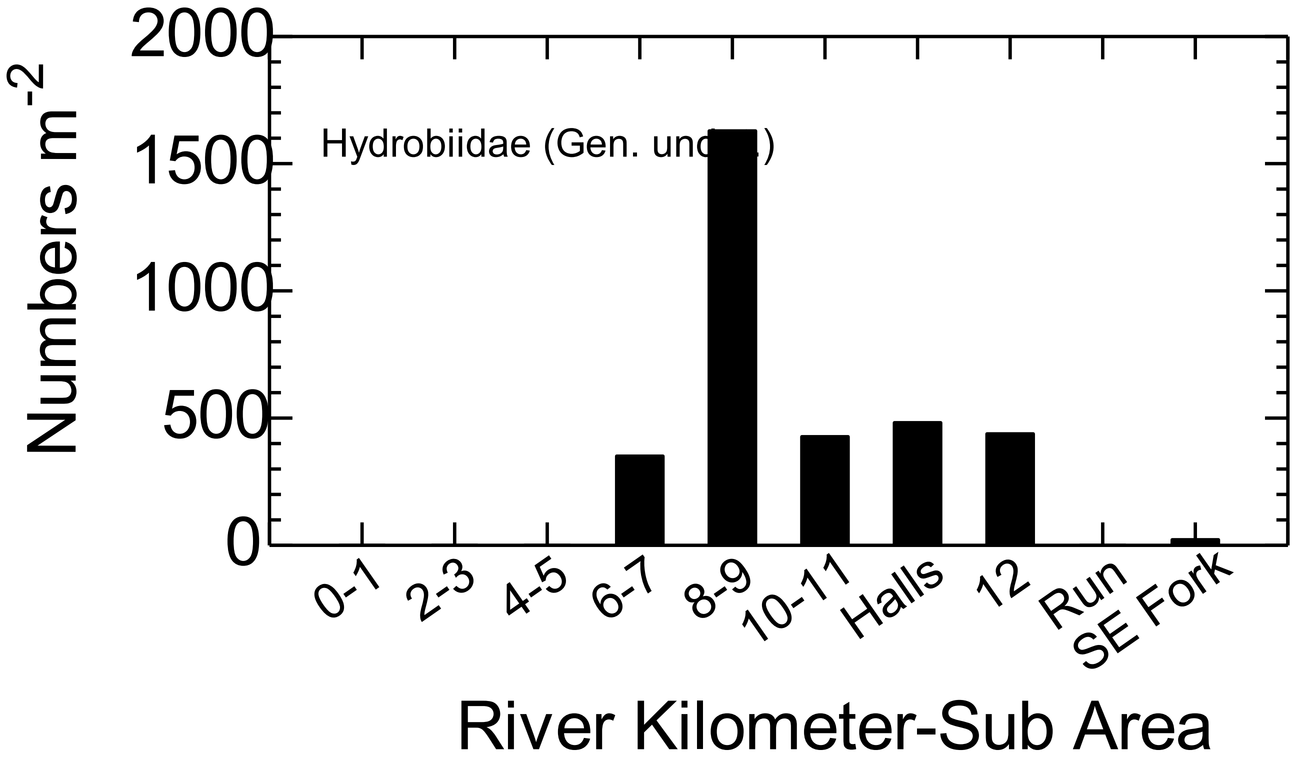
1000
750
500
250
0
Numbers m-2
Parandalia sp.
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area


Cassidinidea ovalis
Numbers m-2
0
1000
2000
3000
4000
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

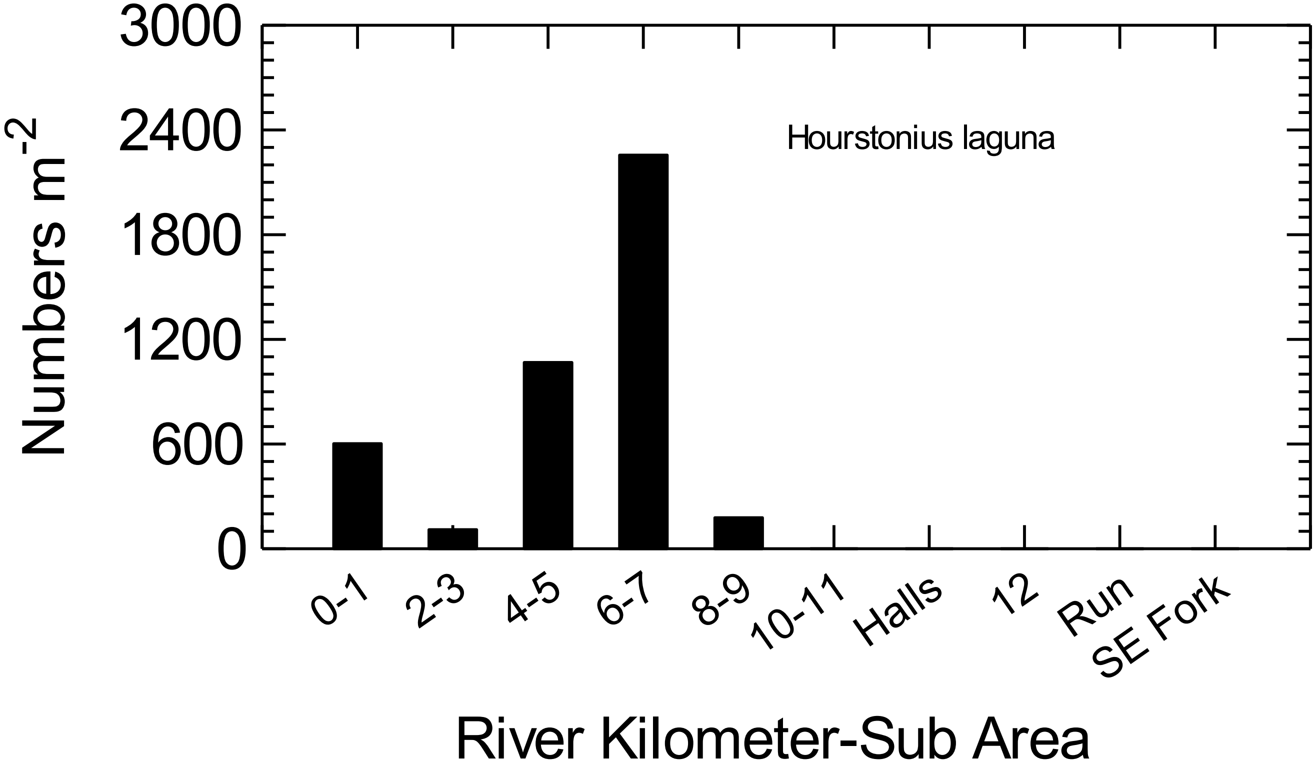

12000
8000
4000
0
Numbers m^{-2}
Typosyllis alosae
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area

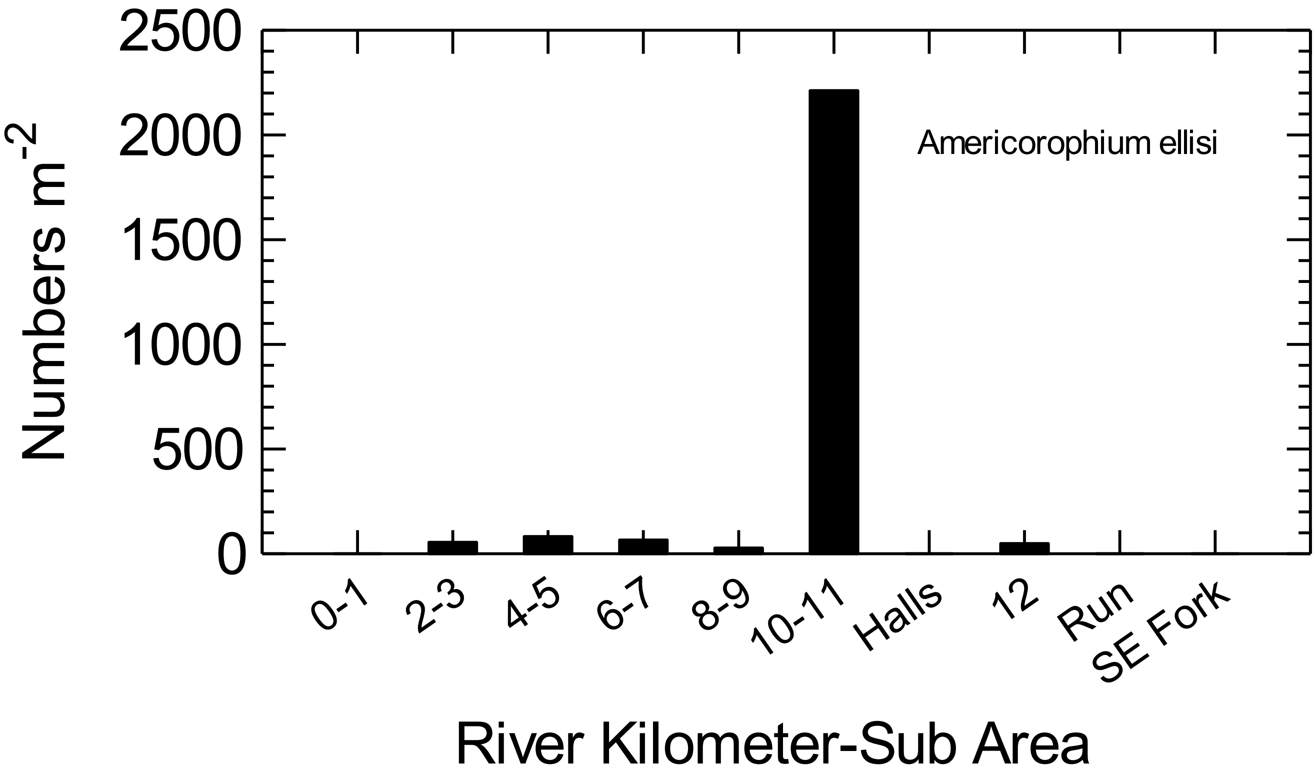


Aoridae (Gen. undet.)
Numbers m-2
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area



Numbers m-2
2000
1500
1000
500
0
Hydrobiidae (Gen. und
)
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area


3000
2400
1800
1200
600
0
Numbers m-2
Hourstonius laguna
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area


Americorophium ellisi
Numbers m-2
2500
2000
1500
1000
500
0
0-1
2-3
4-5
6-7
8-9
10-11
Halls
12
Run
SE Fork
River Kilometer-Sub Area