

# Appendix F

## ANALYSIS OF BENTHIC COMMUNITY STRUCTURE AND ITS RELATIONSHIP TO FRESHWATER INFLOWS IN THE LITTLE MANATEE RIVER ESTUARY

Purchase Order # 05PCSOW0111



Prepared for:  
Southwest Florida Water Management District



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

20 January 2008



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**Prepared for:**

**Southwest Florida Water Management District  
Brooksville, Florida**

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## ACKNOWLEDGEMENTS

This document benefited greatly from discussions with and correspondence from Sid Flannery and Michael Heyl of the Southwest Florida Water Management District (SWFWMD) and Dr. Ernest Estevez and James Culter of the Mote Marine Laboratory. Janicki Environmental, Inc. staff who contributed to this document included Susan Janicki, Michael Wessel, Michael Dema, and Ravic Nijbroek. Benthic sample collections were made by both EPCHC and PBS&J staff. Mote Marine Laboratory and EPCHC staff analyzed the sediment samples. EPCHC biologists and the late Michael Milligan (Center for Ecology and Systematics, Sarasota, FL) analyzed the benthic samples.

Cover photographs:

Top:<http://www.lib.usf.edu/lds/browsephotograph.html?size=1&idix=47>and

Bottom: Christina Holden, EPCHC

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## **1.0 INTRODUCTION**

The Southwest Florida Water Management District (District) is one of five water management districts charged with protecting and managing the State of Florida's water resources. One of the District's legislatively mandated responsibilities is to establish minimum flows and levels for surface water bodies including *freshwater* streams and the freshwater inflow to estuarine waters.

The objectives of this project are to quantify relationships between physical parameters, especially salinity, and the responses of benthic macroinvertebrates in the Little Manatee River estuary.

### **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**

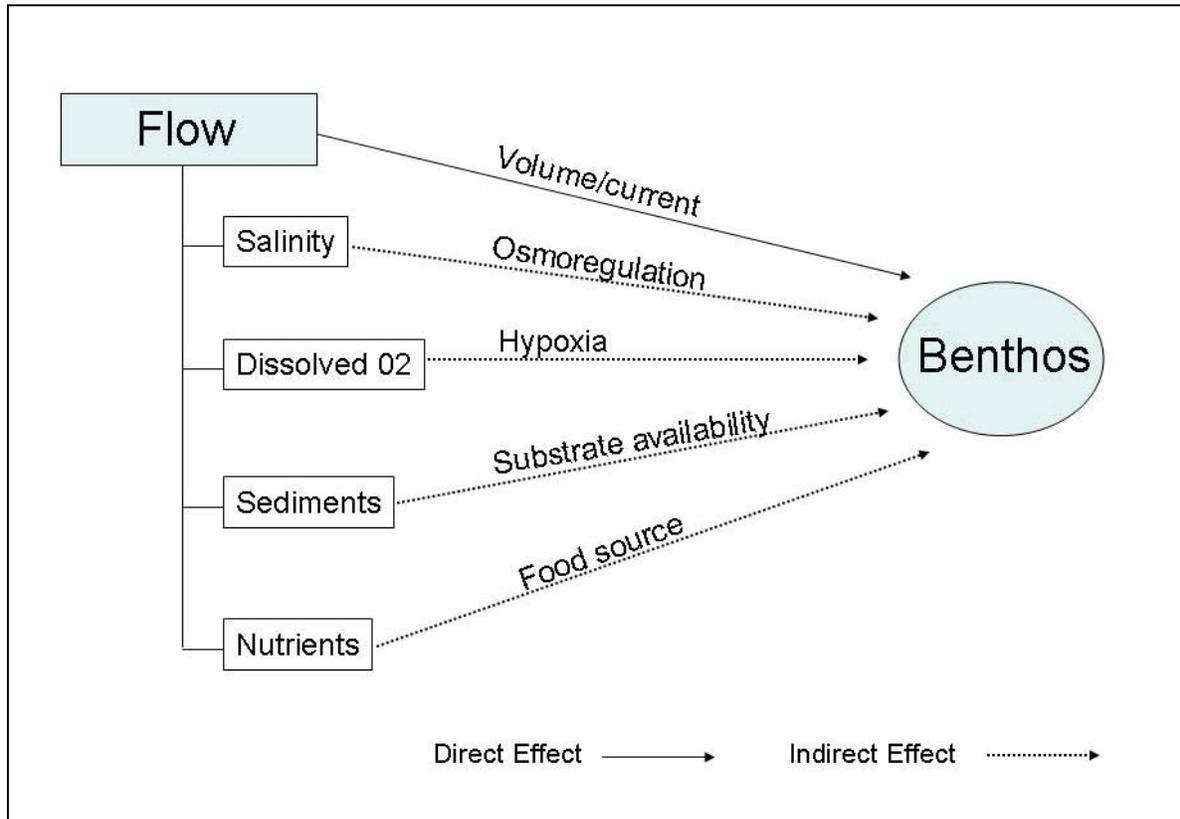
Benthic (bottom-dwelling) organisms are small but important invertebrates that include taxonomic groups such as aquatic insects, worms, snails, clams, and shrimp. The benthos live in or on the substrates of rivers, estuaries, etc. Benthic organisms are generally sessile, although some species may undergo 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. Tubicolous 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 Relationships Between Flow and Benthic Macroinvertebrates**

With respect to supporting MFL development, the benthos is an important biotic resource that is responsive to changes in freshwater inflow. 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 some time 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; SWFWMD, 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 the 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.

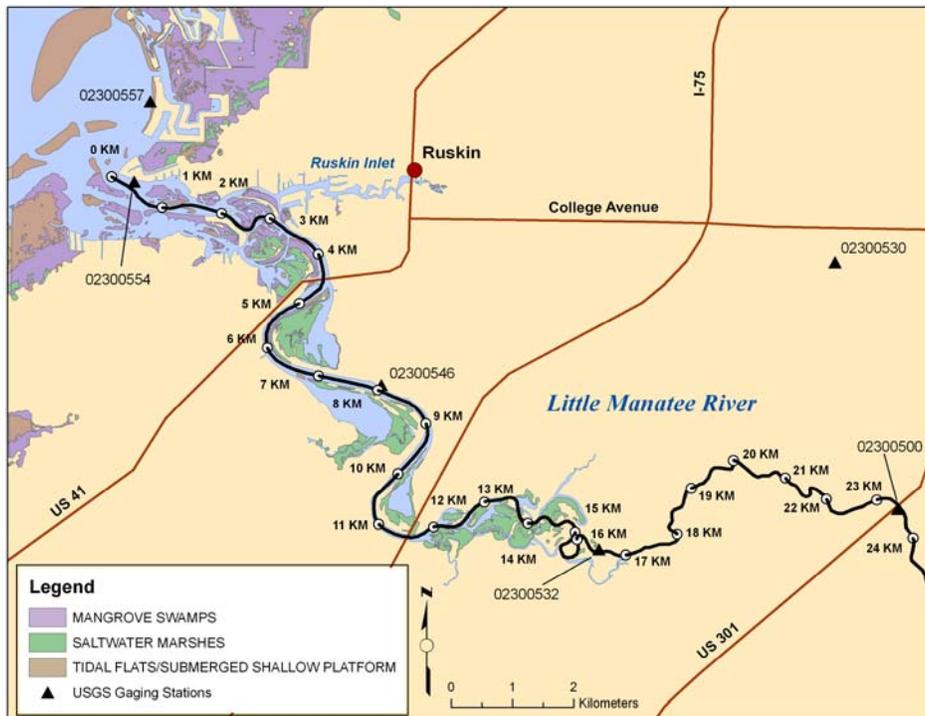
Species abundances are also affected by the stresses caused by altered flows. Such changes may affect the success of individual animals within a species, consequently affecting the overall abundance of that species. For example, while the distribution of a given species may be determined by salinity, 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. However, the presence of a species and/or its abundance can be by differences in collection methodologies between monitoring programs, and particular care must be used when analyzing such data across programs.

#### **1.5 Study Area**

The Little Manatee River (Figure 1-2) originates near the boundary of southeastern Hillsborough and southwestern Polk counties and discharges to Middle Tampa Bay. This river is approximately 65 km in length and drains a watershed of approximately 570 km<sup>2</sup> (Estevez *et al.*, 1991; PBS&J 2001). The river is tidal to approximately 24 km upstream (Dames and Moore 1975).

Land-uses in the basin include agriculture (>45%), open lands, woodlands, swamps (ca. 30%), phosphate mining (6%), and residential (ca. 4.5%), with the latter primarily located in the downstream reaches, adjoining Tampa Bay (Fernandez, 1985; Flannery *et al.*, 1991; Florida Marine Research Institute, 1997; PBS&J, 2001). Phosphate mining is the major industry in the eastern portion of the watershed (Fernandez, 1985; PBS&J, 2001). Mangroves and oyster bars are predominant features in the lower and middle reaches of the estuary with brackish marshes well developed in the upper estuary, especially north of Interstate 75 (Dames and Moore, 1975; Fernandez, 1985; Florida Marine Research Institute, 1997).



**Figure 1-2. The Little Manatee River study area.**

The Little Manatee River is the only estuarine waterbody in the Tampa Bay watershed designated as an “Outstanding Florida Water” (Florida Department of Environmental Protection, 2004) and Flannery (1989) wrote that the Little Manatee River “probably best represents the natural ecological interactions of a river and its watershed with Tampa Bay”.

The only historical data on benthic macroinvertebrates of the estuarine portion of the Little Manatee River that we are aware of was the 1973-1974 survey by Dames and Moore (1975), which included three stations in the estuary proper. Crustaceans, especially amphipods (genera undetermined) predominated at the two most downstream stations. Oligohaline fauna (e.g., oligochaetes, *Rangia*) were characteristic of the third station, located near the town of Ruskin.

## **2.0 METHODS**

### **2.1 Study Design**

Data on benthic assemblages in the Little Manatee River came from three programs. Two programs collected samples during the summer “wet” season only. These programs each employed a probabilistic design. Sixteen samples were collected during 1996-1998 by the EPCHC as part of the Tampa Bay Benthic Monitoring Program (TBEP, 1996). Beginning in 1999 and continuing to the present, samples were collected under the auspices of the Hillsborough Independent Monitoring Program. This monitoring effort is supported by the Hillsborough County BOCC and implemented by the EPCHC.

The absence of “dry” season benthic data led SWFWMD to support a one-time, spatially intensive survey of the benthos to provide a more robust dataset to aid in MFL development. Ninety-six samples were collected during late May-early June 2005 from the Little Manatee River mainstem and three bayous (Bolster, Hays, and Mill). Samples were collected from river kilometer (RKM) 0 (in line with Shell Point) to RKM 17 (upstream of USGS Gaging Station at Wimauma). RKM “0” corresponds to the location of RKM 0 in Fernandez (1985). Ruskin Inlet and intertidal areas were excluded.

Transects were established every 0.5 KM in the main stem of the river (Janicki Environmental, Inc. 2005). Two samples were collected at random locations within each 0.5 kilometer segment from RKM 0 to RKM 17. Eight samples were collected from Mills Bayou, 16 from Hayes Bayou, and four from Bolster Bayou.

A total of 235 samples have been collected; 139 from EPCHC wet season surveys during 1996-2005 and 96 dry season samples collected for the District in 2005. The locations of all benthic samples collected from 1996-2005 are shown in Figure 2-1.

### **2.2 Field Methods**

The EPCHC benthic samples were collected using a stainless steel Young grab sampler (0.04 m<sup>2</sup>). The 2005 survey for the District employed a 7.62 cm diameter hand core (area = 45.6 cm<sup>2</sup>) to sample the benthos. In practice, the samples were collected with a Young sampler and the core was removed from this larger sample. A cored subsample was removed from the Young sampler and retained for later analysis of the silt + clay content (%SC) of the sediment.

Each benthic sample was bagged with an internal label and magnesium sulfate solution was added to relax the organisms. Samples were then stored on ice; sieving and preservation took place at the end of each day.

Samples were sieved (500 µm mesh) to remove finer-grained particles of sediment and meiofauna. They were then fixed in a 10% solution of borax-buffered formalin and Rose Bengal stain.

Water column measurements of temperature, dissolved oxygen, salinity/conductivity, and pH were made every meter, from 0.1 m below the surface to 0.2 m above the bottom.

## Little Manatee River - Location of Benthic Macroinvertebrate Samples

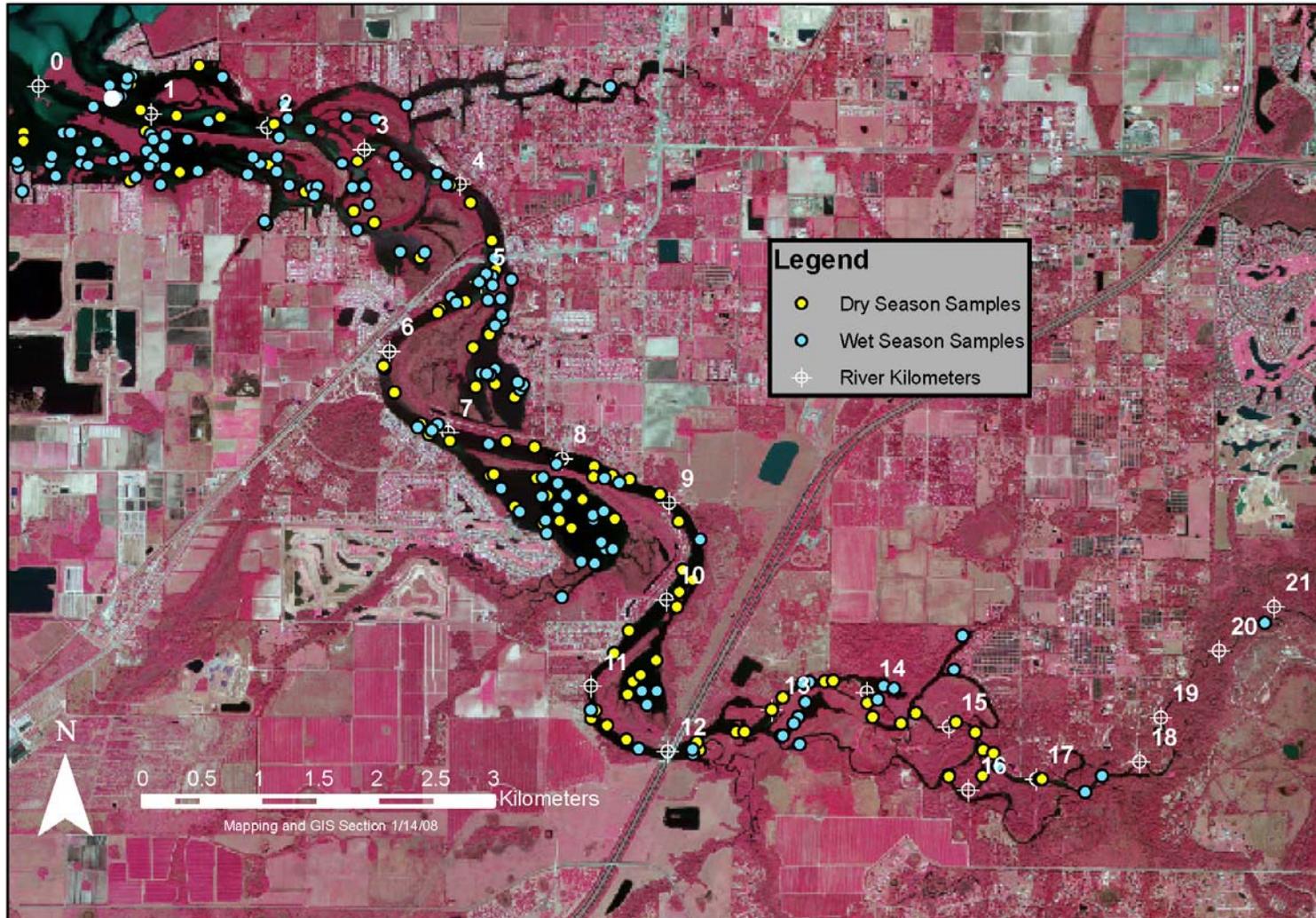


Figure 2-1. Location of benthic sampling stations in the Little Manatee River, 1996-2003 and 2005 (EPCHC unpublished data; map prepared by SWFWMD). Numbers indicate river kilometers along the centerline.

## **2.3 Laboratory Methods**

### **2.3.1 Benthos**

Laboratory analysis procedures were virtually identical for each program considered in this report. Samples were sorted in their entirety, with at least 90% recovery, under a dissecting microscope. Individuals were then 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.

### **2.3.2 Sediment Characterization**

The EPCHC program only measured the percentage of silt+clay and used a gravimetric analysis method similar to Plumb (1981). In 2005, grain-size distribution was measured by Mote Marine Laboratory staff using laser diffraction (Coulter LS-200).

The gravimetric and laser diffraction techniques do not, however, produce comparable results with respect to the Wentworth scale (Janicki Environmental, Inc., 2007b). The Wentworth size classes are used to differentiate sediment classes as coarse, medium, fine, and very fine sands, and mud-sized (silt+ clays) sized sediments. Sediments of  $\leq 43.7\%$  silt+clay analyzed by laser diffraction in 2005 are considered to be sands; sediments of  $\leq 20.2\%$  silt+clay analyzed gravimetrically are considered to be sands.

## **2.4 Data Analysis Approach**

Three generic approaches to analyzing the benthic data were used:

- Several univariate metrics;
- regression (linear and logistic) techniques were used to explore associations between variables; and
- multivariate analyses were used to explore how the benthos assemblage as a whole was organized.

Variables that are affected by the size of the sample, such as numbers of taxa and diversity, cannot be directly compared. The sample area of the Young sampler is almost 900% that of the cores, so not only will more individuals be collected, but more species will also be collected. Analyses based on abundance are included, but caution should be applied when interpreting the results.

### **2.4.1 Univariate Metrics**

Three univariate metrics for calculated for the Little Manatee River benthos:

- Dominant taxa were identified by season. 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).

- Species (taxa) richness is the number of distinct species (taxa) identifiable in a sample. Species or taxa richness is the simplest representation of “diversity”.
- Total abundance (numbers of individuals m<sup>-2</sup>) 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 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, diversity, and abundance and a suite of environmental variables. The environmental variables considered included, at a minimum:

- water temperature;
- salinity;
- dissolved oxygen;
- sample depth; and
- temperature;
- cumulative flows over the 7, 14, 28, 56, and 112-day periods preceding the sample collection date. Montagna and Kalke (1992) used this approach to examine the effects of flow on the benthos of Texas estuaries.

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.

The relationships between species richness and abundance with salinity also were evaluated using linear, quadratic, and polynomial regressions. The resultant relationships and equations can be used to predict expected responses of the benthos to a “best fit” combination of abiotic variables as well as salinity alone.

Janicki Environmental, Inc. (2007a) employed univariate logistic regression (Huisman *et al.*, 1993, 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 selected for logistic regression analyses will be based on dominance ranking as well as the significance of that taxon’s relationship to salinity in five Tampa Bay area tidal rivers (*cf.*, Janicki Environmental, Inc., 2007a).

### 2.4.3 Multivariate Community Metrics

A set of benthic metrics were identified to quantify the effects of salinity and other variables on multivariate benthic community structure. These were selected based on benthic analyses and analytical tools developed by Janicki Environmental, Inc. (2007a).

Abundance was 4<sup>th</sup> root transformed for all multivariate community analyses. The 4<sup>th</sup> 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) have also demonstrated that the 4<sup>th</sup> root transformation is preferred in multivariate community analyses because it represents a “good compromise between untransformed and binary data”. Therefore, the 4<sup>th</sup> root transformation was employed in the multivariate analyses.

The benthic macroinvertebrate data were stratified by season and river kilometer (RKM). Multivariate statistical routines in the PRIMER software package (Clarke and Warwick, 2001) used in this study included:

- non-metric multidimensional scaling (MDS) - MDS was used to graphically represent the resemblance of the benthic assemblages within each of the seasons. MDS is an ordination technique in which rank similarities of a large number of variables are expressed as a two-dimensional map). Groups were subjectively identified. Convex hull plots (Wilkinson *et al.*, 2006) were used to highlight the members of groups containing  $\geq 3$  samples; ellipses were drawn to highlight groups made up of  $< 3$  samples.
- “Similarity Percentage” (SIMPER) - SIMPER objectively identified those taxa that explained relatively large proportions of the similarity within a group (e.g., lower stratum in the dry season).
- “Analysis of Similarities” (ANOSIM) - ANOSIM tests the statistical significance of the pairwise comparisons of the *a priori* defined groups.
- The association abiotic variables and multivariate community structure was explored using the BIO-ENV test in PRIMER. BIO-ENV is an exploratory analysis and should be not be interpreted as being “significant” or causative.
- Principal Components Analysis (PCA) was used by Janicki Environmental, Inc. (2007a) to identify salinity classes based upon the ranges of over which the taxa occurred for data collected from the five major tidal rivers discharging to Tampa Bay—including the Little Manatee River. The PCs are presented as both Varimax rotated and unrotated. A second PCA (unrotated) was performed using Little Manatee River data only. Others have also employed PCA to examine benthic community structure and its relationship to various environmental conditions (Boesch, 1977; Gauch, 1982). Bulger *et al.* (1993) employed the PCA methodology to develop taxa-specific salinity classes for mid-Atlantic estuarine nekton and this formed the basis for the Janicki Environmental, Inc. (2007a) approach.

## **3.0 RESULTS**

This section presents a characterization of the hydrologic and physico-chemical characteristics of the Little Manatee River estuary, a description of the spatial and temporal character of the benthic macroinvertebrate community, and the relationships between the benthic community structure and several abiotic variables.

### **3.1 Abiotic Characteristics**

This section describes the salinity, sediment characteristics, and other physicochemical and flow conditions measured during the two survey periods.

#### **3.1.1 Streamflow**

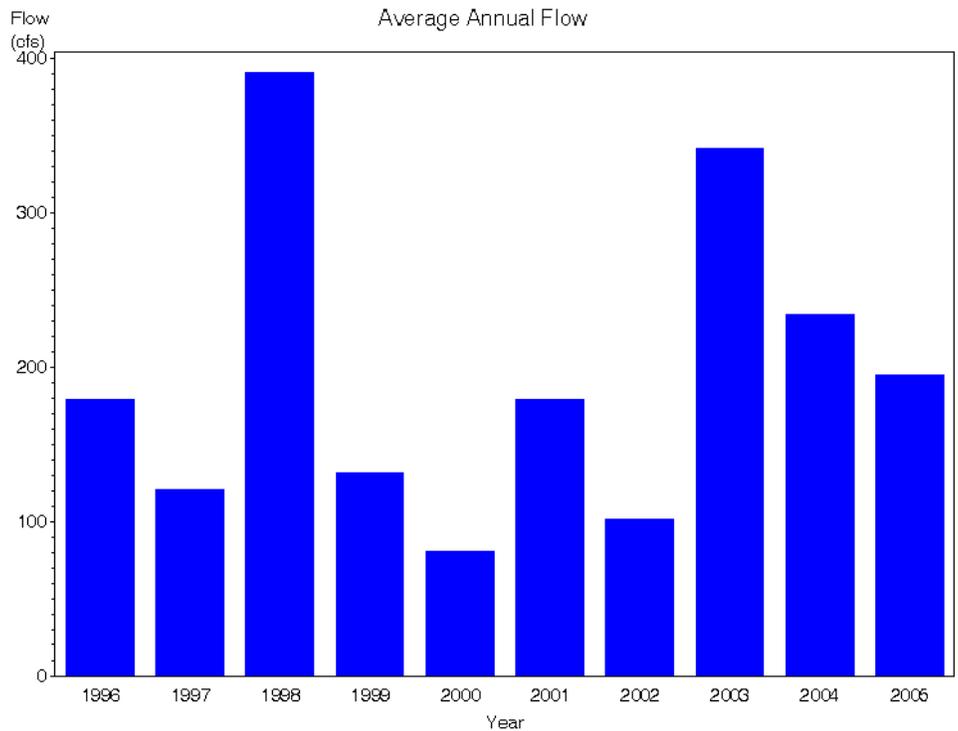
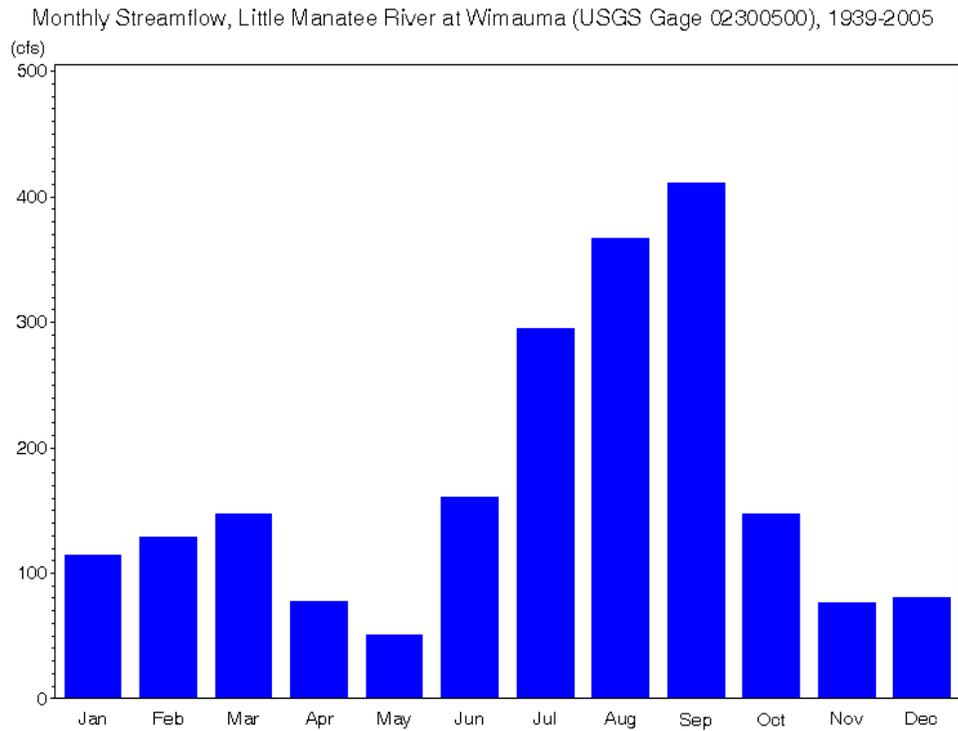
Streamflow data for the Little Manatee River are based upon USGS Gage 02300500, near Wimauma (RKM 23.5) (Figure 3-1). Average monthly flows (1939-2003) have ranged from 50 cfs (May) to 405 cfs (September) (Figure 3-1).

Annual flows for 1996-2005, representing the period of benthic sample collections, are also shown in Figure 3-1. The high flows observed in 1998 were related to the El Niño of December 1997-March 1998. This was one of the strongest El Niño's since 1950 (NOAA-CIRES, 2004). The 2003 high flows were also affected by an El Niño (NOAA-CIRES, 2004). The low flows of 2000 occurred during a La Niña (National Weather Service, 2004). Note that, although unimpounded, there are withdrawals associated with the cooling water needs of Florida Power and Light's Manatee Generating Station.

#### **3.1.2 Hydrographic and Sediment Characteristics**

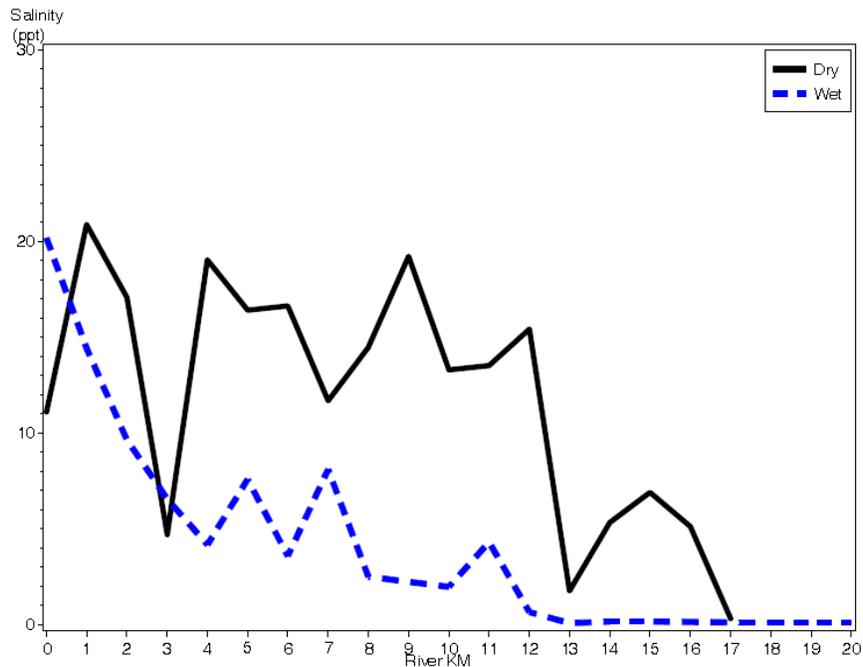
The available hydrographic and sediment data from the Little Manatee River, collected coincident with the benthic samples, are summarized in Table 3-1. Wet-season water temperatures were typically warmer than dry-season temperatures, particularly in the lower five RKM. Salinities in the dry season were generally higher than those of the wet season, except near the river's mouth (Figure 3-2).

The % silt+ clay in the sediments varied widely in the river and there was no evidence of a longitudinal trend in either season (Figure 3-3). Caveat: that the laboratory protocol used in 2005 is not directly comparable to the methods used in prior years (Janicki Environmental, Inc., 2007b). Near-bottom dissolved oxygen concentrations were also generally higher during the dry season (Table 3-1).

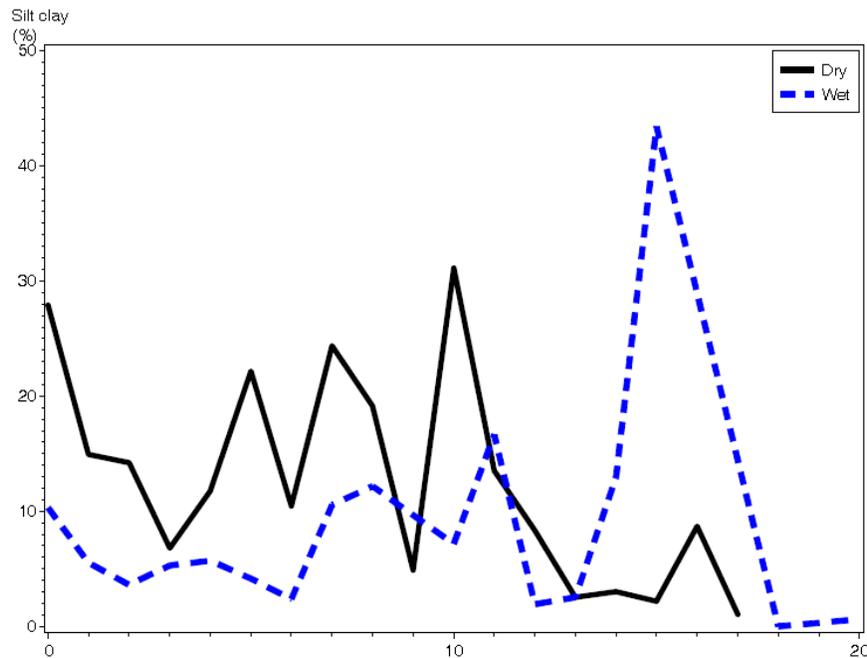


**Figure 3-1. Monthly and annual flows (cfs) in the Little Manatee River at USGS Gage 02300500 near Wimauma.**

<b>Table 3-1. Summary of mean (range) values for measured hydrographic and sediment variables measured coincident with benthic sample collections in the Little Manatee River, 1996-2004 wet seasons and 2005 dry season.</b>		
<b>Variable</b>	<b>Wet Seasons 1996-2004 (n = 116)</b>	<b>Dry Season 2005 (n = 95)</b>
Temperature (°C)	28.7 (25.2-31.4)	26.6 (23.9-30.0)
Salinity (ppt)	10.4 (0.0-26.9)	12.9 (0.2-27.4)
Dissolved Oxygen (mg L <sup>-1</sup> )	3.8 (0.3-8.4)	5.7 (4.1-7.9)
Sediment Silt + Clay (%)	7.1 (0.0-74.4)	15.2 (1.0-56.0)
Sample Depth (m)	0.4 (0.1-3.0)	1.1 (0.2-3.5)



**Figure 3-2. Mean near-bottom salinity by river kilometer and season in the Little Manatee River. Dry season = 2005; Wet season = 1996-2004.**



**Figure 3-3.** Mean sediment percent silt+clay by river kilometer and season in the Little Manatee River. Dry season= 2005; Wet season= 1996-2004. *Note: sample analysis methods are not comparable for the two seasons.* The sand-mud demarcation is 20.2% silt + clay in the 1996-2004 wet season samples and 43.7 % silt + clay in the 2005 dry season samples.

## 3.2 Biota

Species characteristic of the Little Manatee River are identified and compared by season and location within the river. The relationships between benthic community structure and several abiotic variables, including salinity, are presented.

### 3.2.1 Temporal Variation in the Dominant Taxa in the Little Manatee River

Species characteristic of the Little Manatee River are identified and compared by season. Dominant taxa are identified by their Dominance Score which is calculated as  $Dominance\ Score = (\% occurrence * \% composition)^{-0.5}$ . Tables 3-2 lists the 50 top-ranked dominants in each season, their frequency of occurrence, center of abundance and mean salinity of occurrence. Appendix A includes the entire taxonomic inventory along with frequency of occurrence and mean, median, and maximum numbers  $m^{-2}$ .

The amphipods *Grandidierella bonnieroides* and *Apocorophium louisianum* were the two highest ranking species in each season (Table 3-2). Only four taxa (identified to genus or species) were among the ten ranked dominants in both seasons:

- *Grandidierella bonnieroides*
- *Apocorophium louisianum*.
- *Cyathura polita*
- *Amygdalum papyrium*

**Table 3-2. 50 ranked Dominant benthic taxa, frequency of occurrence, mean abundance, mean salinity at capture, and mean center of abundance in the Little Manatee River, by season.**

<b>Wet Season (1996-2004)</b>					
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Dominance</b>	<b>Mean Salinity at Capture (ppt)</b>	<b>Mean Center of Abundance (RKm)</b>
<i>Apocorophium louisianum</i>	32	1,550	23.52	7.1	5.0
<i>Grandidierella bonnieroides</i>	53	586	18.61	8.0	8.1
Tubificidae	64	315	14.98	8.2	7.8
<i>Ampelisca holmesi</i>	39	376	12.80	15.2	0.7
<i>Cerapus spp.</i>	28	441	11.74	16.3	1.7
<i>Cyathura polita</i>	63	194	11.68	8.1	5.8
<i>Xenanthura brevitelson</i>	42	143	8.19	12.5	3.5
<i>Monticellina dorsobranchialis</i>	26	220	7.99	21.0	0.4
<i>Laeonereis culveri</i>	49	106	7.60	8.1	5.0
<i>Amygdalum papyrium</i>	37	132	7.38	16.2	1.1
<i>Glottidia pyramidata</i>	20	182	6.38	19.4	0.0
<i>Tubificoides brownae</i>	23	154	6.29	15.4	1.9
<i>Aricidea philbinae</i>	33	106	6.24	17.9	0.9
<i>Ampelisca abdita</i>	36	77	5.55	12.2	1.8
<i>Polypedilum scalaenum</i>	43	64	5.55	4.7	8.0
<i>Mysella planulata</i>	22	88	4.65	19.4	0.5
<i>Leptocheilia sp.</i>	29	58	4.34	12.8	3.0
<i>Tubificoides motei</i>	17	94	4.22	7.0	6.5
<i>Mytilopsis leucophaeata</i>	21	72	4.11	7.3	8.7
<i>Heteromastus filiformis</i>	35	42	4.04	10.2	2.9
<i>Fabricinuda triloba</i>	18	79	3.99	18.9	1.1
<i>Hobsonia florida</i>	28	44	3.71	12.0	3.3
<i>Streblospio gynobranchiata</i>	28	43	3.65	11.4	4.0
<i>Edotea triloba</i>	37	30	3.49	12.4	2.1
Cirripedia	7	145	3.37	12.5	0.1
<i>Acteocina canaliculata</i>	24	42	3.35	18.9	0.4
<i>Cyclaspis cf. varians</i>	20	50	3.34	18.3	0.5
<i>Ampelisca vadorum</i>	23	43	3.31	17.7	2.6
<i>Tubificoides wasselli</i>	15	59	3.13	20.1	0.4

**Table 3-2. 50 ranked Dominant benthic taxa, frequency of occurrence, mean abundance, mean salinity at capture, and mean center of abundance in the Little Manatee River, by season.**

<b>Wet Season (1996-2004)</b>					
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Dominance</b>	<b>Mean Salinity at Capture (ppt)</b>	<b>Mean Center of Abundance (RKm)</b>
<i>Rhithropanopeus harrisi</i>	34	23	2.97	11.5	4.1
<i>Mulinia lateralis</i>	17	39	2.73	17.8	0.4
<i>Aricidea taylori</i>	16	37	2.57	19.9	0.8
<i>Amphiporus bioculatus</i>	17	32	2.45	17.1	0.6
<i>Bivalvia</i>	29	15	2.21	8.7	5.4
<i>Polypedilum halterale</i>	15	29	2.21	0.9	11.6
Hydrobiidae	17	25	2.18	4.6	9.2
<i>Tagelus plebeius</i>	30	13	2.10	9.4	3.4
<i>Chironomus sp.</i>	16	19	1.84	3.3	6.2
<i>Capitella capitata</i>	19	15	1.78	13.8	1.5
<i>Corbicula fluminea</i>	5	57	1.78	0.1	17.2
<i>Haminoea succinea</i>	16	14	1.56	15.7	0.4
<i>Nassarius vibex</i>	22	10	1.53	20.4	0.4
<i>Macoma tenta</i>	12	16	1.48	18.6	0.3
<i>Procladius sp.</i>	14	14	1.45	1.10	11.0
<i>Archinemertea sp. A</i>	20	9	1.37	10.1	3.4
Nemertea K	11	15	1.36	14.7	1.0
<i>Oxyurostylis smithi</i>	12	11	1.22	18.8	0.1
<i>Pyrgophorus platyrachus</i>	6	21	1.19	0.3	13.0
<i>Glycera americana</i>	17	7	1.18	20.7	0.3
<i>Anomalocardia auberiana</i>	14	9	1.17	17.4	1.0
<b>Dry Season (2005)</b>					
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Dominance</b>	<b>Mean Salinity at Capture (ppt)</b>	<b>Mean Center of Abundance (RKm)</b>
<i>Grandidierella bonnieroides</i>	76	3,668	42.96	14.9	6.5
<i>Apocorophium louisianum</i>	48	3,552	33.59	14.6	6.9
<i>Ampelisca abdita</i>	43	2,135	24.65	15.3	3.0
<i>Cyathura polita</i>	61	657	16.29	14.5	6.9
<i>Amygdalum papyrium</i>	27	954	13.05	15.0	1.8
Tubificidae	35	655	12.32	11.9	11.9
<i>Gammarus tigrinus</i>	26	593	10.1	8.5	13.9

**Table 3-2. 50 ranked Dominant benthic taxa, frequency of occurrence, mean abundance, mean salinity at capture, and mean center of abundance in the Little Manatee River, by season.**

<b>Dry Season (2005)</b>					
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Dominance</b>	<b>Mean Salinity at Capture (ppt)</b>	<b>Mean Center of Abundance (RKm)</b>
<i>Corbicula fluminea</i>	20	315	6.46	6.0	14.4
<i>Heteromastus filiformis</i>	24	196	5.58	14.7	2.7
Nemertea	27	169	5.49	16.9	2.6
<i>Laeonereis culveri</i>	29	116	4.73	15.7	5.5
<i>Euplana gracilis</i>	18	123	3.83	14.3	3.8
<i>Tubificoides heterochaetus</i>	13	144	3.52	14.3	7.7
<i>Aricidea philbinae</i>	7	256	3.44	15.5	0.9
<i>Ampelisca holmesi</i>	6	267	3.26	14.4	1.7
<i>Monticellina dorsobranchialis</i>	8	148	2.80	16.7	0.2
Athenaria	3	335	2.58	15.5	2.1
<i>Polypedilum scalaenum</i>	13	68	2.43	10.1	10.8
<i>Cryptochironomus sp.</i>	13	62	2.30	15.2	11.6
<i>Xenanthura brevitelson</i>	11	64	2.16	15.9	3.5
<i>Leptocheilia sp.</i>	5	135	2.11	14.3	2.0
<i>Streblospio gynobranchiata</i>	13	48	2.03	14.1	4.6
<i>Polymesoda caroliniana</i>	12	48	1.95	12.4	6.4
<i>Apocorophium lacustre</i>	4	132	1.87	5.4	14.0
Bivalvia	10	50	1.82	12.0	5.7
<i>Hobsonia florida</i>	14	34	1.78	17.3	5.0
<i>Cladotanytarsus sp.</i>	6	50	1.41	7.2	15.5
<i>Hourstonius laguna</i>	9	30	1.33	14.4	4.3
<i>Tubificoides brownae</i>	4	57	1.23	12.1	10.1
<i>Eteone heteropoda</i>	6	37	1.20	17.0	1.9
<i>Cyclaspis cf. varians</i>	8	25	1.15	16.2	2.6
<i>Capitella capitata</i>	7	27	1.13	10.1	2.7
<i>Glycinde solitaria</i>	6	32	1.13	18.9	0.5

**Table 3-2. 50 ranked Dominant benthic taxa, frequency of occurrence, mean abundance, mean salinity at capture, and mean center of abundance in the Little Manatee River, by season.**

Dry Season (2005)					
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Dominance	Mean Salinity at Capture (ppt)	Mean Center of Abundance (Rkm)
<i>Ameroculodes miltoni</i>	5	27	0.95	16.3	2.3
<i>Phyllodoce arenae</i>	5	25	0.91	21.0	1.1
<i>Edotea triloba</i>	6	21	0.90	10.8	8.8
<i>Neanthes succinea</i>	6	21	0.90	19.6	2.4
<i>Lyonsia floridana</i>	6	18	0.85	22.6	0.9
<i>Melita elongata</i>	3	37	0.85	23.7	1.4
<i>Polypedilum halterale</i>	2	53	0.83	18.8	14.3
<i>Paraprionospio pinnata</i>	6	16	0.80	16.7	0.7
<i>Fabricinuda triloba</i>	5	18	0.78	16.1	0.6
<i>Leitoscoloplos robustus</i>	5	18	0.78	18.4	1.5
<i>Procladius sp.</i>	5	18	0.78	18.7	11.9
<i>Mysella planulata</i>	4	21	0.74	14.2	1.0
<i>Mytilopsis leucophaeata</i>	5	16	0.73	16.3	6.9
<i>Oxyurostylis smithi</i>	4	14	0.60	19.3	1.0
<i>Tectidrilus wasselli</i>	2	25	0.58	10.4	0.0
<i>Mactra fragilis</i>	3	14	0.52	17.2	0.8
<i>Prionospio sp.</i>	2	14	0.43	14.4	0.0

Thirty-four of the ranked dominants were most abundant in RKM 0-1 (Table 3-3; Appendix A). Few of the ranked dominants reached peak abundance upstream of RKM 5. Figure 3-4 shows the longitudinal distributions of the eight species with the highest Dominance scores overall. Although the wet and dry season data are not from the same year(s), there was some suggestion that 11 species might be found further upstream during the dry season than during the wet (Table 3-2). These include dominants such as *Apocorophium louisianum*, *Ampelisca abdita*, *Cyathura polita*, *Amygdalum papyrium*, and *Laeonereis culveri* (Figure 3-3). Ten species demonstrated an opposite distribution: more abundant upstream during the wet season (Table 3-2).

Overall, the benthos of the Little Manatee River is a diverse assemblage comprised of taxa generally similar to those the Anclote River (Janicki Environmental, 2007a). In these two rivers, crustaceans represent a relatively large proportion of the benthic community as opposed to the predominance

of polychaete worms in the impounded rivers, such as the Lower Hillsborough River and Tampa Bypass Canal (Janicki Environmental, Inc. 2007a).

### **3.2.2 Temporal and Spatial Variation in Univariate Community Metrics**

Three univariate metrics of community structure were selected for analysis of longitudinal and seasonal trends as well as for their association with abiotic variables, including salinity. The metrics are:

- taxa richness;
- Shannon-Wiener diversity; and
- total abundance (numbers of individuals m<sup>-2</sup>).

Both numbers of taxa and diversity varied longitudinally within the Little Manatee River (Figures 3-5 and 3-6). Each metric generally declined upriver during the wet seasons of 1996-2004. In the dry season of 2005, these metrics also underwent a general decrease to ~RKMs 11-13 (Figures 3-5 and 3-6). Total abundance (as numbers of individuals m<sup>-2</sup>) did not appear to exhibit any longitudinal trend (Figure 3-7).

#### **3.2.2.1 Relationships of Univariate Community Metrics with Abiotic Variables**

The association of numbers of taxa and mean abundance with selected abiotic variables, *excluding salinity at the time of collection*, were explored using forward stepwise linear regression analysis. Data were analyzed separately by season since different sampling methods were used.

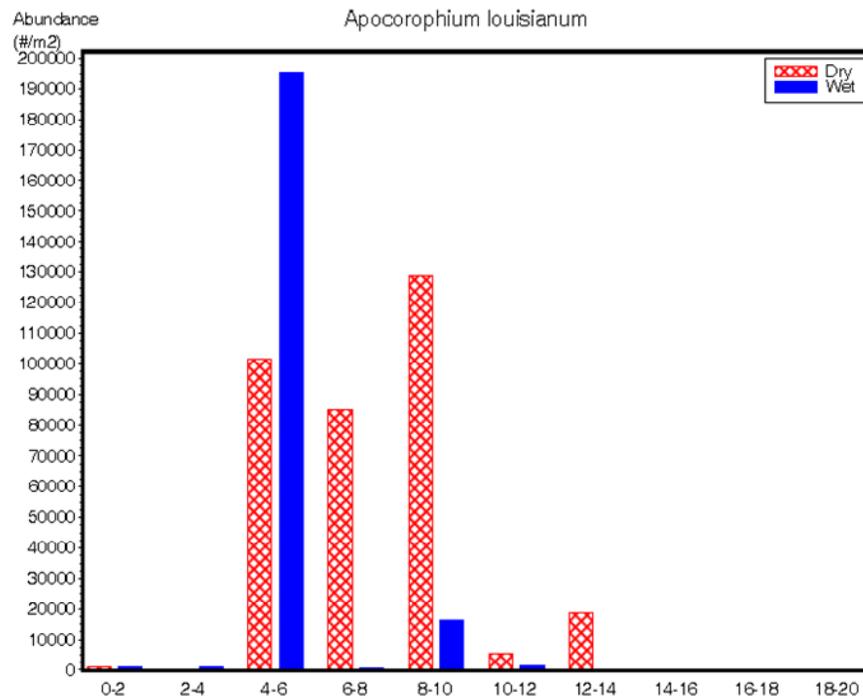
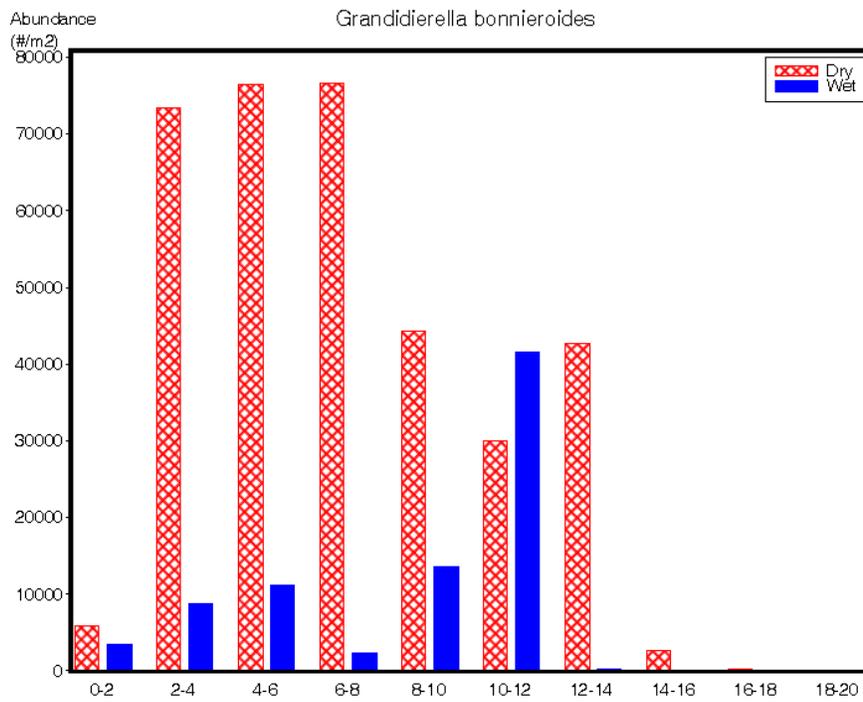
Statistically significant relationships were found between numbers of taxa and total numbers of individuals with various combinations of water quality and sediment variables in each season (Table 3-5; Appendix B). Each of the equations explained between 23% and 54% of the total variance.

**Table 3-3. Taxa identified to genus or species occurring in  $\geq 5\%$  of all samples and the location of their maximum abundance, Little Manatee River estuary, during the 1996-2004 wet seasons and 2005 dry season (cf. Appendix A). Red=dry season maximum; Blue=wet season maximum; Gray=same maximum both seasons.**

	RKM 0-2	RKM 2-4	RKM 4-6	RKM 6-8	RKM 8-10	RKM 10- 12	RKM 12- 14	RKM 14- 16	RKM 16- 18	RKM 18- 21
<b>Nemertea</b>										
<i>Amphiporus bioculatus</i>	Blue									
Archinemertea sp. A	Blue									
Nemertea sp. F		Blue								
<b>Turbellaria</b>										
<i>Euplana gracilis</i>		Red	Blue							
<b>Polychaeta</b>										
<i>Aricidea philbinae</i>	Gray									
<i>Aricidea taylori</i>	Gray									
<i>Capitella capitata</i>		Gray								
<i>Eteone heteropoda</i>	Blue	Red								
<i>Fabricinuda triloba</i>	Gray									
<i>Glycera americana</i>	Gray									
<i>Glycinde solitaria</i>	Gray									
<i>Heteromastus filiformis</i>		Red	Blue							
<i>Hobsonia florida</i>		Blue		Red						
<i>Laeonereis culveri</i>		Blue		Red						
<i>Mediomastus</i> sp.	Gray									
<i>Monticellina</i> cf. <i>dorsobranchialis</i>	Gray									
<i>Neanthes succinea</i>	Red	Blue								
<i>Paraprionospio pinnata</i>	Gray									
<i>Prionospio heterobranchiata</i>	Blue									
<i>Scoloplos rubra</i>	Gray									
<i>Streblospio gynobranchiata</i>	Blue		Red	Red						
<b>Tubificidae</b>										
<i>Tubificoides brownae</i>	Blue					Red				
<i>Tubificoides heterochaetus</i>						Red				
<i>Tubificoides motei</i>					Blue					
<i>Tubificoides wasselli</i>	Blue									
<b>Gastropoda</b>										
<i>Acteocina canaliculata</i>	Gray									
<i>Haminoe succinea</i>	Gray									
<i>Nassarius vibex</i>	Blue									
<b>Bivalvia</b>										
<i>Amygdalum papyrium</i>	Gray									
<i>Anomalocardia auberniana</i>	Gray									
<i>Corbicula fluminea</i>								Red		Blue

**Table 3-3. Taxa identified to genus or species occurring in >5% of all samples and the location of their maximum abundance, Little Manatee River estuary, during the 1996-2004 wet seasons and 2005 dry season (cf. Appendix A). Red=dry season maximum; Blue=wet season maximum; Gray = same maximum both seasons.**

	RKM 0-2	RKM 2-4	RKM 4-6	RKM 6-8	RKM 8-10	RKM 10- 12	RKM 12- 14	RKM 14- 16	RKM 16- 18	RKM 18- 21
<i>Lyonsia floridana</i>	Gray									
<i>Macoma tenta</i>	Blue	Red				Red				
<i>Mulinia lateralis</i>	Gray									
<i>Mysella planulata</i>			Red	Red						
<i>Mytilopsis leucophaeata</i>			Red			Blue				
<i>Polymesoda caroliniana</i>				Gray						
<i>Tagelus plebeius</i>		Blue	Red	Red						
<b>Cumacea</b>										
<i>Almyracuma cf. proximoculi</i>							Blue			
<i>Cyclaspis cf. varians</i>	Gray									
<i>Oxyurostylis smithi</i>	Gray									
<b>Isopoda</b>										
<i>Cyathura polita</i>			Blue	Red						
<i>Edotea triloba</i>	Blue				Red					
<i>Xenanthura brevitelson</i>			Gray							
<b>Tanaidacea</b>										
<i>Leptocheilia sp.</i>		Gray								
<b>Amphipoda</b>										
<i>Ampelisca abdita</i>	Red	Blue								
<i>Ampelisca holmesi</i>	Red	Blue								
<i>Ampelisca vadorum</i>			Gray							
<i>Apocorophium louisianum</i>			Blue		Red					
<i>Cerapus spp.</i>	Blue									
<i>Gammarus cf. tigrinus</i>								Red		
<i>Grandidierella bonnieroides</i>			Red	Red		Blue				
<i>Hourstonius laguna</i>			Gray							
<b>Decapoda</b>										
<i>Pinnixa spp.</i>	Blue									
<i>Rhithropanopeus harrisii</i>			Blue							
<b>Chironomidae</b>										
<i>Chironomus sp.</i>			Blue							
<i>Cryptochironomus</i>			Blue						Red	
<i>Polypedilum halterale Group</i>							Blue	Red		
<i>Polypedilum scalaenum Group</i>						Red	Blue			
<b>Branchiopoda</b>										
<i>Glottidia pyramidata</i>	Blue									



**Figure 3-4. Longitudinal distribution, by season, of the eight taxa with the highest overall Dominance Scores, Little Manatee River, 1996-2005.**

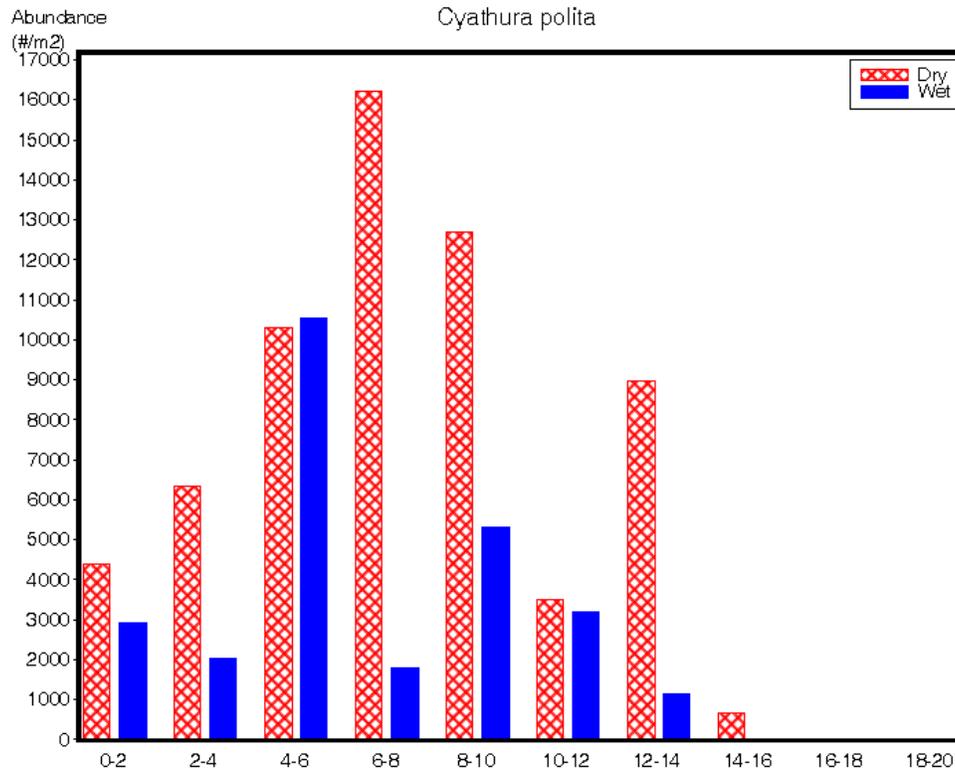
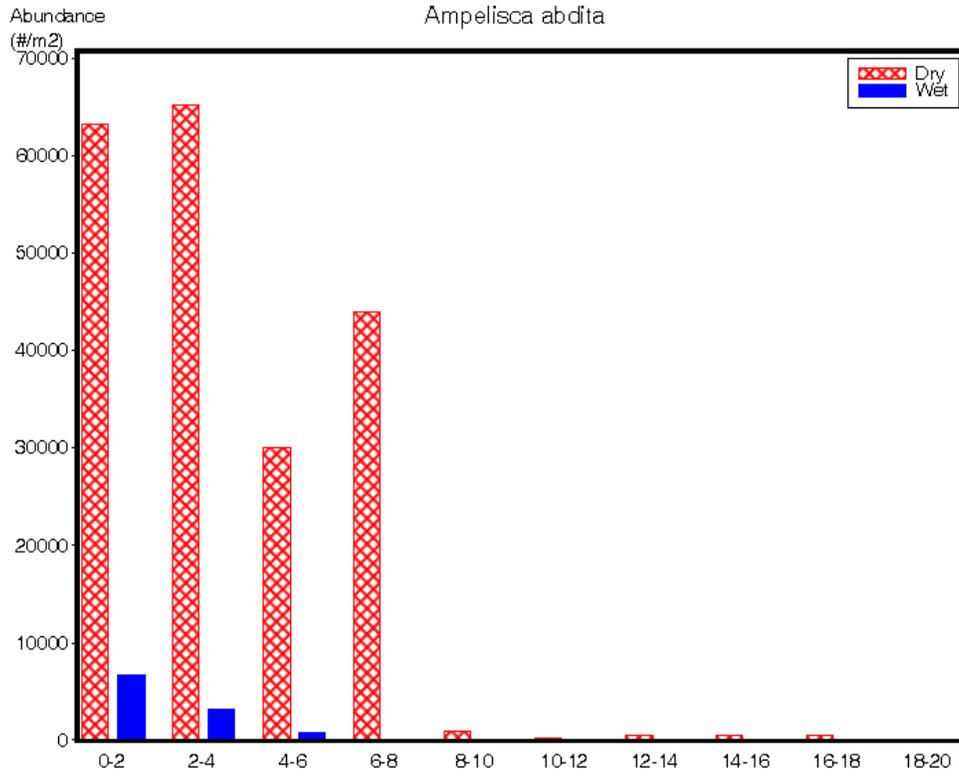


Figure 3-4. continued.

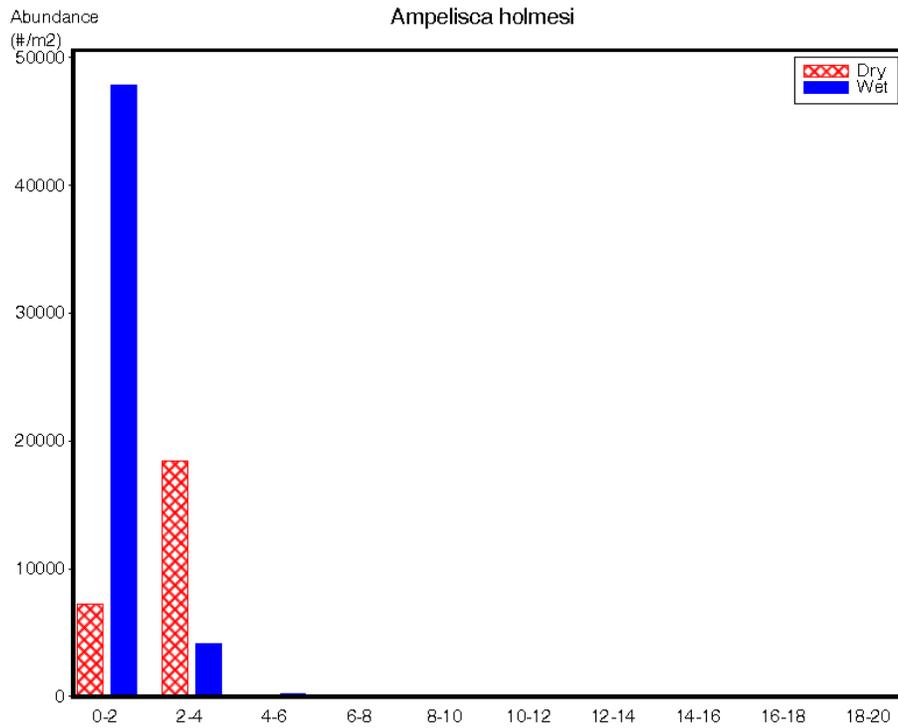
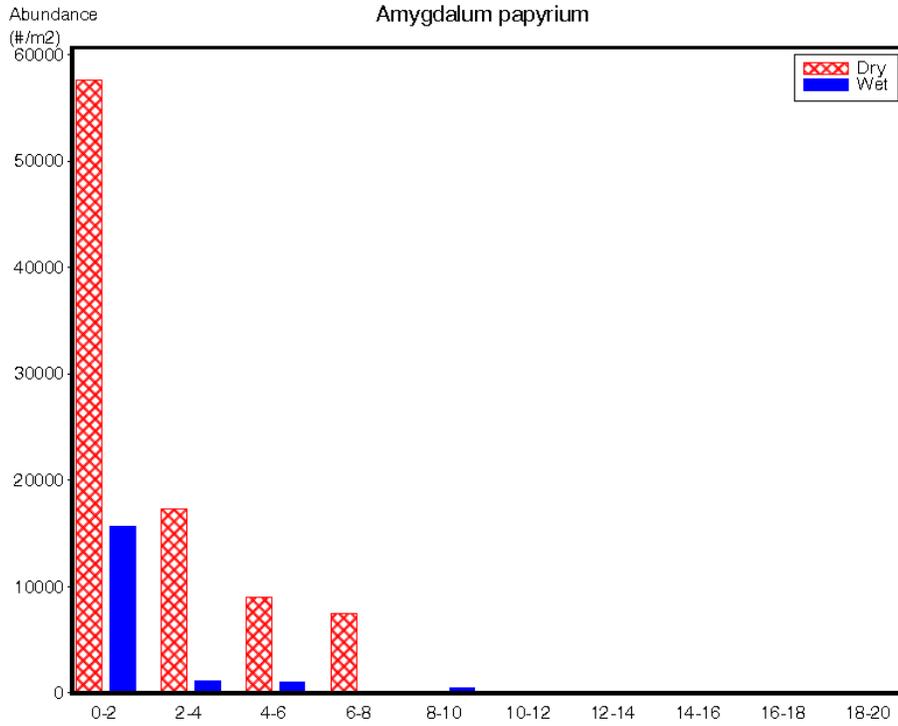


Figure 3-4. continued.

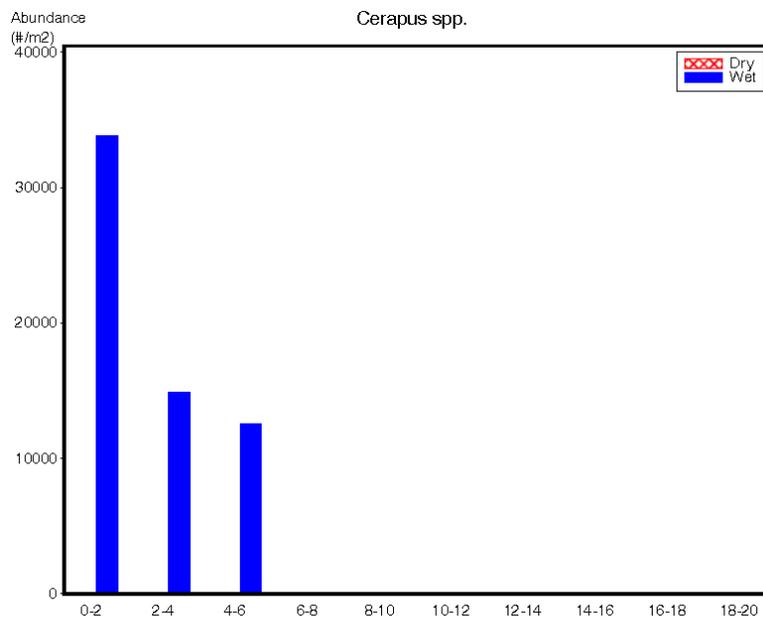
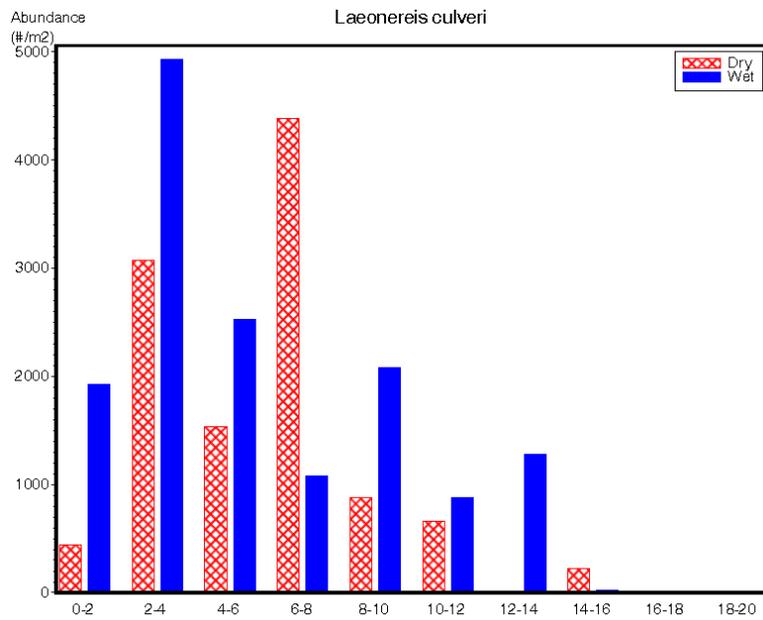


Figure 3-4. continued.

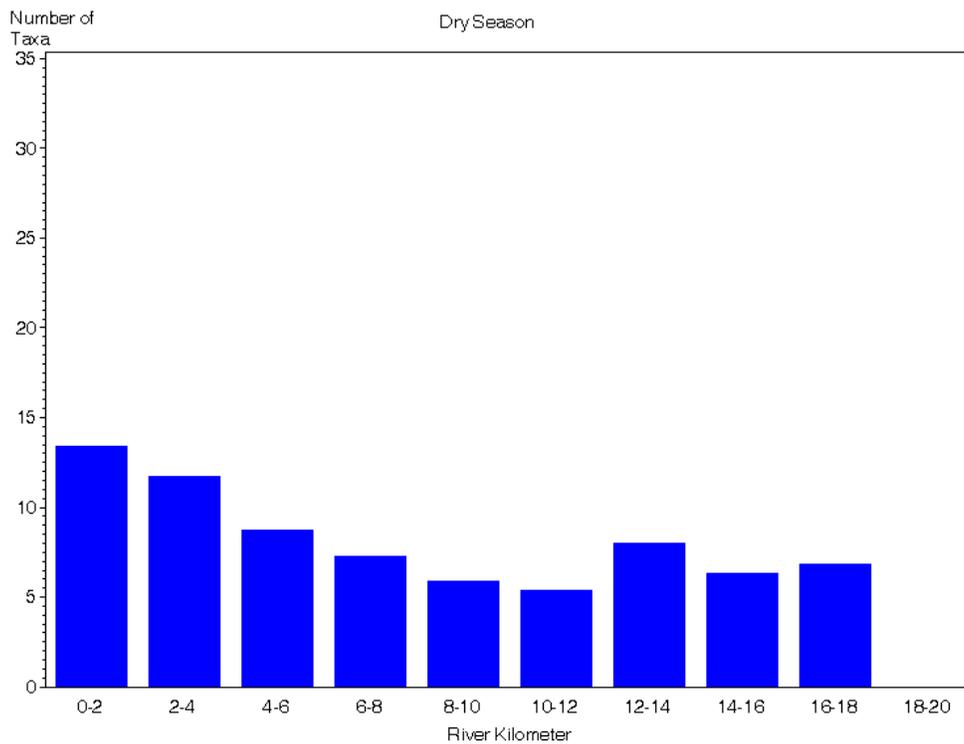
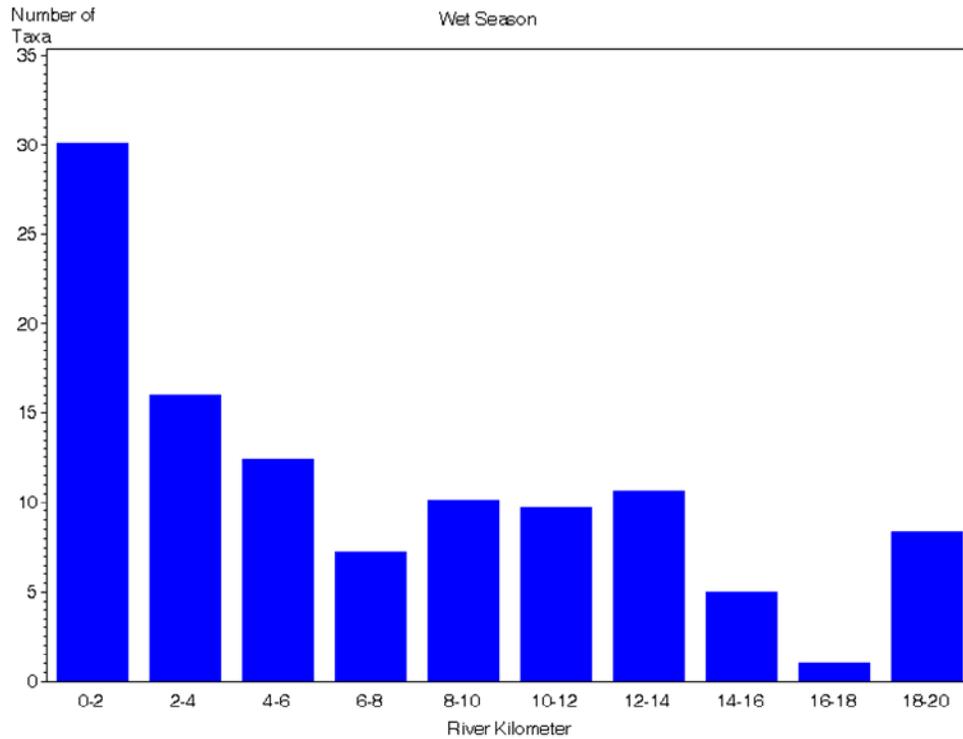
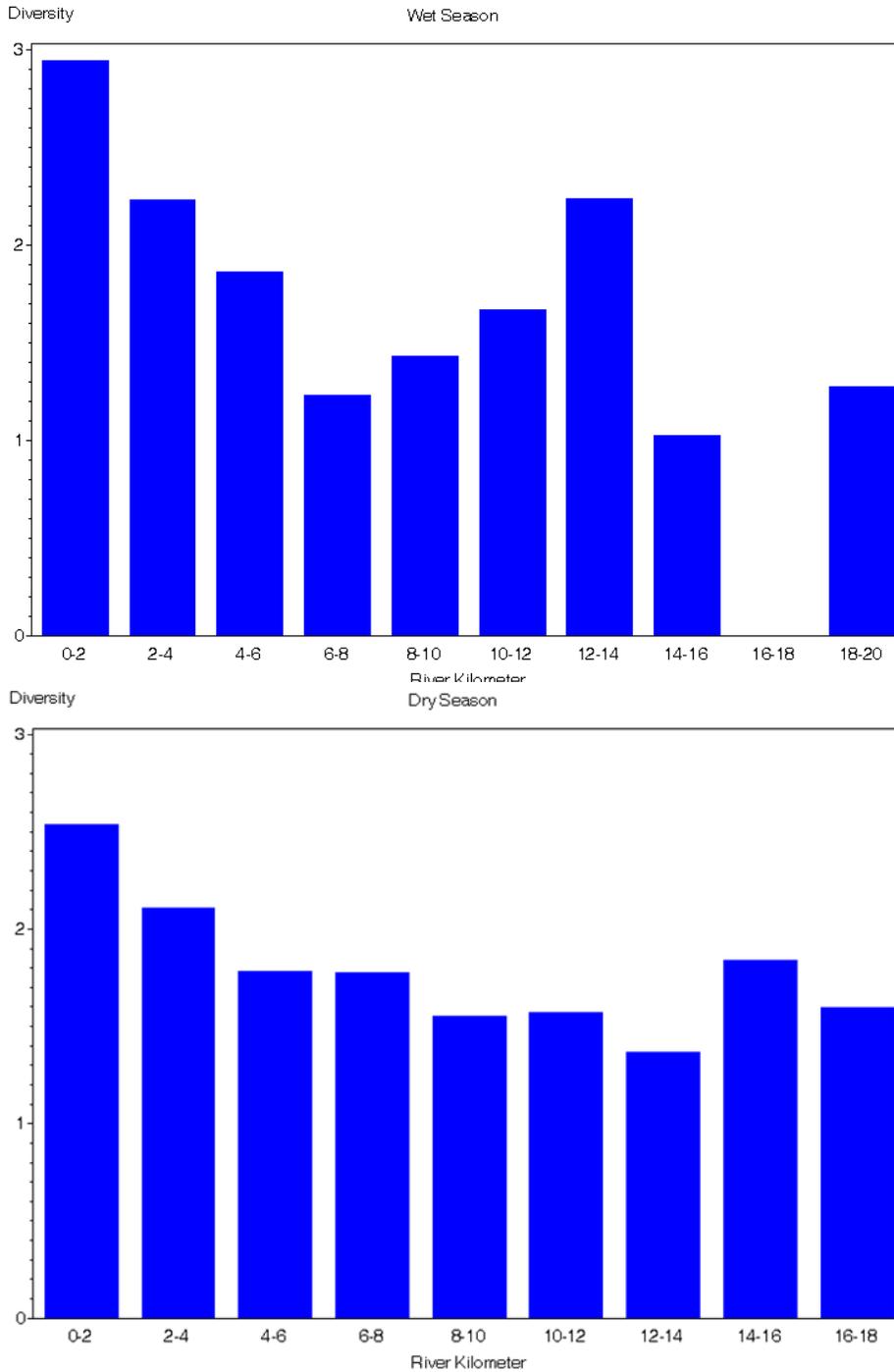


Figure 3-5. Longitudinal distribution of the numbers of benthic taxa in the Little Manatee River, by season. *Wet and dry season numbers are not comparable the sampling gears used in each season sample different areas.*



**Figure 3-6.** Longitudinal distribution of Shannon-Wiener diversity in the Little Manatee River, by season. *Wet and dry season numbers are not comparable because the sampling gears used in each season sample different areas.*

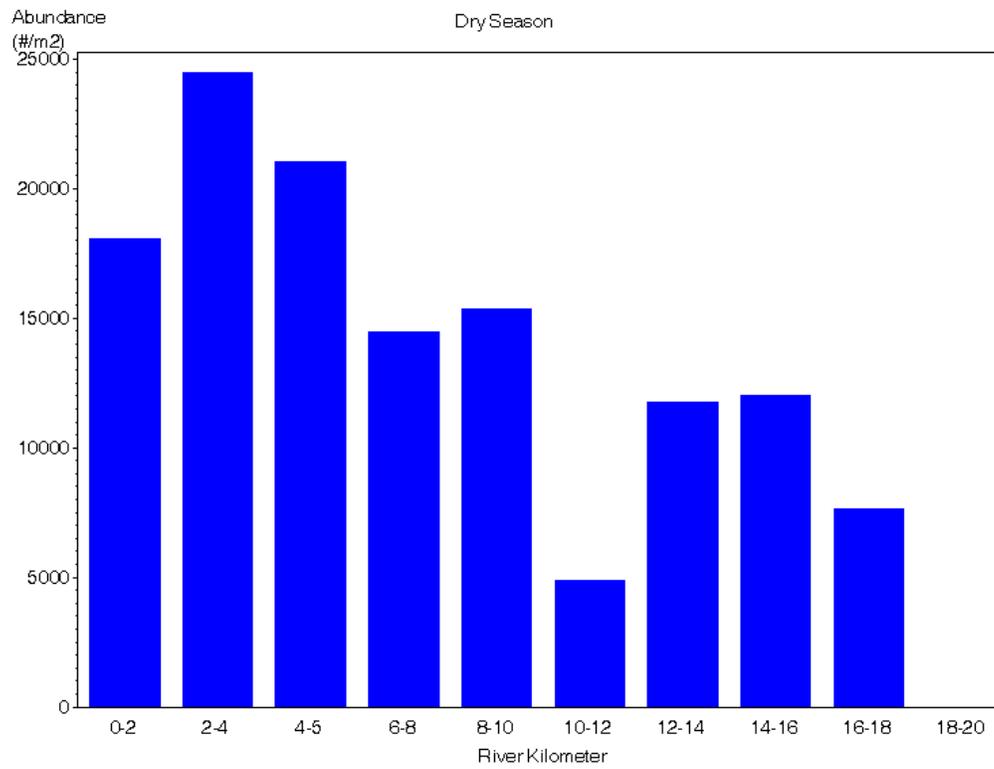
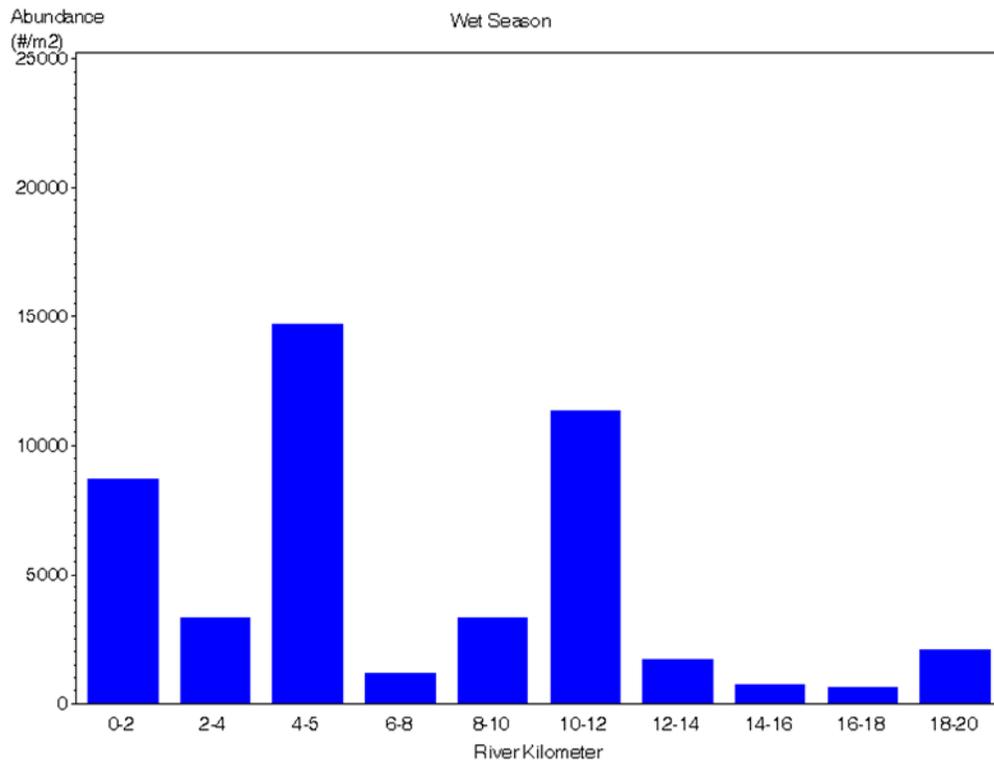


Figure 3-7. Longitudinal distribution of benthic abundance in the Little Manatee River, by season.

### 3.2.2.2 Temporal and Spatial Variation in Univariate Community Metrics

Three univariate metrics of community structure were selected for analysis of longitudinal and seasonal trends as well as for their association with abiotic variables, including salinity. The metrics are:

- taxa richness;
- Shannon-Wiener diversity; and
- total abundance (numbers of individuals m<sup>-2</sup>).

Both numbers of taxa and diversity varied longitudinally within the Little Manatee River (Figures 3-5 and 3-6). Each metric generally declined upriver during the wet seasons of 1996-2004. In the dry season of 2005, these metrics also underwent a general decrease to ~RKM 11-13 (Figures 3-5 and 3-6). Total abundance (as numbers of individuals m<sup>-2</sup>) did not appear to exhibit any longitudinal trend (Figure 3-7).

<b>Table 3-4. Results of forward stepwise multiple regression analyses that examine the relationship between numbers of taxa and abundance and abiotic variables in the Little Manatee River, by season. Salinity at the time of collection was excluded from these analyses. Variables selected must have <math>p &lt; 0.05</math> to be included.</b>	
<b>Wet Season</b>	<b>R<sup>2</sup></b>
<b>Numbers of Taxa</b>	
Y = 111.34 – (1.65*RKM) – (0.26*% silt+clay) + (1.18*DO) – (1.98*Temperature) – (46.3*Log <sub>10</sub> 28-Day Flow) + (43.5*Log <sub>10</sub> 56-Day Flow) - (6.95*Log <sub>10</sub> 112-Day Flow)	0.42
<b>Log<sub>10</sub> Abundance</b>	
Y = 6.22 – (0.05*RKM) – (0.03*% silt+clay) + (0.12*DO) - (0.78*Log <sub>10</sub> 28-Day Flow)	0.23
<b>Dry Season</b>	
<b>Numbers of Taxa</b>	
Y = -107.38 – (0.52*RKM) – (0.09*% silt+clay) + (255.7*Log <sub>10</sub> 112-Day Flow)	0.54
<b>Log<sub>10</sub> Abundance</b>	
Y = 4.77 - (0.05*RKM) - (0.03*% silt+clay)	0.49

Location within the river (as RKM) was selected as the best predictor of numbers of taxa and abundance in each season (Table 3-4). % silt + clay was the second best predictor of each metric (Table 3-4). Both numbers of taxa and abundance declined upriver and with increasing silt+clay content in each season (Table 3-4). RKM can be interpreted as a variable that integrates salinity over some long-term period, since for a given species to occur at a specific location in the river it must be tolerant of the salinity fluctuations of that location.

### 3.2.3. Spatial Variation in Multivariate Benthic Community Structure

Spatial differences in the structure of the Little Manatee River benthic community were examined. MDS and two complementary analyses were used to achieve this objective. Additionally, the association between community structure and various environmental variables measured in conjunction with the collection of the benthic samples was also examined.

An MDS plot is an effective graphical tool to identify samples that aggregated in multidimensional space. The greater the distance between points (samples) on the MDS plot, the greater the

dissimilarity of the samples. Samples with more similar benthic community structure, therefore, will be more closely aggregated in the MDS plot.

Five Season x RKM groups (A-E) were identified in the MDS plot (Figure 3-8). Group A represented wet season samples from the lower two RKMs and Group B was formed by dry season samples collected from RKMs 0-6 (Figure 3-8). Species such as *Monticellina cf. dorsobranchialis* and *Ampelisca holmesi* were more abundant in the wet season group and *Heteromastus filiformis*, *Amygdalum papyrium*, *Cyathura polita*, *Ampelisca abdita*, *Apocorophium louisianum*, and *Grandidierella bonnieroides* were more abundant in the dry season group (Table 3-5).

The remainder of the river was also segregated seasonally. Wet season groups C, and E were similar in composition (Table 3-5). Dry season samples upstream to RKM 6 formed Group B.

The wet season groups A and C differed in that:

- *Aricidea philbinae*, *Monticellina cf. dorsobranchialis*, *Tubificoides brownae*, *Amygdalum papyrium*, *Mysella plaulata*, *Ampelisca holmesi*, *Cerapus spp.*, and *Glottidia pyramidata* were more abundant in Group A; and
- Tubificid oligochaetes, *Cyathura polita*, and *Grandidierella bonnieroides* were more abundant upriver.

The dry season groups B and D differed in that:

- *Amygdalum papyrium* and *Grandidierella bonnieroides* were more abundant downstream; and
- *Apocorophium louisianum* was more abundant upstream.

The larger wet (C) and dry (D) season groups differed in that four key taxa (tubificids, *Cyathura polita*, *Apocorophium louisianum*, and *Grandidierella bonnieroides*) were each more abundant in the dry season than the wet.

The MDS analysis, then, has shown that, during the wet season, the lowest two RKMs supported a different faunal assemblage than the rest of the river. The benthos of the wet season was generally similar from RKM to RKM 20. The dry season benthos showed evidence of a shift in assemblages at RKMs 6 2 to 7.

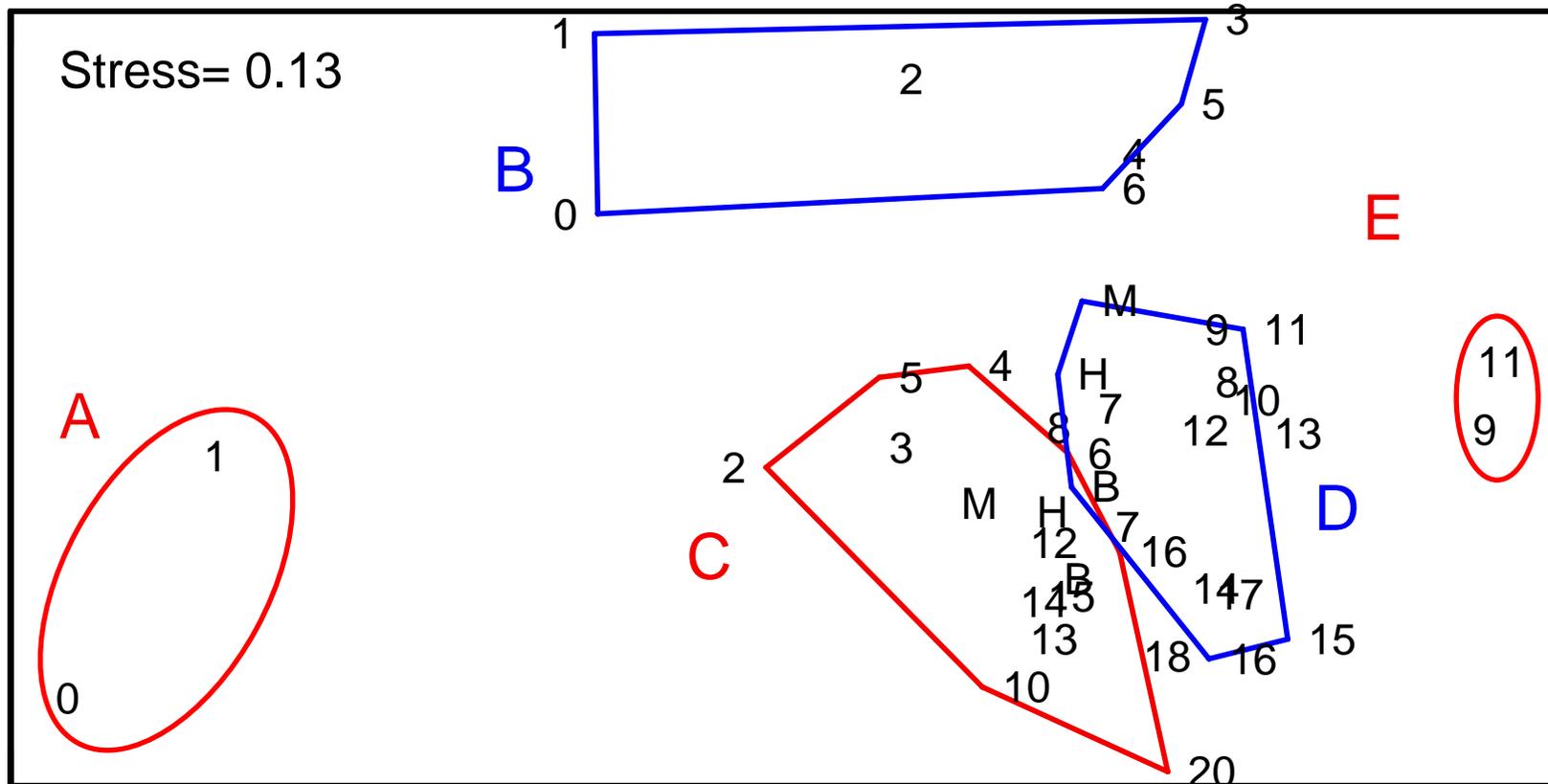


Figure 3-8. MDS plot showing the similarity of the Little Manatee River benthos by season (dry and wet), river kilometer (0-20) and bayou (B=Bolster; H=Hayes; M=Mill) within the 1996-2004 wet seasons and the May 2005 dry season surveys. Subjectively identified Season-RKM groups are designated A-E.

**Table 3-5. Dominant organisms that contribute to between-group differences identified in the MDS analyses (cf. Figure 3-8). Probability of significance for group comparisons in parentheses. NS= $p > 0.05$ ; \*\*= $p < 0.01$ ; \*\*\*= $p < 0.001$ . Letters indicate the group that the taxon was more abundant in.**

Taxa	A vs. B (***)	A vs. C (***)	A vs. D (***)	A vs. E (NS)	B vs. C (***)	B vs. D (***)	B vs. E (NS)	C vs. D (***)	C vs. E (NS)	D vs. E (**)
<b>Polychaeta</b>										
<i>Aricidea philbinae</i>		A								
<i>Monticellina dorsobranchialis</i>		A	A							
<b>Oligochaeta</b>										
Tubificidae		B	D					D		E
<b>Bivalvia</b>										
<i>Amygdalum papyrium</i>	B	A			B	B				
<i>Mysella planulata</i>		A								
<b>Isopoda</b>										
<i>Cyathura polita</i>	B		D							
<b>Amphipoda</b>										
<i>Ampelisca abdita</i>	B				B	B				
<i>Ampelisca holmesii</i>	A	A	A							
<i>Apocorophium louisianum</i>	B		D			D		D		E
<i>Cerapus spp.</i>		A								
<i>Gammarus cf. tigrinus</i>			D							
<i>Grandidierella bonnieroides</i>	B	E	D		B			D		E
<b>Brachiopoda</b>										
<i>Glottidia pyramidata</i>		A								

### 3.2.4 Benthic Community Structure and Abiotic Variables

A BIO-ENV test was performed to identify abiotic variables related to multivariate community structure. Salinity at the time of collection was *a priori* excluded because the benthos responds to the salinity regime over some longer, undefined, time period. *Note that the BIO-ENV test is an exploratory analysis; the statistical significance of  $\rho_s$  is not established.*

This analysis showed that, in the 1996-2004 wet seasons, each of the  $\rho_s$  values for between one and five variables was  $<0.1$  (Table 3-6). The  $\rho_s$  values for the 2005 dry season analysis were much higher ( $>0.29$ ) than those of the wet season analysis (Table 3-6). Location in the river (as RKM) had the highest  $\rho_s$  of any single variable and was included in each combination of variables (Table 3-6). RKM is indicative as an integrating response to some longer-term salinity/flow regime. The addition of other variables reduced the  $\rho_s$ . The decline in  $\rho_s$  values with increasing numbers of variable shows that variables such as temperature ( $\rho_s=0.8$ ), depth ( $\rho_s=0.11$ ), *et al.* have little influence on community structure.

<b>Table 3-6. Association (Spearman rank correlations, <math>\rho_s</math>) between benthic community structure in the Little Manatee River, 1996-2004 (wet seasons) and 2005 (dry season), and selected abiotic variables. Benthic abundances 4<sup>th</sup> root transformed; abiotic variables normalized; Euclidean distance. <i>Salinity measured at time of collection was excluded.</i></b>						
<b>1996-2004 Wet Seasons</b>						
<b>Number of Variables</b>	<b><math>\rho_s</math></b>	<b>Log<sub>10</sub> 56-day Cumulative Flow</b>	<b>Log<sub>10</sub> 28-day Cumulative Flow</b>	<b>Log<sub>10</sub> 112-day Cumulative Flow</b>	<b>River Kilometer</b>	<b>Log<sub>10</sub> 14-day Cumulative Flow</b>
1	0.09					
2	0.09					
3	0.07					
4	0.06					
5	0.03					
<b>2005 Dry Season</b>						
<b>Number of Variables</b>	<b><math>\rho_s</math></b>	<b>River Kilometer</b>	<b>Temperature</b>	<b>Depth</b>	<b>Dissolved Oxygen</b>	<b>% Silt + Clay</b>
1	0.48					
2	0.43					
3	0.39					
4	0.34					
5	0.29					

### 3.2.4.1 Relationships Among Salinity Classes

Principal Components Analysis has been used to identify salinity classes that are related to differences in benthic species distributions (Janicki Environmental, Inc., 2007a). This approach has been used particularly to operationally define oligohaline (*i.e.*, low salinity) conditions that are maintained by freshwater inflow. Recently, this approach has been questioned (Greenwood *et al.*, 2007), particularly with respect to the effect of axis rotation.

Janicki Environmental, Inc. (2007a) used this method to identify salinity classes for five Tampa Bay area tidal rivers, including the Little Manatee River (Figure 3-9). Both varimax rotation and an unrotated PCA are shown. Regardless of axis rotation, the PCA results identify an oligohaline class:

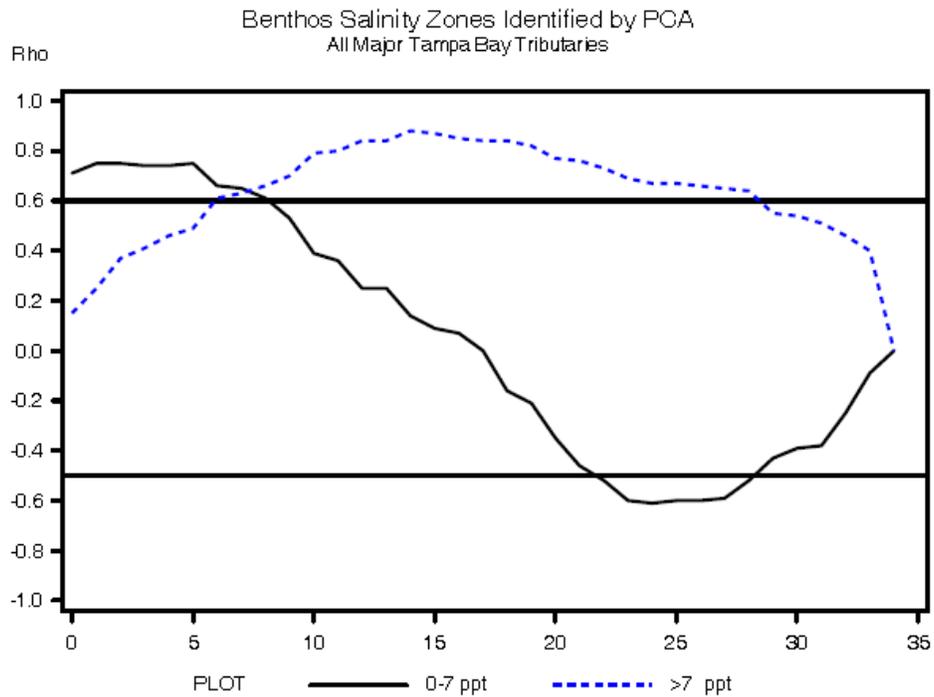
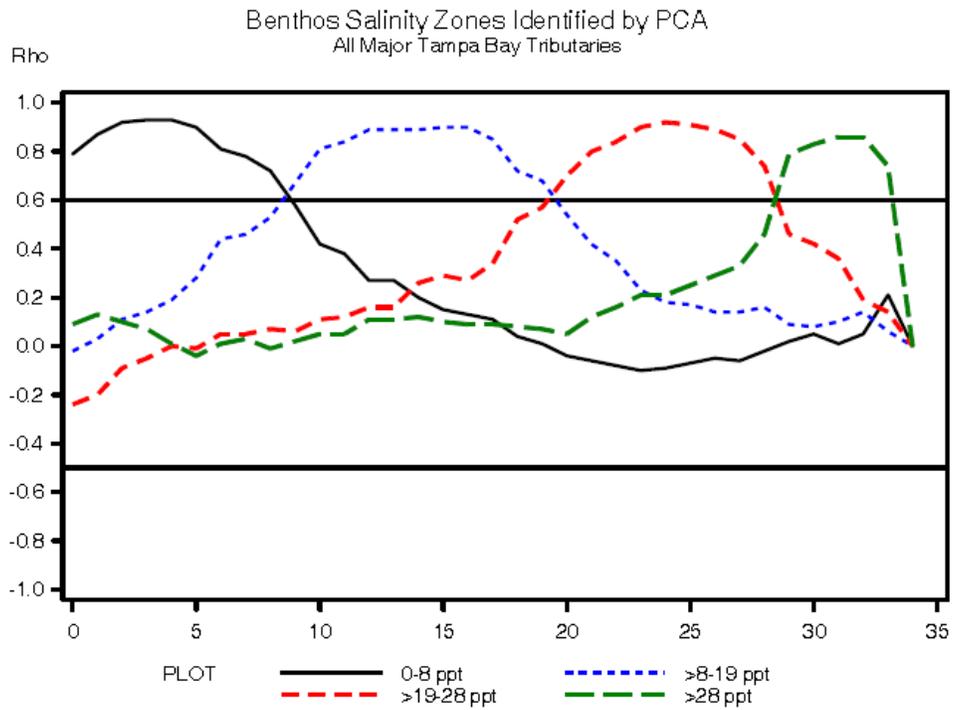
- ~0-8 ppt (Varimax rotated); and
- ~0-7 ppt (unrotated).

Oligohaline salinities were observed throughout most of the Little Manatee River estuary. The median location of oligohaline salinities in the 2005 dry season was approximately 5 RKMs upstream of its 1996-2004 wet season median location. Mesohaline and polyhaline salinities were rarely found above RKM 10 in the 2005 dry season survey. Note, however, that the river's discharge in May and early June 2005 was relatively high for this time frame (*cf.* <http://waterdata.usgs.gov/nwis/>). The inference, then, is that mesohaline and polyhaline waters should be found further upstream in a more "typical" year.

Taxa characteristic of each salinity class in the two PCAs are shown in Table 3-7. Taxa that differentiate salinity classes within each season are summarized in Table 3-8.

The dry season oligohaline assemblages had higher percentages of tubificids, *Grandidierella*, *Gammarus cf. tigrinus*, *Corbicula*, and *Apocorophium louisianum* than did the wet season (Table 3-8). The wet season oligohaline fauna had higher percentages of tubificids and *Grandidierella* and lower percentages of *Xenanthura brevitelson* than the wet season mesohaline fauna. The dry season assemblages of these two salinity classes differed in that *Gammarus cf. tigrinus* and tubificids were more abundant at oligohaline salinities and *Grandidierella* and *Apocorophium louisianum* were more abundant at mesohaline salinities.

*Grandidierella*, *Apocorophium*, and *Ampelisca abdita* were proportionately more abundant during the dry season whereas tubificids were more abundant in the wet season (Table 3-9). Tubificids were also more abundant at mesohaline salinities during the wet season than polyhaline salinities (Table 3-8). At polyhaline salinities, *Grandidierella*, *Apocorophium*, and *Ampelisca abdita* were proportionately more abundant during the dry season.



**Figure 3-9.** Salinity classes based upon the distribution of the benthos from five Tampa Bay area tidal rivers (From Janicki Environmental, Inc., 2007a). Top: Varimax rotation; Bottom: not rotated.

Table 3-7. Taxa characteristic of the salinity classes in the Little Manatee River, 1996-2005, based upon PCA of the Tampa Bay area tidal rivers (cf. Janicki Environmental, Inc., 2007a).		
Tampa Bay Area PCA		
Oligohaline (0-8 ppt)	Mesohaline (8-19 ppt)	Polyhaline (19-28 ppt)
Tubificidae	<i>Apocorophium louisianum</i>	<i>Amygdalum papyrium</i>
<i>Cyathura polita</i>	<i>Grandidierella bonnieroides</i>	<i>Cyathura polita</i>
<i>Grandidierella bonnieroides</i>		<i>Ampelisca abdita</i>
		<i>Grandidierella bonnieroides</i>

Table 3-8. Comparison of community structure in the Little Manatee River for dominant taxa that contributed primarily to the differences between the adjacent salinity classes identified by the PCA of the Tampa Bay area tidal rivers benthic communities (Janicki Environmental, Inc., 2007a) and season. Probability of significance in parentheses. NS= $p > 0.05$ ; *= $p < 0.05$ ; **= $p < 0.01$ ; ***= $p < 0.001$ . Letters in cells indicate the season/salinity class a taxon was more abundant. D=dry season; W=wet season; M=mesohaline; O=oligohaline; P=polyhaline.							
Taxa	Oligohaline Wet vs. Oligohaline Dry (*)	Oligohaline Wet vs. Mesohaline Wet (*)	Oligohaline Dry vs. Mesohaline Dry (NS)	Mesohaline Wet vs. Mesohaline Dry (***)	Mesohaline Dry vs. Polyhaline Dry (NS)	Mesohaline Wet vs. Polyhaline Wet (*)	Polyhaline Wet vs. Polyhaline Dry (***)
<b>Annelida</b>							
<i>Aricidea philbinae</i>						P	
<i>Laeonereis culveri</i>		O					
<i>Monticellina dorsobranchialis</i>						P	
Tubificidae		O				M	
<b>Bivalvia</b>							
<i>Amygdalum papyrium</i>						P	
<i>Corbicula fluminea</i>	D						
<b>Isopoda</b>							
<i>Cyathura polita</i>		O		D		M	D
<i>Xenanthura brevitelson</i>		M					
<b>Amphipoda</b>							
<i>Ampelisca abdita</i>				D			D
<i>Ampelisca holmesi</i>						P	W
<i>Apocorophium louisianum</i>		M		D		P	D
<i>Cerapus sp.</i>						P	
<i>Gammarus cf. tigrinus</i>	D						
<i>Grandidierella bonnieroides</i>	D	O		D		M	D
<b>Chironomidae</b>							
<i>Polypedilum scalaenum Group</i>		O					

The salinity classification scheme developed for the Tampa Bay area tidal rivers (including the Little Manatee) does appear to be a useful tool to set a MFL in the Little Manatee River.

### 3.2.4.2. Relationship Between 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 (Huisman *et al.*, 1993; Peeters and Gardiniers, 1998; Ysebaert *et al.*, 2002). Janicki Environmental (2007) 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 “optimal habitat range” was calculated as the salinity range  $\pm 25\%$  of the estimated maximum probability of occurrence (Peeters and Gardiniers, 1998).

Figure 3-11 summarizes salinity optima derived from univariate logistic regressions (Janicki Environmental, Inc., 2007a) of selected benthic taxa. These include several dominants from the Little Manatee River, including representatives of taxonomic groups (e.g., amphipods such as *Grandidierella bonnieroides* and *Ampelisca abdita*) that have been identified as being preferred prey items by Peebles (2005). The coefficients for the logistic regression analyses are summarized in Appendix D.

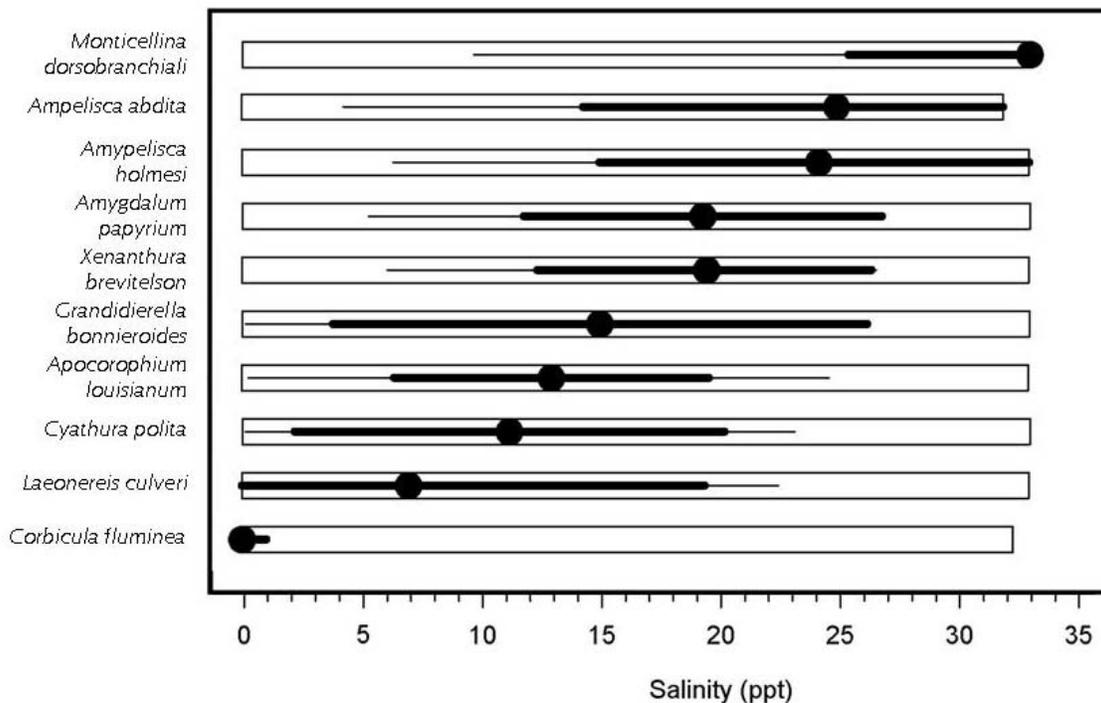


Figure 3-10. Summary of salinity optimum (circle), optimal habitat range (solid bar), 10<sup>th</sup> to 90<sup>th</sup> percentile probability of occurrence (thin line), and model domain (open bar) of salinity for ten selected benthic taxa derived from 12 southwest Florida tidal rivers (wet and dry seasons) by Janicki Environmental (2007a).

*Corbicula fluminea* was the only ranked dominant with an oligohaline salinity optimum during both wet and dry seasons (Figure 3-11; Janicki Environmental, Inc., 2007a). However, in the Little Manatee River the greatest density occurred at RKM 14 in 2005 at a salinity of 18.4 ppt and it was collected as far downstream as RKM 10 (Appendix A). *Corbicula* was more widely distributed in the 2005 dry season survey than in the nine wet season surveys, although this could be an artifact of the different sampling designs (Appendix B)

*Laeonereis culveri* had an oligohaline optimum in the wet season and a mesohaline optimum in the dry season (Figure 3-10; Janicki Environmental, Inc., 2007a). *Laeonereis* was widely distributed during both seasons in the Little Manatee River and was most abundant at RKMs 2-4 (Appendix A).

Two species, *Apocorophium louisianum* and *Cyathura polita* (Figure 3-10; Janicki Environmental, Inc., 2007a) had mesohaline optima during both wet and dry seasons. *Apocorophium* was most abundant between RKMs 4-6 (Appendix A).

*Cyathura* was found as far upstream as RKM 13 in the wet season and RKM 15 in the dry season. Highest densities occurred between RKMs 4-8 in the wet season and 6-9 in the dry season. Figure 3-11 shows how the “Center of Abundance” (Janicki Environmental, Inc., 2007a) for *Cyathura* can shift under different flow conditions. In this example, using the observed range of 56-day cumulative flows, the center of abundance for *Cyathura* shifted approximately 4.5 kilometers upstream, from RKM 1 at the highest flows (approximately 34,500 cfs) to RKM 5.5 at the lowest flows (approximately 3,000 cfs). Note that the  $R^2$  was only 0.11 ( $p=0.06$ ).

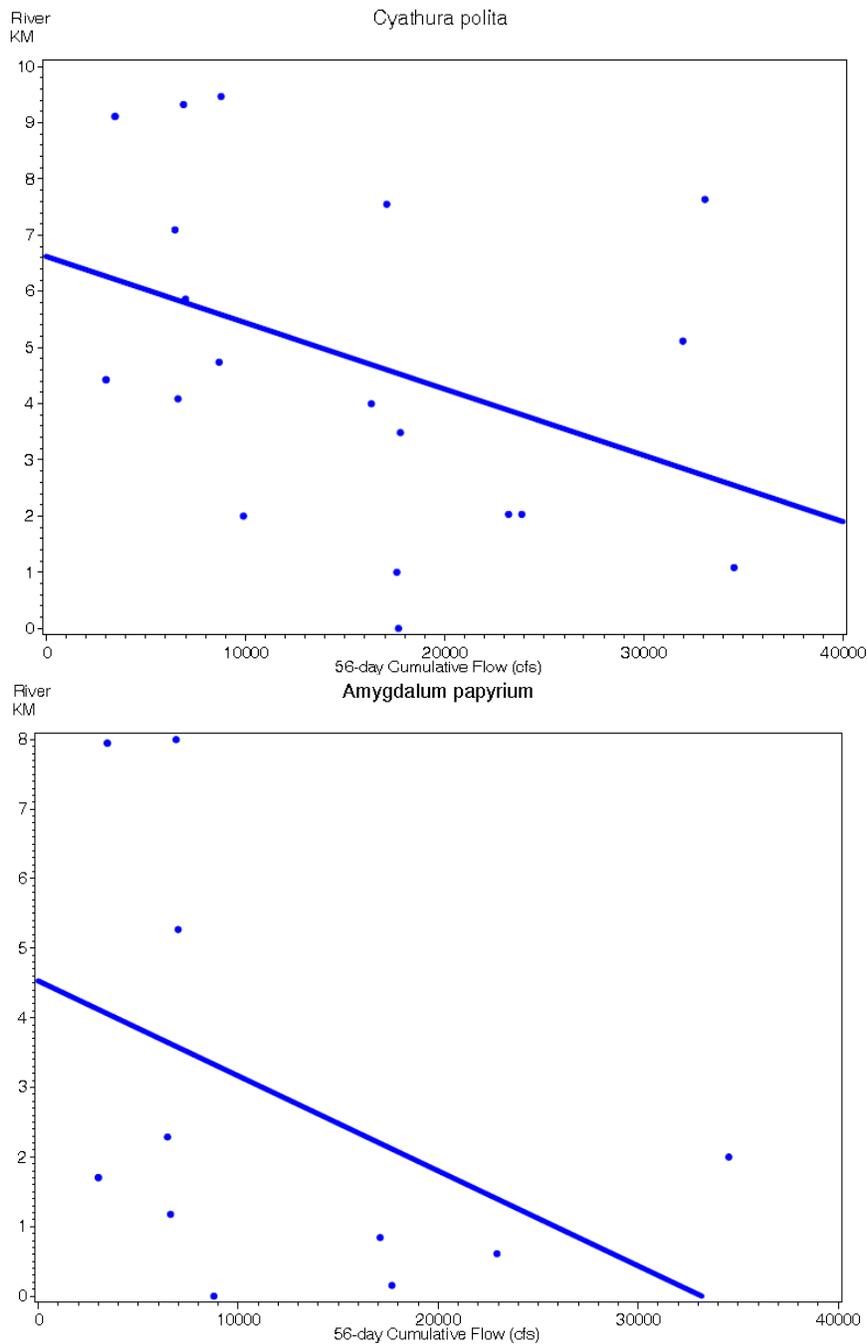
The optimum salinity for *Amygdalum papyrium* and *Grandidierella bonnieroides* was within the mesohaline class in the wet season and within the polyhaline class in the dry season (Figure 3-10; Janicki Environmental, Inc., 2007a). *Amygdalum* was only collected near the river’s mouth in the wet season surveys and as far as 6 kilometers upstream in the dry season (Figure 3-10). COA analysis showed that, as in the case of *Cyathura*, *Amygdalum* could also expand its distribution under diminished flows (Figure 3-11). At the highest observed flows *Amygdalum*’s predicted COA was in Tampa Bay, and not within the river. At the lowest observed flows the COA had moved upstream to near RKM 3.3. Again, the  $R^2$  was low (0.11;  $p=0.06$ ).

*Amygdalum* produces planktonic larvae and, after settlement, is sessile. *Cyathura polita*, on the other hand, does not have planktonic larvae and does possess some natatory capability. Higher salinities (and lower flows) would likely have to persist for a longer duration for an *Amygdalum* population to be established upriver than for a more motile species such as *Cyathura*.

*Grandidierella* was widely distributed in the Little Manatee River, ranging to RKM 18 in the wet season and from RKMs 1-17 in the dry season (Figure 3-10). Wet season densities were highest at RKMs 11 and 8; dry season maxima were observed at RKMs 2-4 as well as in Mill Bayou.

*Xenanthura brevitelson* had a wet season optimum salinity in the mesohaline class and a polyhaline optimum during the dry season (Figure 3-10). *Xenanthura* was more widely distributed (RKMs 0-10 vs. RKMs 1-4) and collected at higher densities during the wet season than during the dry season. Highest densities were typically found at RKMs 4-5 (Appendix A).

*Ampelisca abdita* and *Ampelisca holmesi* each had wet season salinity optima in the polyhaline salinity class and euhaline optima in the dry season (Figure 3-10; Janicki Environmental, Inc., 2007a).



**Figure 3-11. Relationship between the Center of Abundance (as RKM) for *Cyathura polita* and *Amygdalum papyrium* in the Little Manatee River, 1996-2005, and different flow regimes (as the cumulative flow over 56-days).**

*Ampelisca abdita* was rarely abundant in the Little Manatee River during the wet season and only penetrated upstream to RKM 11. During the dry season it was abundant to RKM 6 and was collected as far upstream as RKM 16 (Appendix B). *Ampelisca holmesi* was confined to the lower 2 kilometers of the river in the 2005 dry season survey. It was collected as far upstream as RKM 13 in the wet season but above RKM 4 there only one or two individuals in those samples.

The penetration of the Little Manatee River above RKM 2 by either of these *Ampelisca* species (as well as other *Ampelisca* known to occur in Tampa Bay) appear to be good indicators of an increase in salinity. Both species are abundant in Tampa Bay proper (Grabe et al. 1995; 2002; 2003). Because both are tube-builders, they will only be successful where sediment grain sizes are suitable (Bousfield, 1973; Lombardo 1981).

The polychaete *Monticellina cf. dorsobranchialis*) was the only dominant with a euhaline salinity optimum during either season (Figure 3-10; Janicki Environmental, Inc., 2007a). Euhaline salinities were not detected in the Little Manatee River in any of these surveys—though they are not uncommon in Middle Tampa Bay during the dry season (*cf.* Grabe et al., 2003). *Monticellina* was confined to RKMs 0 and 1 (Appendix A) in the Little Manatee River. Any evidence of upstream colonization would be another indicator of an altered salinity regime in the Little Manatee River.

## 4.0 CONCLUSIONS

The following conclusions can be drawn from the analysis of the benthic macroinvertebrate data:

- Salinity varied widely both longitudinally and seasonally.
- The Little Manatee River benthos was dominated by a number of crustacean taxa, particularly the amphipods *Grandidierella bonnieroides* and *Apocorophium louisianum*.
- Dominant taxa were generally similar between wet and dry season surveys, although the rank orders differed.
- Numbers of taxa generally declined upstream during each season.
- Abundance of benthic macroinvertebrates did not show any consistent longitudinal trend during either season.
- Statistically significant relationships between the number of taxa and a number of habitat variables were found. Location within the river (as RKM), % silt+clay and the 28-day cumulative flow each had negative coefficients and the 56-day cumulative flow had a positive coefficient. Salinity at the time of collection was *a priori* excluded because the benthos responds to the salinity regime over some longer, undefined, time period.
- Abundance declined upriver and with higher percentages of silt+clay and increased with salinity.
- Salinity, considered alone, was only weakly associated with numbers of taxa and abundance.
- Multivariate community structure, based upon samples stratified by river kilometer and season showed that:
  - during the wet season, the lowest two RKMs supported a different faunal assemblage than the rest of the river;
  - the benthos of the wet season was generally similar from RKMs 2-20; and
  - the dry season benthos showed evidence of a shift in assemblages at RKMs 6-8.
- Location in the river (RKM) was the single abiotic variable with the highest Spearman rank correlation coefficient to multivariate community structure.
- The community structure of the benthos differed among Tampa Bay area salinity classes and seasons.
- Ten of ranked dominant taxa were found to have significant relationships between salinity and their probability of occurrence.
- Populations of at least two species, *Cyathura*, and *Amygdalum*, showed some evidence of upstream movement of their centers of abundance with diminished flows. Other taxa (e.g., *Ampelisca* spp. and *Monticellina*) which occur in the lower river, especially in the dry season, could also move upstream with diminished flows.

## 5.0 LITERATURE CITED

Anonymous. 1959. Simposio sulla classificazione della acque salmastre/Symposium on the classification of brackish waters, Venice 8–14th April, 1958. *Archivio di Oceanografia e Limnologia* 11(Suppl): 1–248.

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.

Bulger, A.J., B.P. Hayden, M.E. Monaco, D.M. Nelson, and M.G. McCormick-Ray. 1993. Biologically-based estuarine salinity zones derived from a multivariate analysis. *Estuaries* 16:311-322.

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.

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

Dean, W.E. Jr., 1974: Determination of carbonate and organic matter in calcareous sediments and sedimentary rocks by loss on ignition: Comparison with other methods. *Journal of Sedimentary Petrology* 44:242-248.

Estevez, E.D., K.D. Dixon, and M.S. Flannery. 1991. West-coastal rivers of peninsular Florida. Pages 187-221. In: R.J. Livingston (ed.). *Rivers of Florida*. *Ecological Studies* No. 83. Springer-Verlag, New York.

FDER. 1985. *Limnology of the Suwannee River, Florida*. Biology Section, Division of Environmental Programs, Florida Department of Environmental Regulation. March 1985. 407 pp.

Fernandez, M., Jr. 1985. *Salinity characteristics and distribution and effects of alternative plans for freshwater withdrawal, Little Manatee River estuary and adjacent areas of Tampa Bay, Florida*. U.S. Dept. of the Interior, Geological Survey, Denver, Colo. Open-File Services Section, Western Distribution Branch, U.S. Geological Survey

Flannery, M.S., H. Downing, G. A. McGarry, and M. O. Walters. 1991. Increased nutrient loading and baseflow supplementation in the Little Manatee River Watershed. Ppages 369–395. *In*: S.A. Treat and P. A. Clark (eds.) *Tampa Bay Area Scientific Information Symposium (BASIS) 2*. Tampa Bay Regional Planning Council. Clearwater, Florida.

Flannery, M.S., E.P. Peebles, and R.T. Montgomery. 2002. A percent-of-flow approach for managing reductions to freshwater inflow from unpounded rivers to southwest Florida estuaries. *Estuaries* 25 6(b):1318-1332.

Florida Marine Research Institute. 1997. *Development of GIS-based Maps for the Tidal Reaches of Five Gulf Coast Rivers*. Report prepared by the Florida Department of Environmental Protection for the Southwest Florida Water Management District.

Gibson, G.R., M.L. Bowman, J. Gerritsen, and B.D. Snyder. 2000. *Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical Guidance*. EPA 822-B-00-024. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

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. Prepared for Big Cypress Basin Board, SFWMD, Naples

Grabe, S.A., D.J. Karlen, C.M. Holden, B. Goetting, T. Dix and S. Markham. 2002. *Tampa Bay Benthic Monitoring Program: Status of Hillsborough Bay: 1993-1998*. EPCHC.

Grabe, S.A., D.J. Karlen, C.M. Holden, B. Goetting, T. Dix, S. Markham and C. Pearson. 2003. *Big Bend Area Benthic Monitoring Program Fall 1999 - Fall 2002*. Prepared for Hillsborough County Water Resource Team and Florida Dept. of Environmental Protection. DRAFT

Gray, J.S. 1981. *The Ecology of Marine Sediments*. Cambridge University Press. Cambridge. 185p.

Grizzle, R.E. 1984. Pollution indicator species of macrobenthos in a coastal lagoon. *Marine Ecology Progress Series* 18:191-200.

Iverson, R.L., and H.F. Bittaker, 1986. Seagrass distribution in the eastern Gulf of Mexico. *Estuarine, Coastal and Shelf Science* 22:577-602.

Huisman, J., H. Oliff, and L.F.M. Fresco. 1993. A hierarchical set of models for species response analysis. *Journal of Vegetation Science* 4:37-46.

Janicki Environmental, Inc. 2005. *Design of Sampling Events for a Statistical Analysis of Relationships of Benthic Macroinvertebrates With Substrate and Water Quality in Five Gulf Coast Tidal Rivers*. Prepared for: Southwest Florida Water Management District. Brooksville.

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.

Janicki Environmental, Inc. 2007b. *Analysis of Benthic Structure in the Manatee and Braden Rivers*. Prepared for: Southwest Florida Water Management District. Brooksville. DRAFT

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.

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. 45p.

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.

McNulty, J.K., W.N. Lindall Jr., and J.E. Sykes. 1972. *Cooperative Gulf of Mexico Estuarine Inventory and Study, Florida: Phase I, Area Description*. NOAA Tech. Rep., NMFS Circ. 368.

Montagna, P.A. and R.D. Kalke 1992. The effect of freshwater inflow on meiofaunal and macrofaunal populations in the Guadalupe and Nueces estuaries, Texas. *Estuaries* 15:307-326.

Peeters, E.T.H.M. and J.J.P. Gardeniers. 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.

Plumb, R.H. 1981. *Procedure for Handling and Chemical Analysis of Sediment and Water Samples*. Tech. Rep. EPA/CE-81-1, US Army Waterways Experiment Station, Vicksburg, MS.

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

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.

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. 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, Florida.

Weisberg, S.B., J.A. Ranasinghe, D.M. Dauer, L.C. Schaffner, R.J. Diaz, and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for the Chesapeake Bay. *Estuaries* 20:149-158.

Wilkinson, L., A. Anand and R. Grossman. 2006. High-Dimensional Visual Analytics: Interactive Exploration Guided by Pairwise Views of Point Distributions. *National Center for Data Mining*. (<http://www.ncdm.uic.edu/publications/files/journal-033.pdf>)

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.

## 6.0 APPENDICES

**APPENDIX A: Mean, Median, and Maximum Abundance of All Benthic Taxa  
(Excludes Samples in Which Taxon was Absent)**

<b>Wet Seasons (1996-2004)</b>				
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Median Density (#/m<sup>2</sup>)</b>	<b>Maximum Density (#/m<sup>2</sup>)</b>
Tubificidae	64	683	250	14,575
<i>Cyathura polita</i>	63	429	150	5,725
<i>Grandidierella bonnieroides</i>	53	1,536	175	41,600
<i>Laeonereis culveri</i>	49	300	150	1,500
<i>Polypedilum scalaenum</i>	43	208	125	925
<i>Xenanthura brevitelson</i>	42	474	163	2,275
<i>Ampelisca holmesi</i>	39	1,342	400	8,400
<i>Amygdalum papyrium</i>	37	496	125	4,825
<i>Edotea triloba</i>	37	111	50	1,025
<i>Ampelisca abdita</i>	36	297	100	2,250
<i>Heteromastus filiformis</i>	35	166	100	1,100
<i>Rhithropanopeus harrisi</i>	34	95	50	1,125
<i>Aricidea philbinae</i>	33	446	125	2,750
<i>Apocorophium louisianum</i>	32	6,734	88	146,725
<i>Tagelus plebeius</i>	30	61	50	200
Bivalvia	29	72	50	525
<i>Leptochelia sp.</i>	29	279	25	3,175
<i>Cerapus spp.</i>	28	2,190	513	12,475
<i>Hobsonia florida</i>	28	219	88	1,125
<i>Streblospio gynobranchiata</i>	28	212	125	950
<i>Monticellina dorsobranchialis</i>	26	1,176	575	5,975
<i>Acteocina canaliculata</i>	24	243	113	1,325
<i>Ampelisca vadorum</i>	23	258	75	2,075
<i>Tubificoides brownae</i>	23	932	400	4,500
<i>Mysella planulata</i>	22	556	288	2,275
<i>Nassaricus vibex</i>	22	60	50	125
<i>Mytilopsis leucophaeata</i>	21	477	75	5,150

<b>Wet Seasons (1996-2004)</b>				
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Median Density (#/m<sup>2</sup>)</b>	<b>Maximum Density (#/m<sup>2</sup>)</b>
Archinemertea sp. A	20	59	50	175
<i>Cyclaspis cf. varians</i>	20	348	150	1625
<i>Glottidia pyramidata</i>	20	1,268	288	11,775
<i>Capitella capitata</i>	19	109	50	800
<i>Fabricinuda triloba</i>	18	611	238	3,575
<i>Glycinde solitaria</i>	18	51	25	175
<i>Amphiporus bioculatus</i>	17	259	175	850
<i>Glycera americana</i>	17	60	50	150
Hydrobiidae	17	204	50	1,925
<i>Mulinia lateralis</i>	17	322	175	1,925
<i>Scoloplos rubra</i>	17	57	25	175
<i>Tubificoides motei</i>	17	768	275	5,650
<i>Aricidea taylori</i>	16	322	113	1,500
<i>Chironomus sp.</i>	16	166	75	1,150
<i>Cryptochironomus sp.</i>	16	66	50	200
Gastropoda	16	53	25	175
<i>Haminoea succinea</i>	16	119	63	450
<i>Mediomastus sp.</i>	15	65	25	200
<i>Polypedilum halterale</i>	15	271	75	1,675
<i>Tubificoides wasselli</i>	15	543	125	2,850
<i>Anomalocardia auberiana</i>	14	88	75	325
<i>Procladius sp.</i>	14	134	50	750
<i>Almyracuma proximoculi</i>	13	71	50	200
<i>Leitoscoloplos robustus</i>	13	77	50	175
Nemertea F	13	77	50	250
<i>Macoma tenta</i>	12	190	75	1,075
<i>Oxyurostylis smithi</i>	12	129	38	525
<i>Pinnixa spp.</i>	12	67	38	325
<i>Prionospio heterobranchia</i>	12	110	88	375
<i>Hourstonius laguna</i>	11	127	75	350
Nemertea K	11	191	100	675
<i>Paraprionospio pinnata</i>	11	75	50	325
<i>Sphenia antillensis</i>	11	80	50	275

Wet Seasons (1996-2004)				
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Median Density (#/m <sup>2</sup> )	Maximum Density (#/m <sup>2</sup> )
<i>Tellina cf. versicolor</i>	11	141	100	475
<i>Abra aequalis</i>	10	103	25	325
Chironomidae	10	50	38	125
<i>Magelona pettiboneae</i>	10	75	50	150
<i>Phascolion cryptum</i>	10	48	38	125
<i>Rangia cuneata</i>	10	60	38	200
<i>Astyris lunata</i>	9	36	25	75
<i>Gammarus mucronatus</i>	9	50	25	200
<i>Podarkeopsis levifusca</i>	9	89	50	225
<i>Sabaco americanus</i>	9	31	25	50
<i>Eteone heteropoda</i>	8	31	25	50
<i>Prionospio perkinsi</i>	8	219	150	525
<i>Stenoninereis martini</i>	8	97	63	275
Thenaria E	8	88	38	375
<i>Apoprionospio pygmaea</i>	7	89	50	175
<i>Bowmaniella floridana</i>	7	39	25	75
<i>Cirripedia</i>	7	2,882	50	19,000
<i>Macoma constricta</i>	7	50	50	100
<i>Neanthes succinea</i>	7	150	50	650
<i>Nereiphylla castanea</i>	7	86	75	200
<i>Scolelepis texana</i>	7	39	25	75
<i>Tagelus divinus</i>	7	50	50	100
<i>Tubulanus pellucidus</i>	7	43	25	100
<i>Dipolydora socialis</i>	6	146	88	500
<i>Erpobdella punctata</i>	6	46	25	150
<i>Lyonsia floridana</i>	6	46	25	125
<i>Melinna maculata</i>	6	33	25	50
<i>Notomastus hemipodus</i>	6	54	25	175
<i>Phyllodoce arenae</i>	6	54	50	100
<i>Polydora cornuta</i>	6	133	100	375
<i>Pyrgophorus platyrachus</i>	6	488	363	1,250
<i>Tellina tampaensis</i>	6	46	38	75

Wet Seasons (1996-2004)				
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Median Density (#/m <sup>2</sup> )	Maximum Density (#/m <sup>2</sup> )
Amphilocidae	5	110	75	300
<i>Caecum pulchellum</i>	5	60	50	100
<i>Carazziella hobsonae</i>	5	45	25	125
<i>Corbicula fluminea</i>	5	1,580	1,175	3,725
Enteropneusta	5	70	75	125
<i>Gammarus tigrinus</i>	5	35	25	75
<i>Littoridinops palustris</i>	5	305	50	950
<i>Lucinisca nassula</i>	5	85	25	200
<i>Mediomastus californiensis</i>	5	225	50	925
<i>Odostomia</i> spp.	5	85	100	150
Ophiuroidea	5	70	75	125
<i>Paramphinome</i> sp. B	5	60	50	100
<i>Sigambra tentaculata</i>	5	60	25	150
<i>Teinostoma biscaynense</i>	5	60	75	100
<i>Tellina</i> sp.	5	35	25	75
Veneroidea	5	120	25	475
<i>Ambidexter symmetricus</i>	4	56	25	150
<i>Cladotanytarsus daviesi</i>	4	300	288	550
<i>Dicrotendipes</i> sp.	4	31	25	50
<i>Euplana gracilis</i>	4	119	88	275
<i>Eustylochus meridionalis</i>	4	50	50	75
<i>Hemipholis elongata</i>	4	200	125	500
Holothuroidea C	4	31	25	50
<i>Laevicardium mortoni</i>	4	69	63	125
<i>Littoridinops</i> sp.	4	119	50	350
Nemertea A	4	31	25	50
Nemertea T	4	38	38	50
Nemertea U	4	31	25	50
Nereididae	4	56	38	125
<i>Paracladopelma doris</i>	4	31	25	50
<i>Phoronis</i> sp.	4	50	38	100
<i>Rudilemboides naglei</i>	4	100	88	200
<i>Tanytarsus</i> sp.	4	256	25	950

Wet Seasons (1996-2004)				
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Median Density (#/m <sup>2</sup> )	Maximum Density (#/m <sup>2</sup> )
<i>Tectonatica pusilla</i>	4	44	25	100
<i>Tellina iris</i>	4	163	100	425
<i>Tellina tenella</i>	4	31	25	50
<i>Bittium varium</i>	3	67	75	100
Ceratopogonidae	3	58	25	125
<i>Cladotanytarsus sp.</i>	3	233	50	600
<i>Cymadusa compta</i>	3	33	25	50
<i>Diopatra cuprea</i>	3	25	25	25
<i>Diplodonta semiaspera</i>	3	25	25	25
<i>Erichsonella attenuata</i>	3	158	200	250
<i>Glyptotendipes sp.</i>	3	58	25	125
<i>Hartmanodes nyei</i>	3	25	25	25
<i>Kinbergonuphis simoni</i>	3	25	25	25
<i>Leitoscoloplos fragilis</i>	3	83	50	175
<i>Mediomastus ambiseta</i>	3	108	125	175
<i>Melita elongata</i>	3	25	25	25
<i>Micrura leidyi</i>	3	75	25	175
<i>Nais communis sp</i>	3	108	75	225
Nemertea B	3	25	25	25
<i>Nereiphylla fragilis</i>	3	25	25	25
<i>Onobops sp.</i>	3	25	25	25
<i>Ophiodromus obscura</i>	3	75	50	125
<i>Ophiophragmus filigraneus</i>	3	25	25	25
<i>Parahesionella luteola</i>	3	58	75	75
<i>Parastarte triquetra</i>	3	592	25	1,725
<i>Sayella hemphillii</i>	3	33	25	50
Synaptidae sp. A	3	42	50	50
<i>Tanytus stellatus</i>	3	50	50	75
<i>Tanytarsus H</i>	3	50	50	75
<i>Tubulanus sp. B</i>	3	33	25	50
<i>Zygeupolia cf. rubens</i>	3	25	25	25
<i>Amphioplus thrombodes</i>	2	150	150	150
<i>Asthenothaerus hemphillii</i>	2	25	25	25
Athenaria	2	225	225	350
<i>Branchiostoma floridae</i>	2	25	25	25

Wet Seasons (1996-2004)				
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Median Density (#/m <sup>2</sup> )	Maximum Density (#/m <sup>2</sup> )
<i>Capitella jonesi</i>	2	38	38	50
<i>Chone cf. americana</i>	2	38	38	50
<i>Coelotanypus sp.</i>	2	38	38	50
<i>Corbula contracta</i>	2	50	50	75
<i>Crassostrea virginica</i>	2	25	25	25
<i>Cryptotendipes sp.</i>	2	50	50	75
<i>Cyrtopleura costata</i>	2	25	25	25
<i>Dicrotendipes modestus</i>	2	250	250	450
<i>Dicrotendipes neomodestus</i>	2	25	25	25
<i>Dorvillea cf. rudolphi</i>	2	38	38	50
<i>Dosinia discus</i>	2	25	25	25
<i>Elasmopus laevis</i>	2	138	138	225
<i>Epitonium sp.</i>	2	75	75	125
<i>Erycina floridana</i>	2	188	188	225
<i>Eteone foliasa</i>	2	38	38	50
<i>Goeldichironomus sp.</i>	2	25	25	25
<i>Halmyrapseudes bahamensis</i>	2	713	713	1,400
<i>Haminoea antillarum</i>	2	38	38	50
Hydracarina	2	150	150	275
Libellulidae	2	25	25	25
<i>Limnodriloides sp.</i>	2	113	113	200
<i>Lineus cf. ruber</i>	2	38	38	50
<i>Magelona riojai</i>	2	25	25	25
<i>Malmgreniella maccrarya</i>	2	75	75	75
<i>Marphysa cf. sanguinea</i>	2	38	38	50
<i>Megalomma pigmentum</i>	2	25	25	25
<i>Metharpinia floridana</i>	2	500	500	950
Nemertea I	2	50	50	75
Nemertea Q	2	75	75	100
<i>Nucula proxima</i>	2	25	25	25
<i>Pectinaria gouldii</i>	2	38	38	50
<i>Polypedilum simulans</i>	2	25	25	25
<i>Rheotanytarsus sp.</i>	2	25	25	25
<i>Rictaxis</i>	2	38	38	50

Wet Seasons (1996-2004)				
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Median Density (#/m <sup>2</sup> )	Maximum Density (#/m <sup>2</sup> )
<i>punctostriatus</i>				
<i>Sigambra bassi</i>	2	38	38	50
<i>Sphaerium sp.</i>	2	25	25	25
<i>Sphaerosyllis longicauda</i>	2	25	25	25
<i>Spio pettiboneae</i>	2	38	38	50
<i>Spiochaetopterus costarum</i>	2	25	25	25
<i>Syllis gracilis</i>	2	25	25	25
<i>Tagelus sp.</i>	2	25	25	25
<i>Thalassodrilides sp.</i>	2	25	25	25
Thenaria G	2	25	25	25
Turbellaria C	2	50	50	75
<i>Turbonilla dalli</i>	2	25	25	25
<i>Vitrinella floridana</i>	2	88	88	100
<i>Ablabesmyia rhamphe</i>	1	25	25	25
Alpheidae	1	50	50	50
<i>Americamysis almyra</i>	1	25	25	25
<i>Americamysis stucki</i>	1	25	25	25
Ampharetidae	1	50	50	50
<i>Amphioplus sepultus</i>	1	25	25	25
<i>Amphipholis atra</i>	1	25	25	25
<i>Amphipholis gracillima</i>	1	25	25	25
<i>Anisoptera sp.</i>	1	25	25	25
Anthozoa sp. A	1	25	25	25
<i>Bhawania heteroseta</i>	1	75	75	75
<i>Busycotypus spiratus</i>	1	25	25	25
<i>Cabira incerta</i>	1	25	25	25
<i>Carinoma cf. tremaphoros</i>	1	25	25	25
Cephalocardida	1	25	25	25
<i>Cerebratulus lacteus</i>	1	25	25	25
<i>Chaoborus sp.</i>	1	25	25	25
<i>Chione elevata</i>	1	25	25	25
<i>Chironomini sp.</i>	1	25	25	25
<i>Cirrophorus sp.</i>	1	25	25	25
<i>Cladopelma sp.</i>	1	75	75	75
<i>Cladotanytarsus sp. A</i>	1	50	50	50

<b>Wet Seasons (1996-2004)</b>				
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Median Density (#/m<sup>2</sup>)</b>	<b>Maximum Density (#/m<sup>2</sup>)</b>
<i>Cladotanytarsus sp. F</i>	1	50	50	50
Collembola	1	25	25	25
Cumacea	1	25	25	25
<i>Cyclinella tenuis</i>	1	50	50	50
<i>Cyrenoida floridana</i>	1	125	125	125
<i>Dasybranchus lumbricoides</i>	1	25	25	25
<i>Dicrotendipes lobus</i>	1	25	25	25
<i>Einfeldia natchitochaeae</i>	1	400	400	400
<i>Einfeldia sp. A</i>	1	575	575	575
Elysiidae	1	25	25	25
<i>Eobrolgus spinosus</i>	1	25	25	25
<i>Eudevenopus honduranus</i>	1	75	75	75
<i>Exogone dispar</i>	1	25	25	25
<i>Fargoa gibbosa</i>	1	25	25	25
<i>Gemma gemma</i>	1	50	50	50
Goniadidae	1	25	25	25
<i>Grubeosyllis clavata</i>	1	25	25	25
<i>Gyptis crypta</i>	1	25	25	25
Halacaridae	1	275	275	275
<i>Haminoea sp.</i>	1	50	50	50
<i>Harrieta faxoni</i>	1	25	25	25
<i>Hexapanopeus sp.</i>	1	25	25	25
<i>Hutchinsoniella sp.</i>	1	25	25	25
Isopoda	1	175	175	175
<i>Kalliapseudes macsweenyi</i>	1	25	25	25
Laseidae	1	150	150	150
<i>Leitoscoloplos sp.</i>	1	50	50	50
<i>Limnodriloides baculatus</i>	1	100	100	100
<i>Littoridinops monroensis</i>	1	75	75	75
<i>Loimia medusa</i>	1	50	50	50
<i>Macoma sp. A</i>	1	25	25	25
<i>Microphthalmus sp A</i>	1	275	275	275
Nemertea	1	25	25	25
Nemertea J	1	275	275	275
Nemertea R	1	75	75	75
Nemertea W	1	25	25	25

<b>Wet Seasons (1996-2004)</b>				
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Median Density (#/m<sup>2</sup>)</b>	<b>Maximum Density (#/m<sup>2</sup>)</b>
<i>Neverita duplicata</i>	1	25	25	25
<i>Notomastus americanus</i>	1	25	25	25
<i>Notomastus cf. tenuis</i>	1	25	25	25
<i>Notomastus n. sp</i>	1	25	25	25
<i>Notomastus sp.</i>	1	75	75	75
<i>Olivella pusilla</i>	1	50	50	50
<i>Ophiophragmus wurdemanii</i>	1	25	25	25
<i>Orobitella floridana</i>	1	25	25	25
<i>Pagurus sp.</i>	1	25	25	25
<i>Panopeus sp.</i>	1	25	25	25
<i>Paradoneis lyra</i>	1	125	125	125
<i>Parakiefferiella sp. F</i>	1	50	50	50
<i>Parvilucina multilineata</i>	1	50	50	50
<i>Petitilla crosseana</i>	1	25	25	25
<i>Phascolion cf. caupo</i>	1	50	50	50
<i>Phoronida B</i>	1	25	25	25
<i>Phyllodoce mucosa</i>	1	25	25	25
<i>Pinnixa A</i>	1	100	100	100
<i>Pinnixa D</i>	1	100	100	100
<i>Pinnixa pearsei</i>	1	175	175	175
<i>Pisidium punctiferum</i>	1	50	50	50
<i>Polymesoda caroliniana</i>	1	25	25	25
<i>Pseudochironomus sp.</i>	1	25	25	25
Pyramidellidae	1	75	75	75
<i>Pyrgocythara plicosa</i>	1	100	100	100
<i>Rheosmittia arcuata</i>	1	175	175	175
Rissoidae	1	25	25	25
<i>Sayella laevigata</i>	1	175	175	175
<i>Scolecopsis squamata</i>	1	25	25	25
<i>Sinelobus stanfordi</i>	1	25	25	25
<i>Sinum perspectivum</i>	1	25	25	25
Sipuncula	1	25	25	25
<i>Sphaerosyllis</i>	1	25	25	25

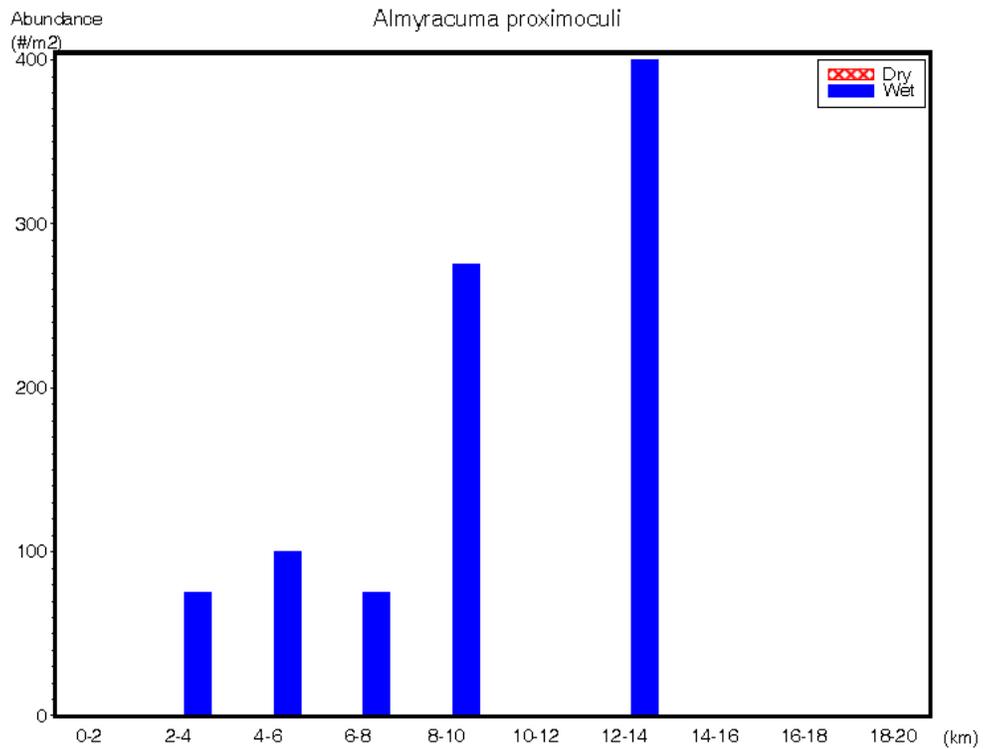
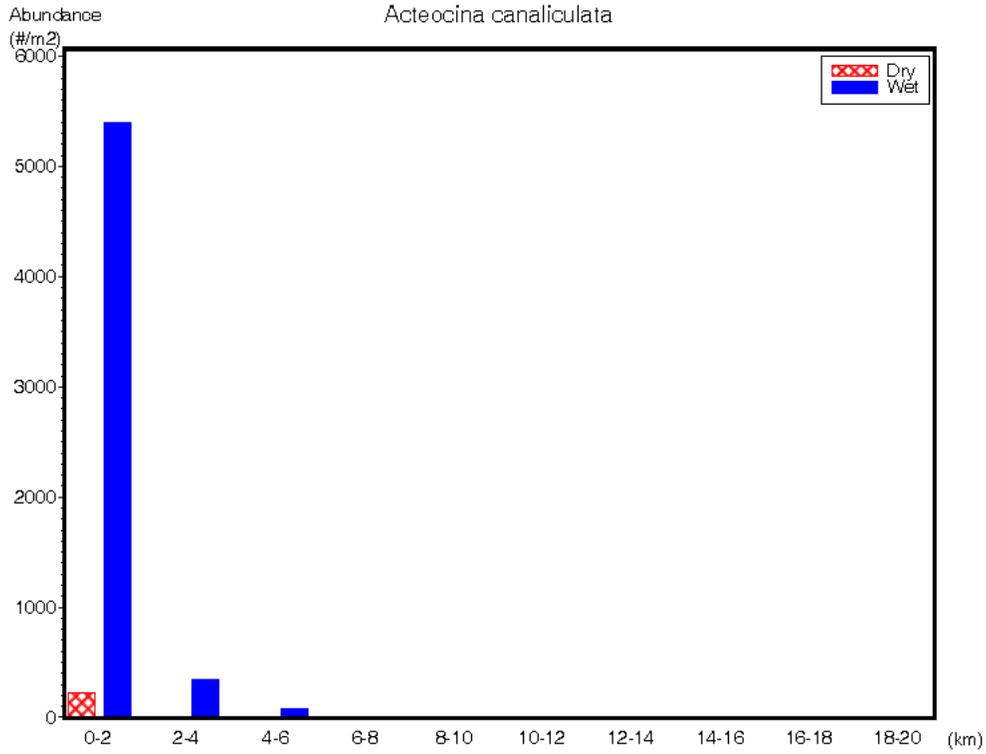
<b>Wet Seasons (1996-2004)</b>				
<b>Taxon</b>	<b>Frequency of Occurrence</b>	<b>Mean Density (#/m<sup>2</sup>)</b>	<b>Median Density (#/m<sup>2</sup>)</b>	<b>Maximum Density (#/m<sup>2</sup>)</b>
<i>labyrinthophila</i>				
<i>Stephensonia trivandran</i>	1	350	350	350
Syllidae	1	25	25	25
<i>Syllis (typosyllis) tortugaensi</i>	1	25	25	25
<i>Syllis sp.</i>	1	100	100	100
<i>Synalpheus sp.</i>	1	25	25	25
<i>Tanytarsus g</i>	1	25	25	25
<i>Taphromysis bowmani</i>	1	50	50	50
Tellinidae	1	50	50	50
<i>Thalassodrilides ineri</i>	1	25	25	25
<i>Thalenessa sp.</i>	1	25	25	25
Thenaria	1	50	50	50
Thenaria A	1	1300	1300	1300
<i>Travisia hobsonae</i>	1	25	25	25
<i>Tryonia aequicostata</i>	1	150	150	150
<i>Turbonilla conradi</i>	1	200	200	200
<i>Turbonilla hemphilli</i>	1	25	25	25
<i>Turbonilla toyatani</i>	1	25	25	25
<i>Upogebia affinis</i>	1	25	25	25
<i>Uromunna sp.</i>	1	175	175	175
<i>Zygonemertes virescens</i>	1	25	25	25

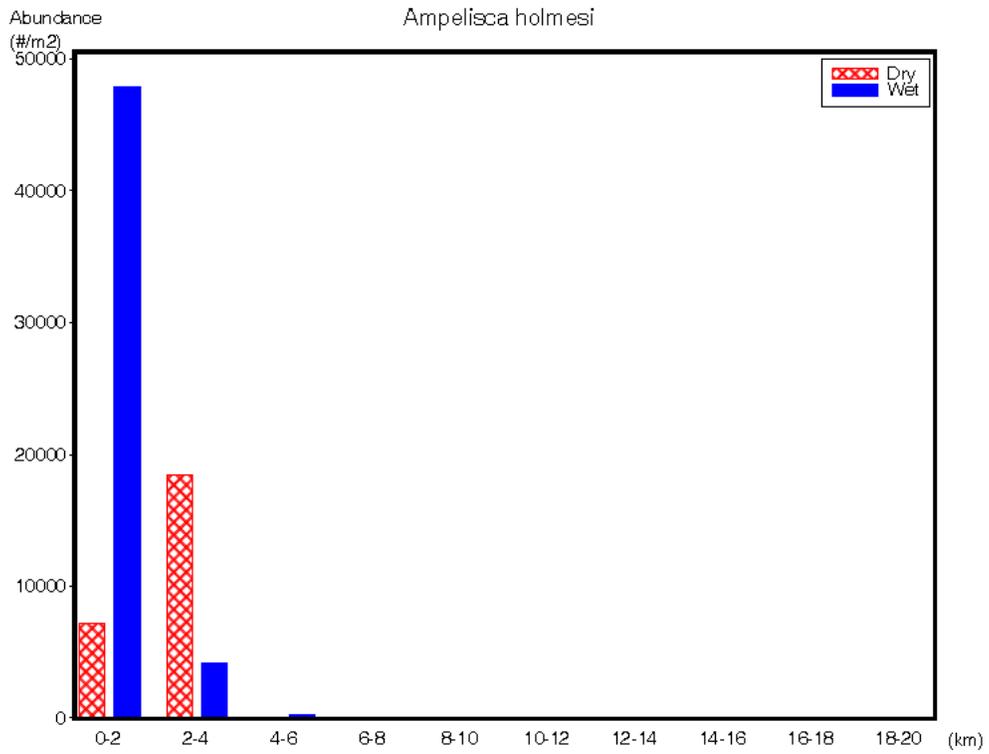
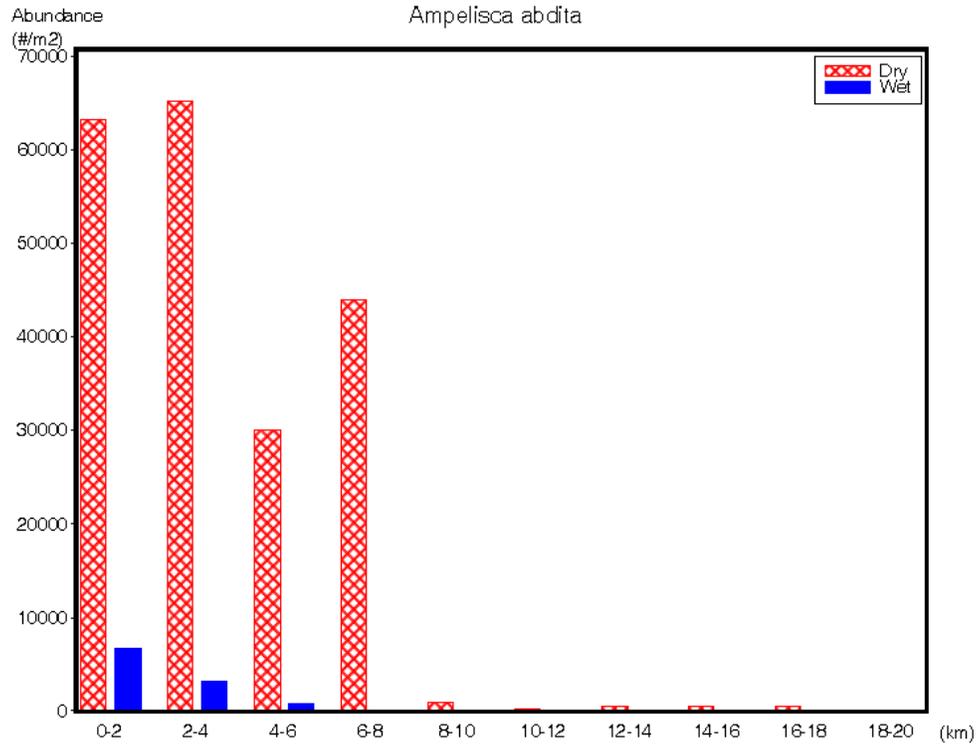
Dry Season (2005)				
Taxon	Frequency of Occurrence	Mean Density (#/m <sup>2</sup> )	Median Density (#/m <sup>2</sup> )	Maximum Density (#/m <sup>2</sup> )
<i>Grandidierella bonnieroides</i>	76	4,634	2,409	26,280
<i>Cyathura polita</i>	61	1,034	876	3,723
<i>Apocorophium louisianum</i>	48	7,104	1,971	63,291
<i>Ampelisca abdita</i>	43	4,767	1,971	28,470
Tubificidae	35	1,796	876	8,322
<i>Laeonereis culveri</i>	29	385	219	1,095
<i>Amygdalum papyrium</i>	27	3,390	1,752	15,111
Nemertea	27	600	219	3,285
<i>Gammarus tigrinus</i>	26	2,190	767	18,396
<i>Heteromastus filiformis</i>	24	785	438	2,847
<i>Corbicula fluminea</i>	20	1,511	986	5,256
<i>Euplana gracilis</i>	18	657	329	4,380
<i>Hobsonia florida</i>	14	235	219	438
<i>Cryptochironomus sp.</i>	13	455	219	1,533
<i>Polypedilum scalaenum</i>	13	505	438	1,752
<i>Streblospio gynobranchiata</i>	13	354	219	657
<i>Tubificoides heterochaetus</i>	13	1,061	438	5,037
<i>Polymesoda caroliniana</i>	12	383	219	1,314
<i>Xenanthura brevitelson</i>	11	557	219	1,971
Bivalvia	10	482	329	1,752
<i>Hourstonius laguna</i>	9	316	219	657
<i>Cyclaspis cf. varians</i>	8	301	219	876
<i>Monticellina dorsobranchialis</i>	8	1,779	1,314	5,913
<i>Aricidea philbinae</i>	7	3,504	1,533	17,301
<i>Capitella capitata</i>	7	375	219	876
<i>Ampelisca holmesii</i>	6	4,271	1,643	18,177
<i>Cladotanytarsus sp.</i>	6	803	876	1,314
<i>Edotea triloba</i>	6	329	219	657
<i>Eteone heteropoda</i>	6	584	329	1,971
<i>Glycinde solitaria</i>	6	511	438	876
<i>Lyonsia floridana</i>	6	292	219	438
<i>Neanthes succinea</i>	6	329	329	438

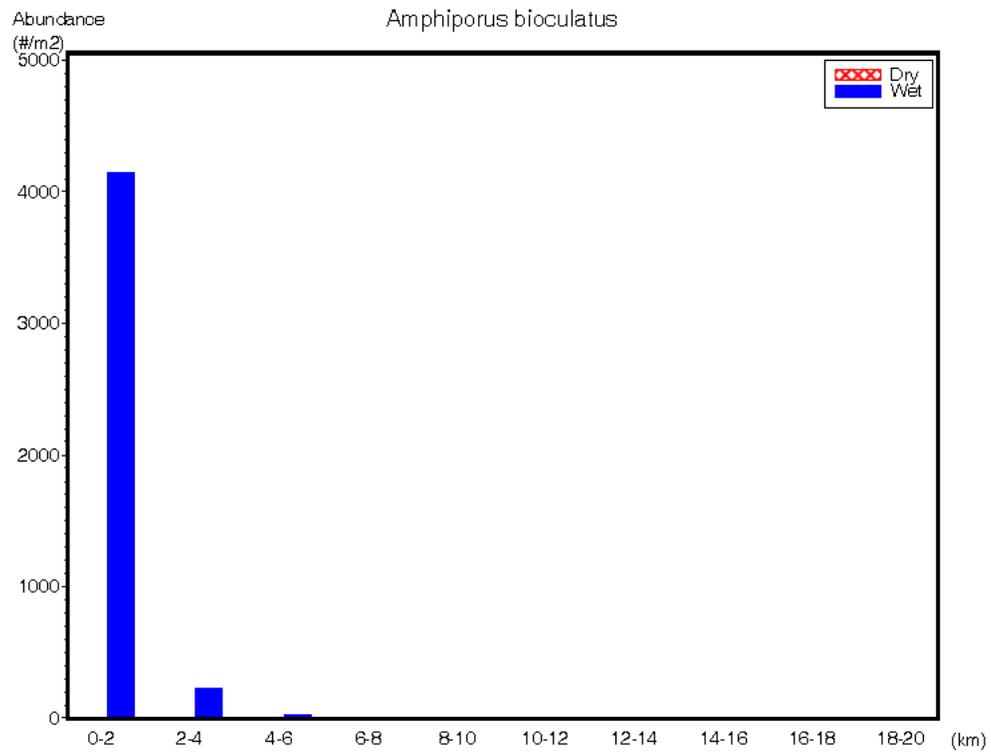
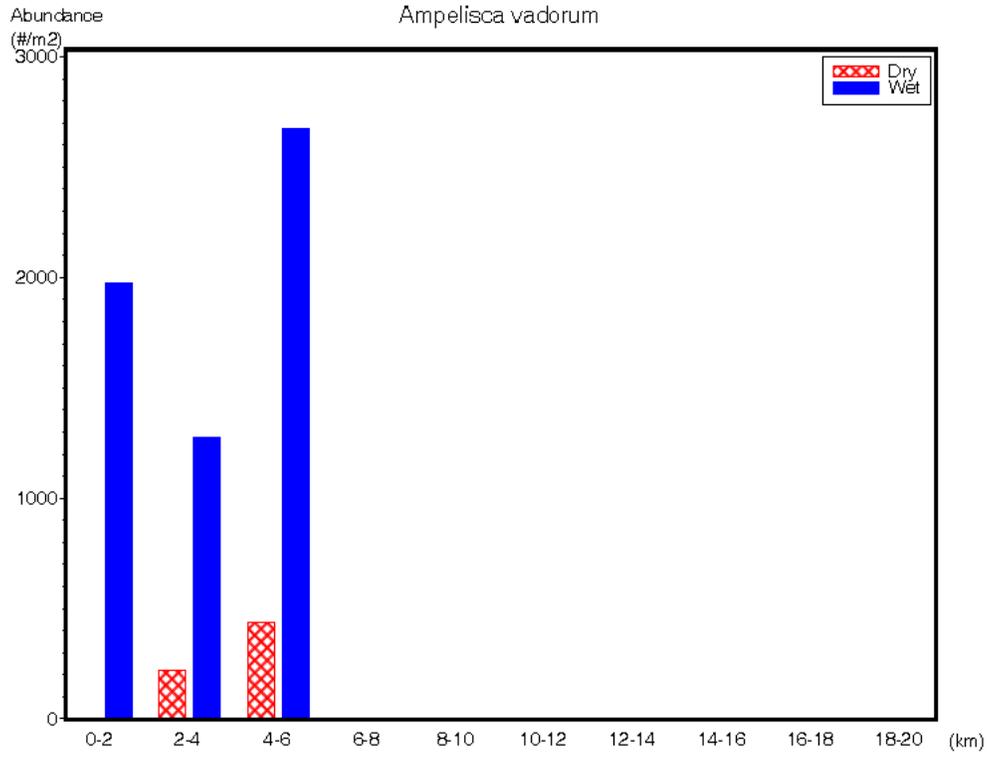
<i>Paraprionospio pinnata</i>	6	256	219	438
<i>Ameroculodes miltoni</i>	5	526	438	876
<i>Fabricinuda triloba</i>	5	350	219	657
<i>Leitoscoloplos robustus</i>	5	350	219	876
<i>Leptocheilia sp.</i>	5	2,584	657	10,512
<i>Mytilopsis leucophaeata</i>	5	307	219	657
<i>Phyllodoce arenae</i>	5	482	438	876
<i>Procladius sp.</i>	5	350	438	438
<i>Apocorophium lacustre</i>	4	3,176	2,409	7,665
<i>Mysella planulata</i>	4	493	438	876
<i>Oxyurostylis smithi</i>	4	329	329	438
<i>Tubificoides brownae</i>	4	1,369	1,314	2,628
<i>Ampelisca vadorum</i>	3	219	219	219
<i>Athenaria</i>	3	11,000	219	31,755
<i>Coelotanypus sp.</i>	3	219	219	219
<i>Mactra fragilis</i>	3	438	438	657
<i>Melita elongata</i>	3	1,168	1,095	2,190
<i>Mulinia lateralis</i>	3	219	219	219
<i>Rithropanopeus harrisi</i>	3	219	219	219
<i>Asychis elongatus</i>	2	219	219	219
<i>Bowmaniella floridana</i>	2	438	438	657
<i>Capitella jonesi</i>	2	219	219	219
<i>Dicrotendipes sp.</i>	2	438	438	657
<i>Macoma tenta</i>	2	219	219	219
<i>Melinna maculata</i>	2	219	219	219
<i>Oecetis sp.</i>	2	219	219	219
<i>Polypedilum halterale</i>	2	2,519	2,519	4,818
<i>Prionospio sp.</i>	2	657	657	1,095
<i>Spiochaetopterus costarum</i>	2	219	219	219
<i>Stenoninereis martini</i>	2	329	329	438
<i>Tagelus plebeius</i>	2	219	219	219
<i>Tanytarsus sp.</i>	2	219	219	219
<i>Tectidrilus wasselli</i>	2	1,205	1,205	1,971
<i>Acteocina canaliculata</i>	1	219	219	219
<i>Anomalocardia auberiana</i>	1	219	219	219
<i>Aricidea taylori</i>	1	657	657	657
<i>Aulodrilus pigueti</i>	1	219	219	219

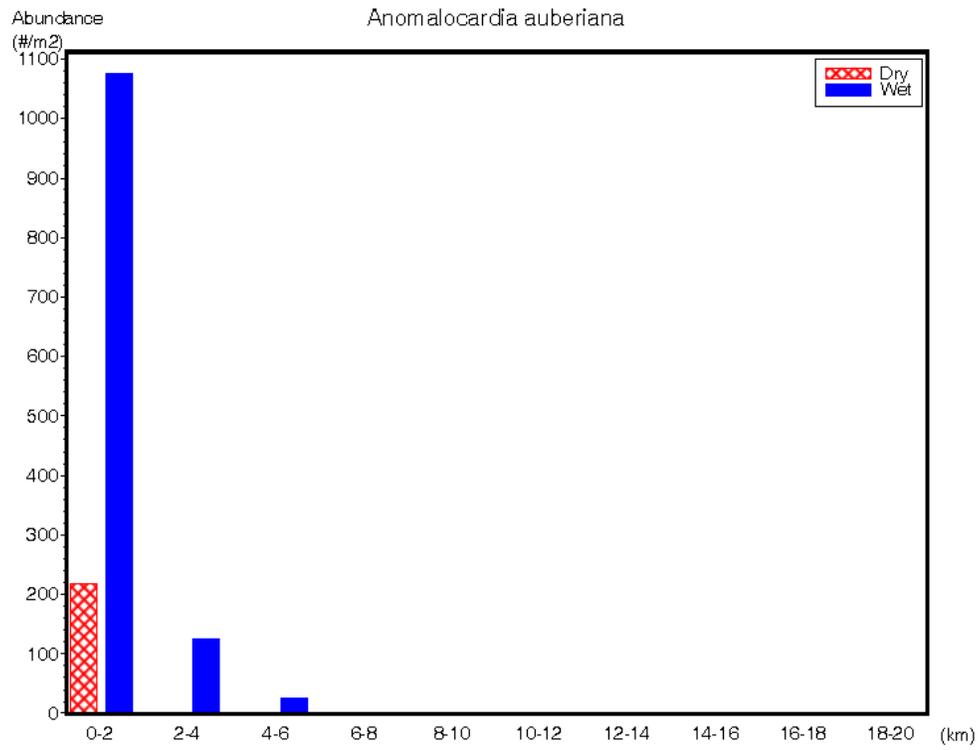
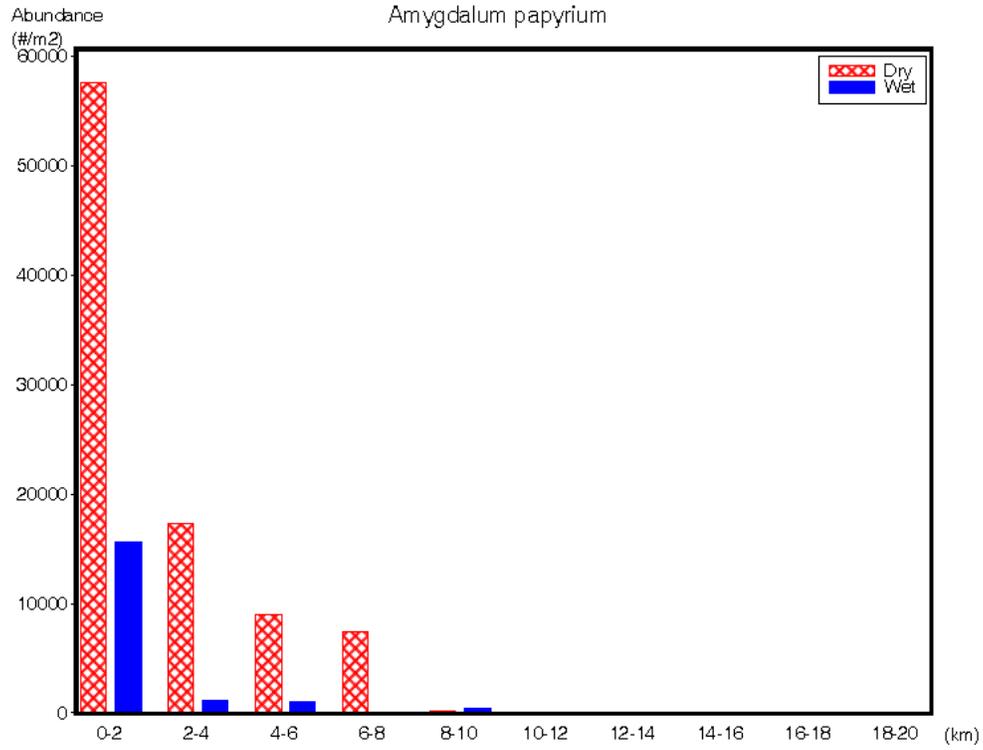
<i>Axiothella mucosa</i>	1	219	219	219
<i>Cirripedia</i>	1	219	219	219
<i>Gammarus mucronatus</i>	1	219	219	219
<i>Glycera americana</i>	1	219	219	219
<i>Haminoea succinea</i>	1	219	219	219
<i>Hartmanodes nyei</i>	1	219	219	219
<i>Helobdella stagnalis</i>	1	219	219	219
<i>Hydrobiidae</i>	1	219	219	219
<i>Kinbergonuphis simoni</i>	1	438	438	438
<i>Leitoscoloplos fragilis</i>	1	219	219	219
<i>Limnodriloides rubicundus</i>	1	876	876	876
<i>Limnodrilus hoffmeisteri</i>	1	219	219	219
<i>Macoma constricta</i>	1	219	219	219
<i>Mediomastus sp.</i>	1	438	438	438
<i>Mogula occidentalis</i>	1	219	219	219
<i>Panopeus sp.</i>	1	219	219	219
<i>Paralauterborniella nigrohalter</i>	1	219	219	219
<i>Parandalia americana</i>	1	438	438	438
<i>Podarkeopsis levifuscina</i>	1	657	657	657
<i>Polydora ligni</i>	1	219	219	219
<i>Polydora socialis</i>	1	219	219	219
<i>Polynices duplicatus</i>	1	219	219	219
<i>Pyrgophorus platyrachus</i>	1	219	219	219
<i>Scoloplos rubra</i>	1	219	219	219
<i>Sphaerium sp.</i>	1	219	219	219
<i>Synchelidium americanum</i>	1	219	219	219

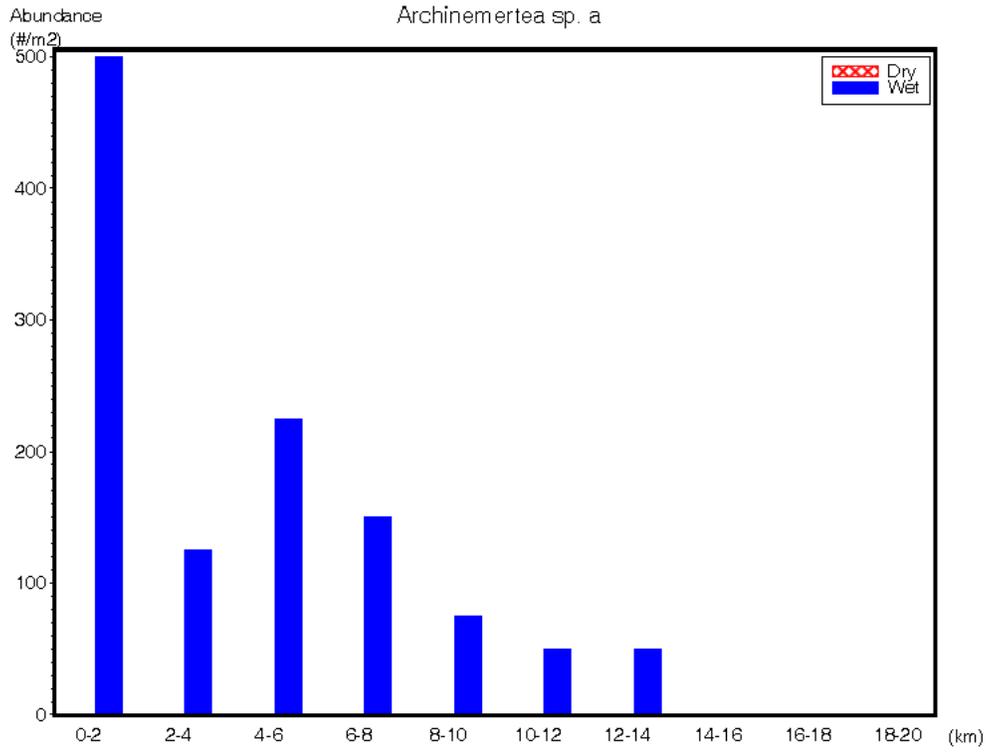
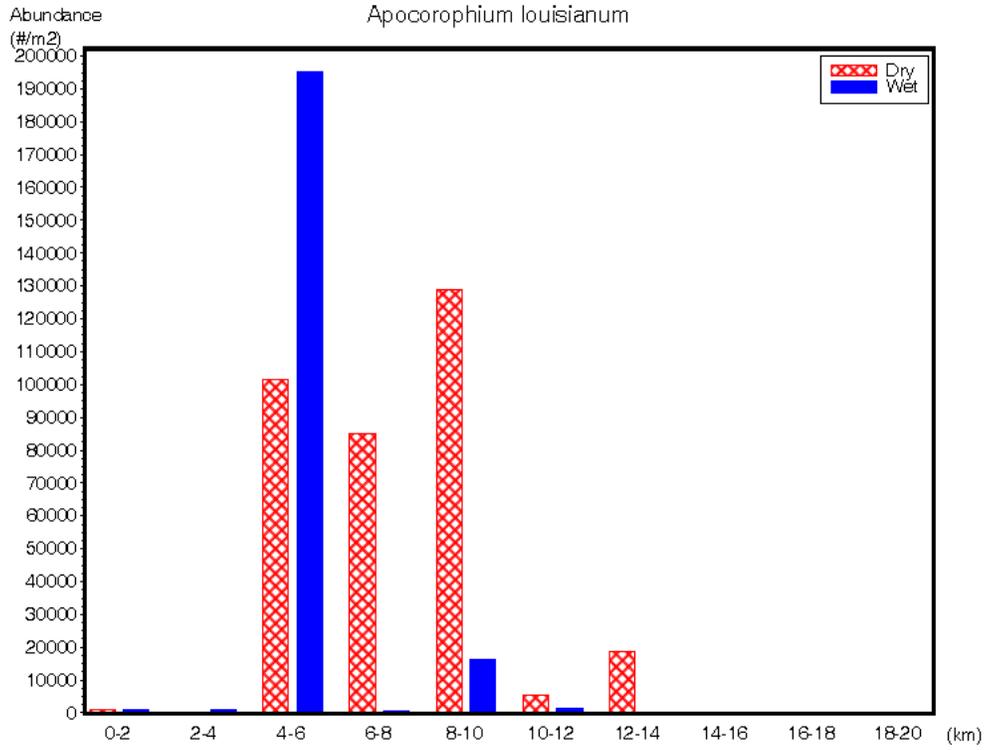
**APPENDIX B: Longitudinal Distribution, by Season, of Taxa Occurring in  $\geq 5\%$  of Benthic Samples Collected in the Little Manatee River, 1996-2005**

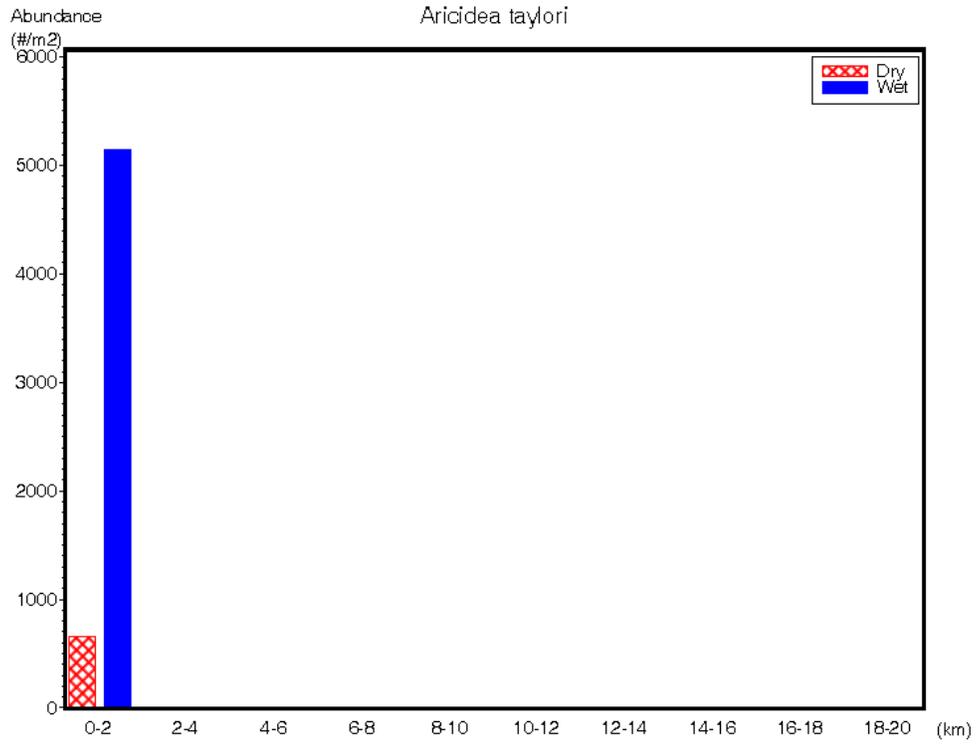
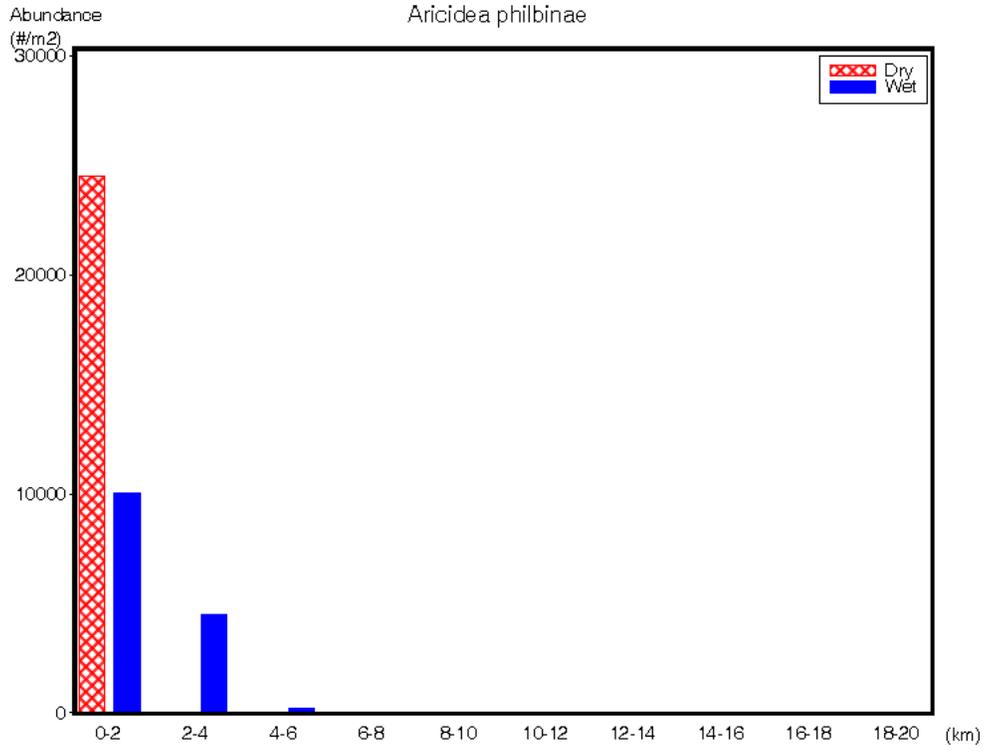


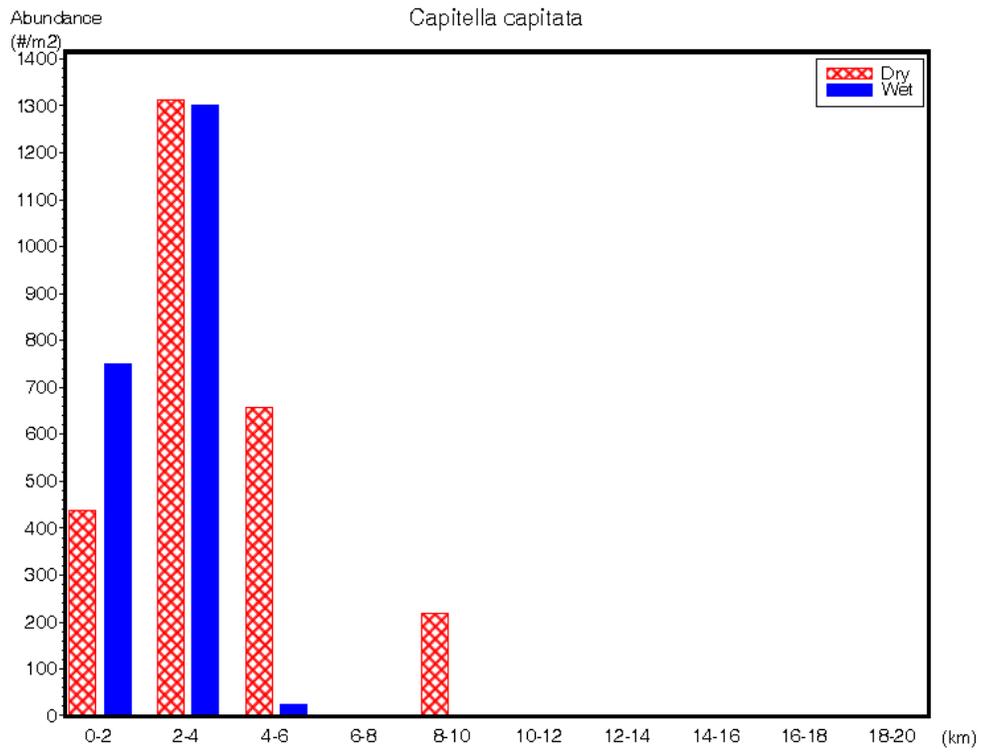
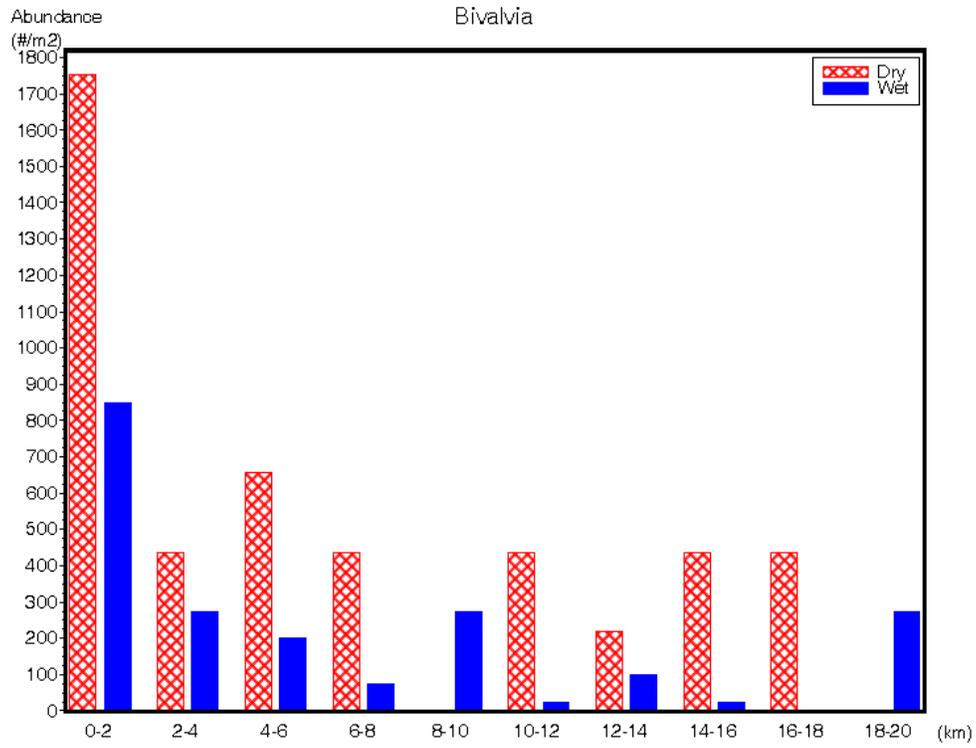


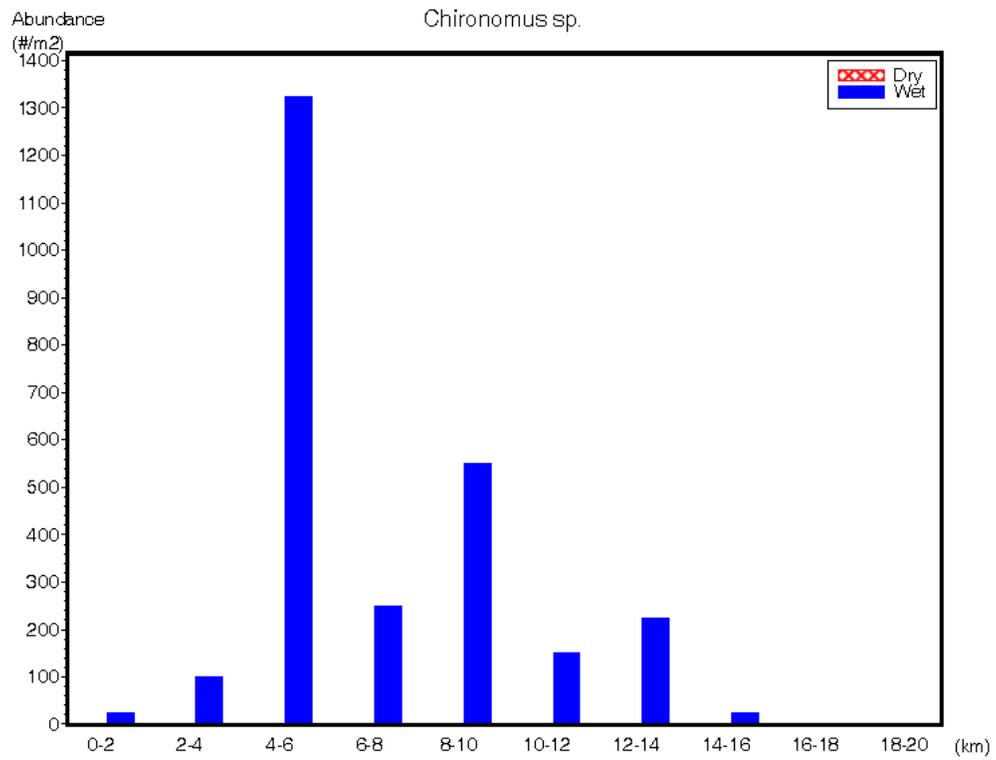
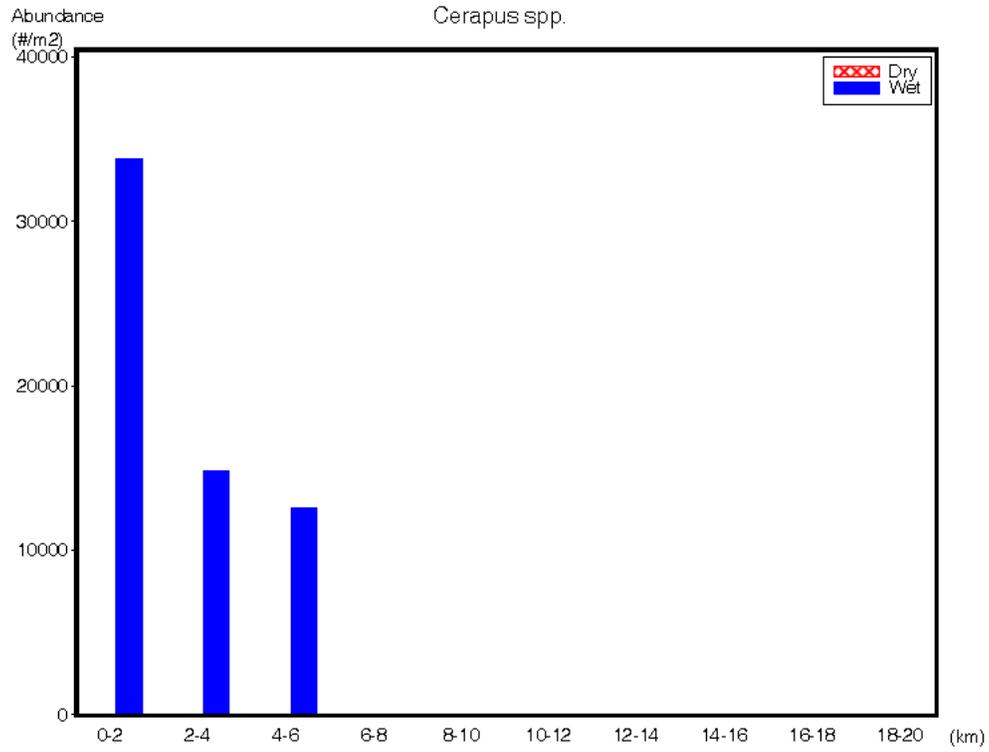


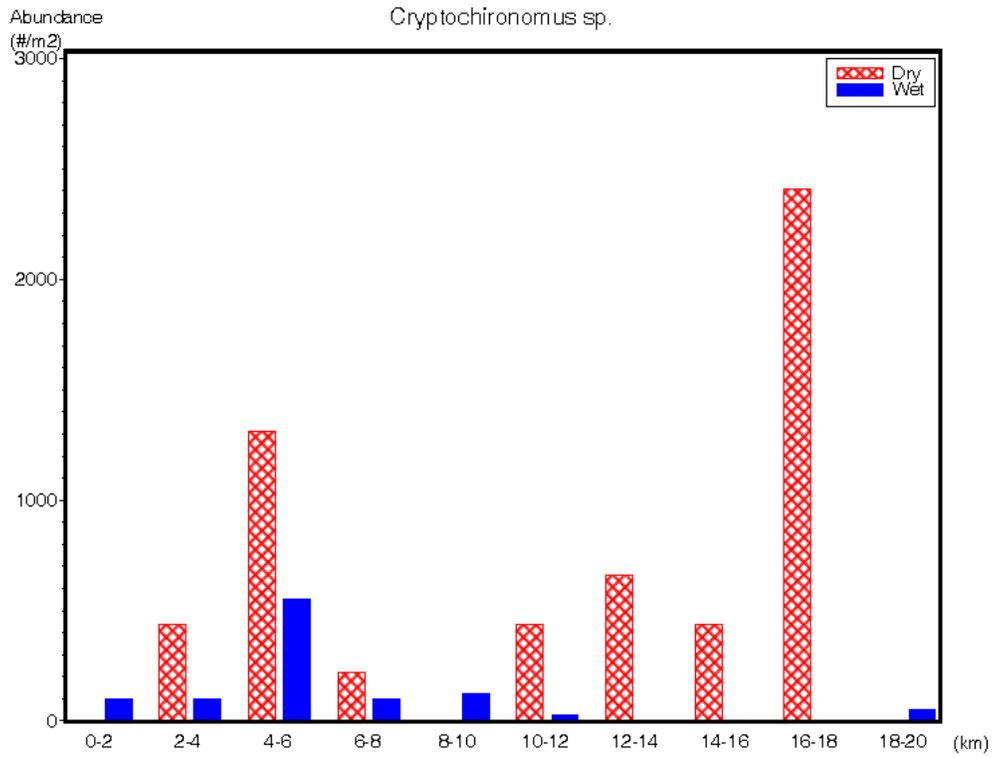
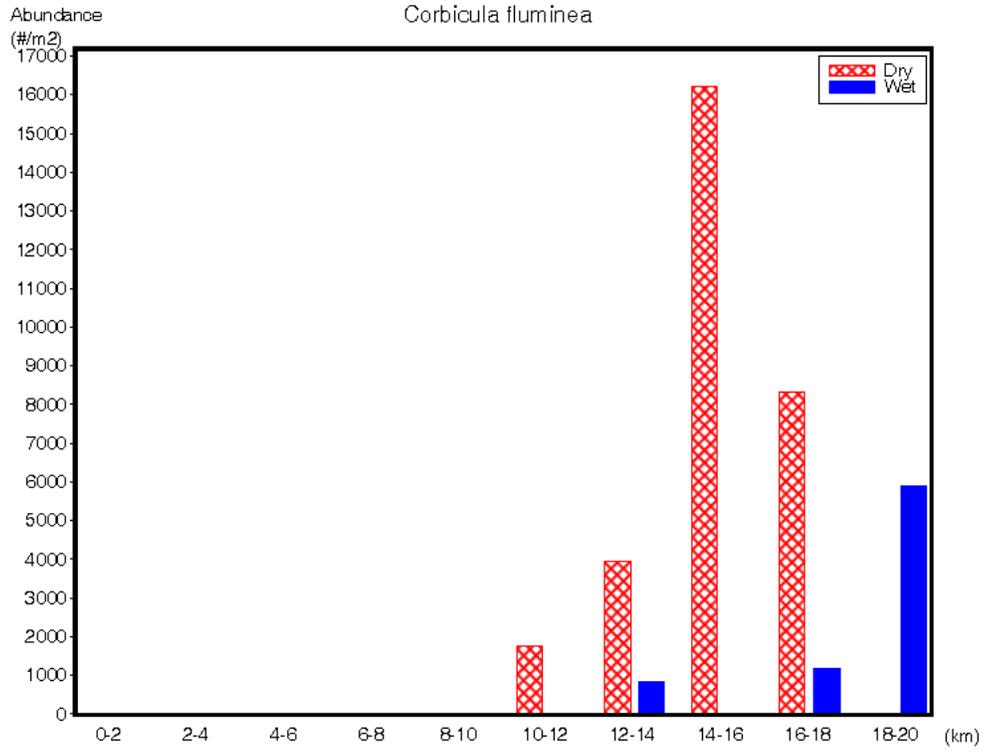


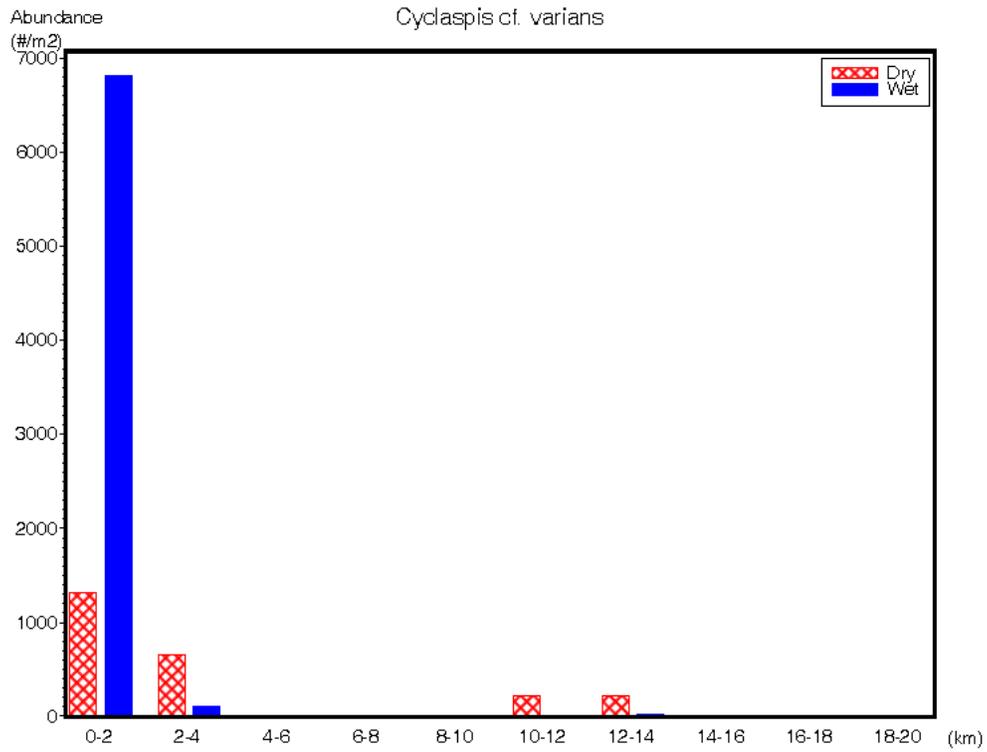
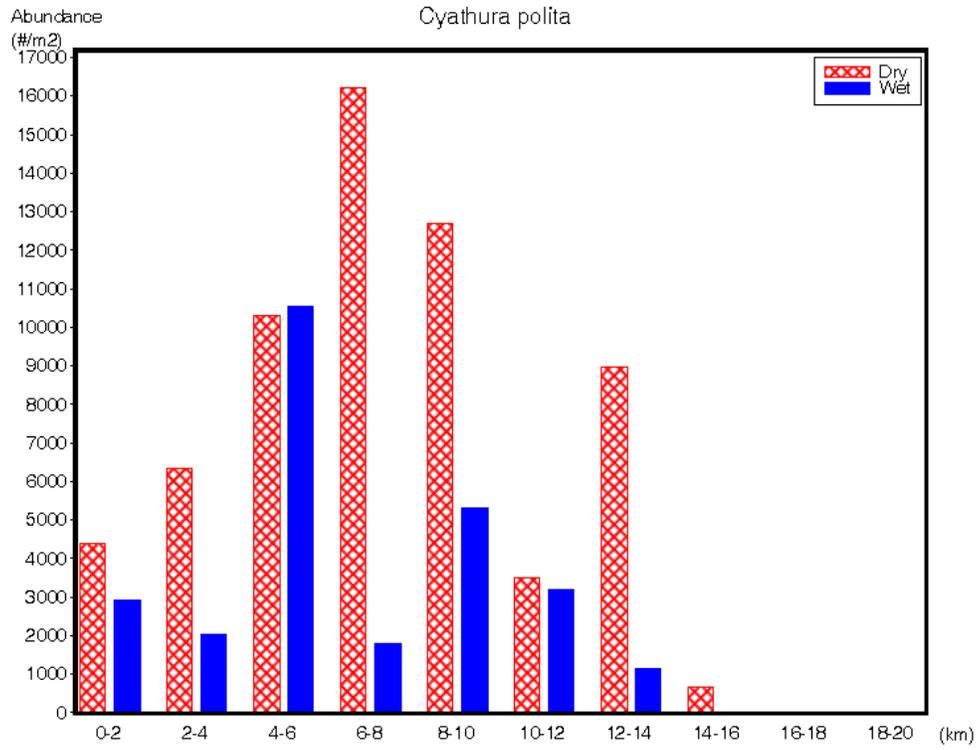


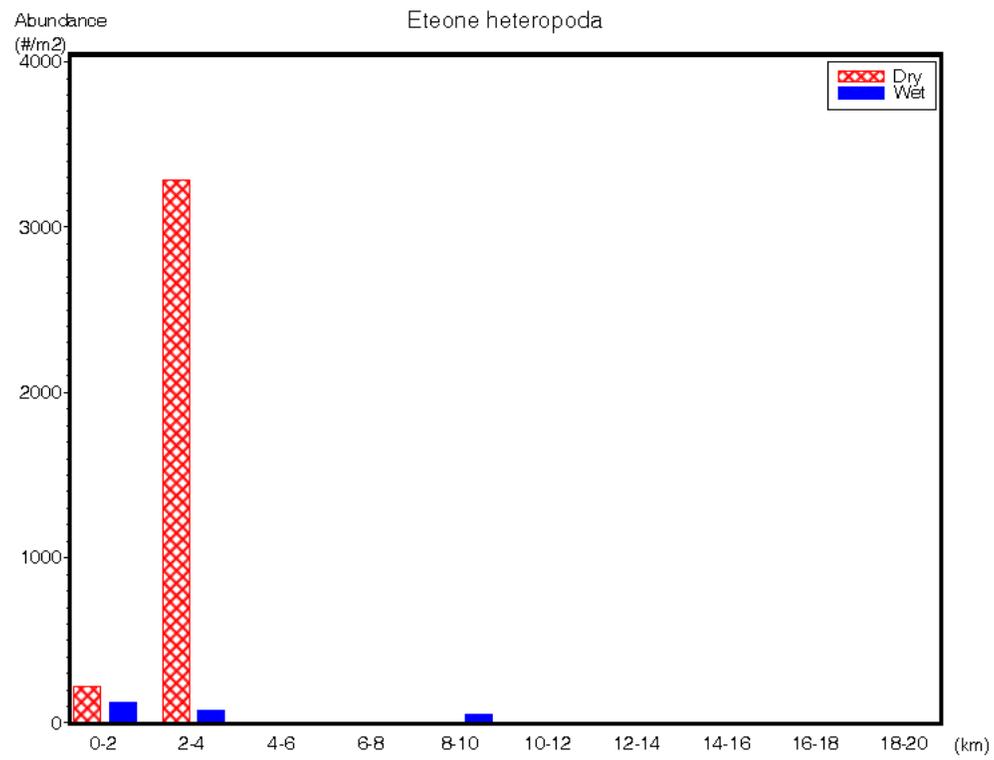
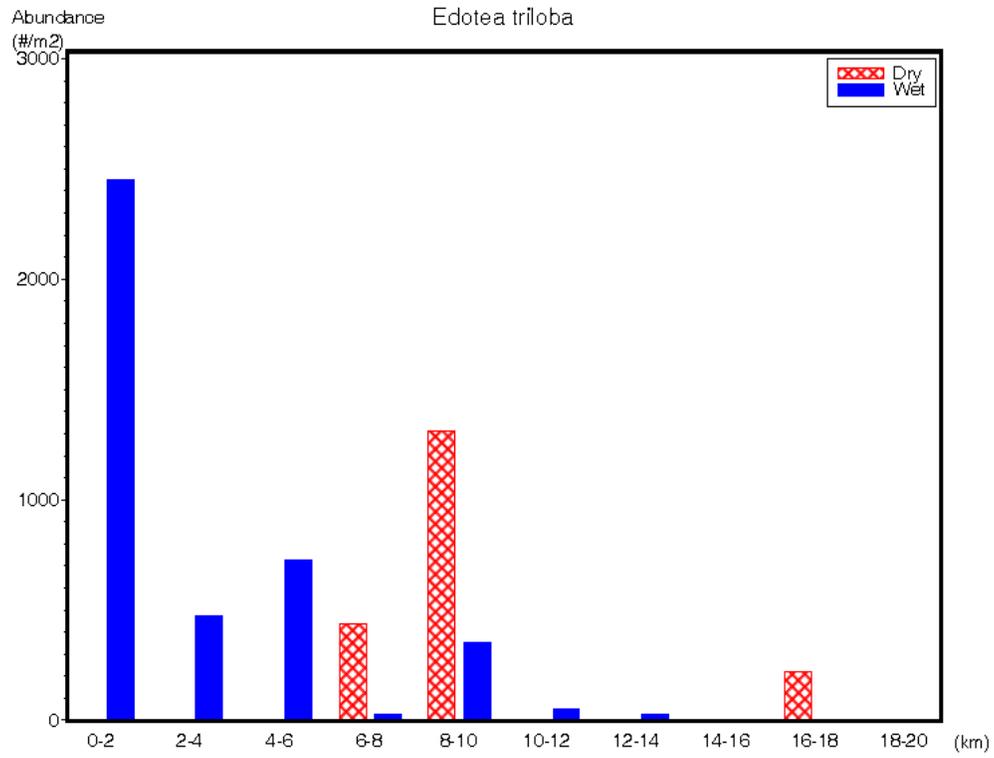


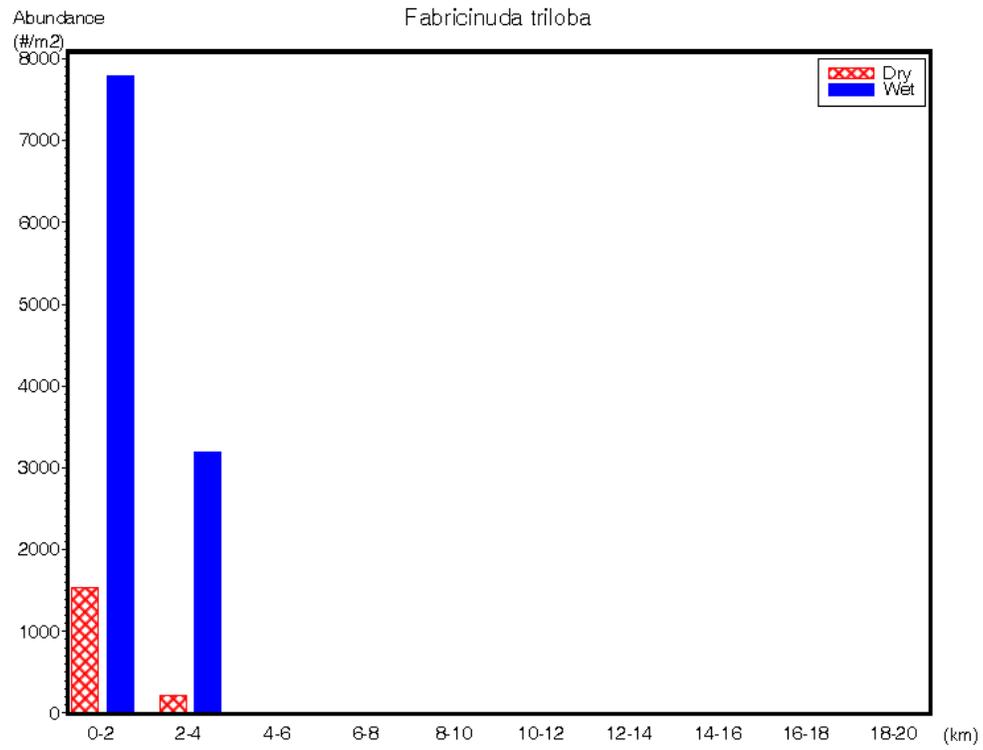
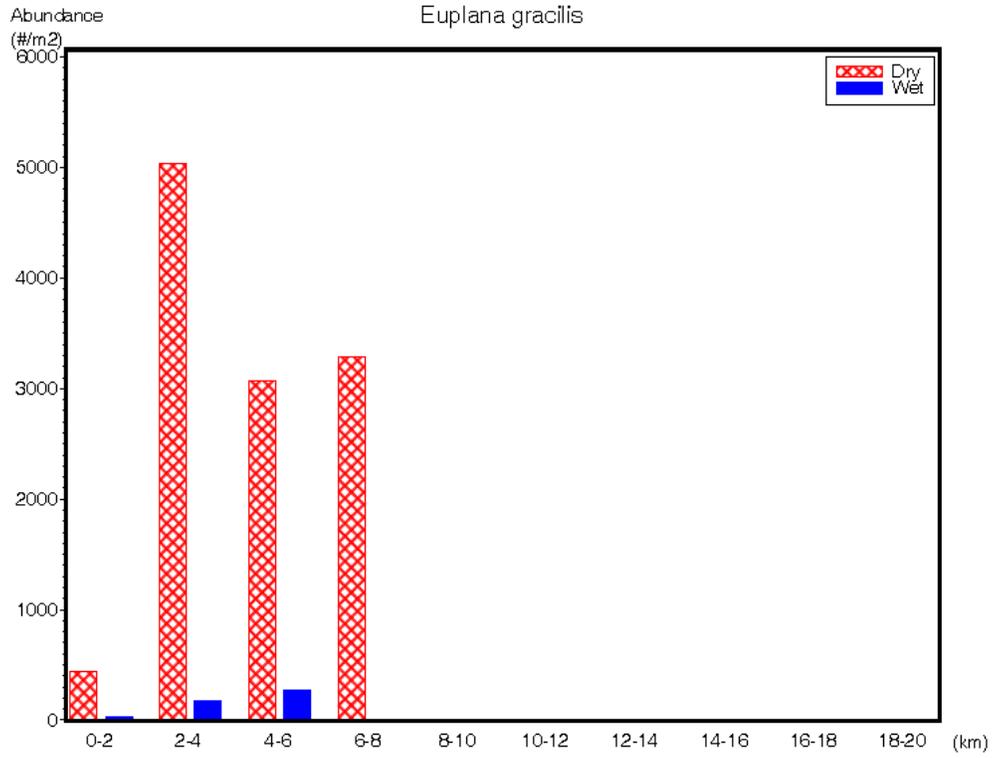


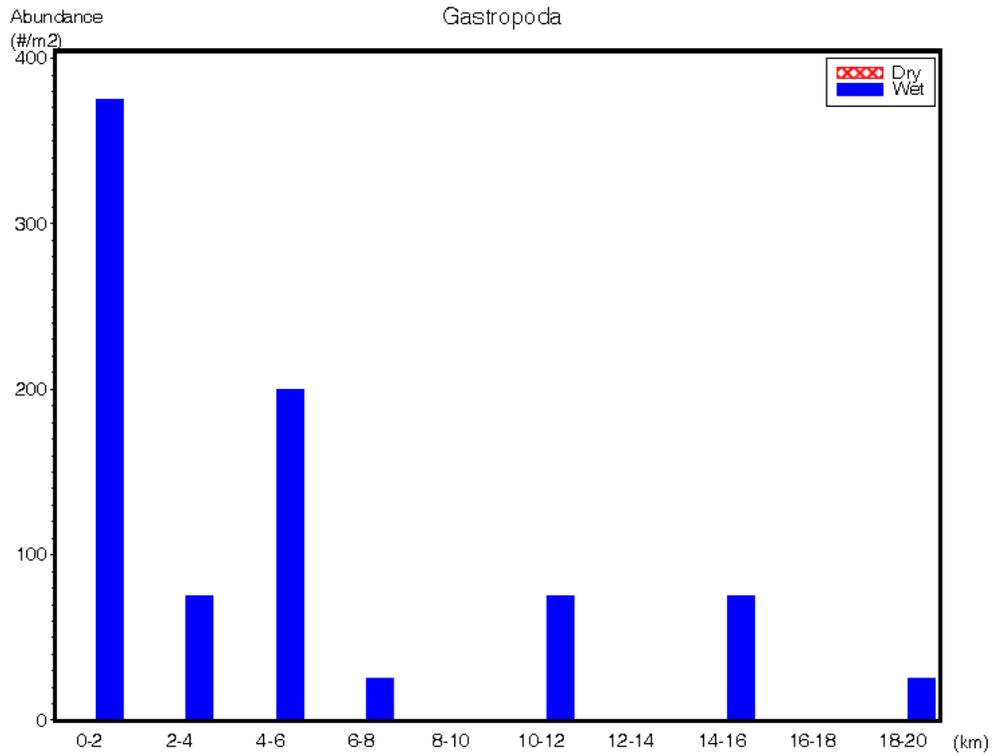
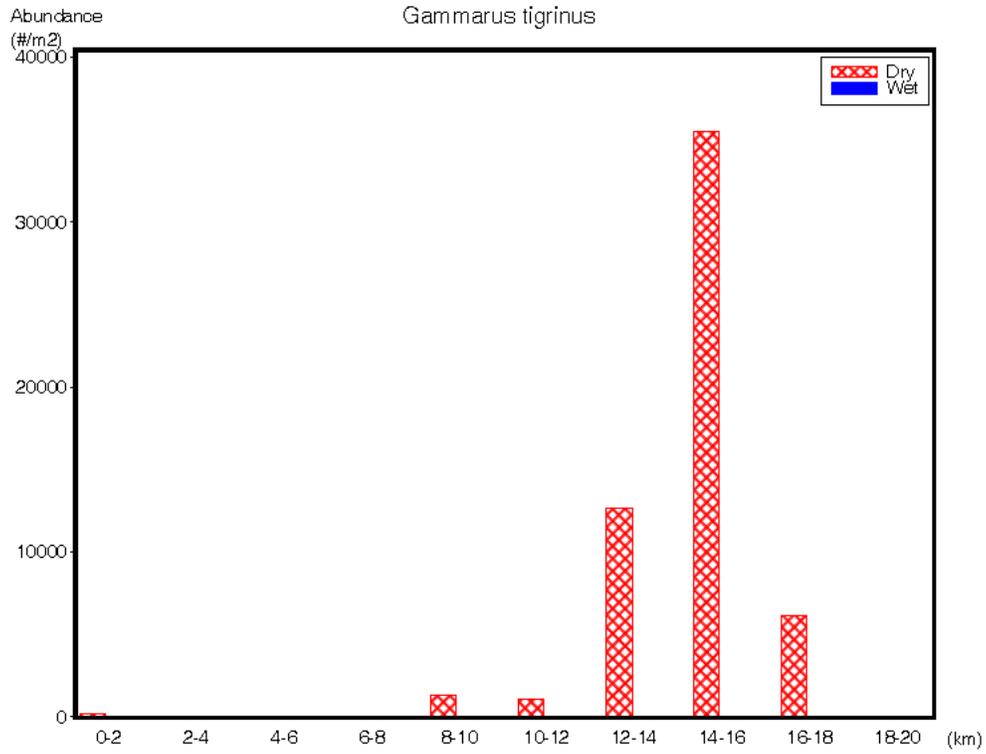


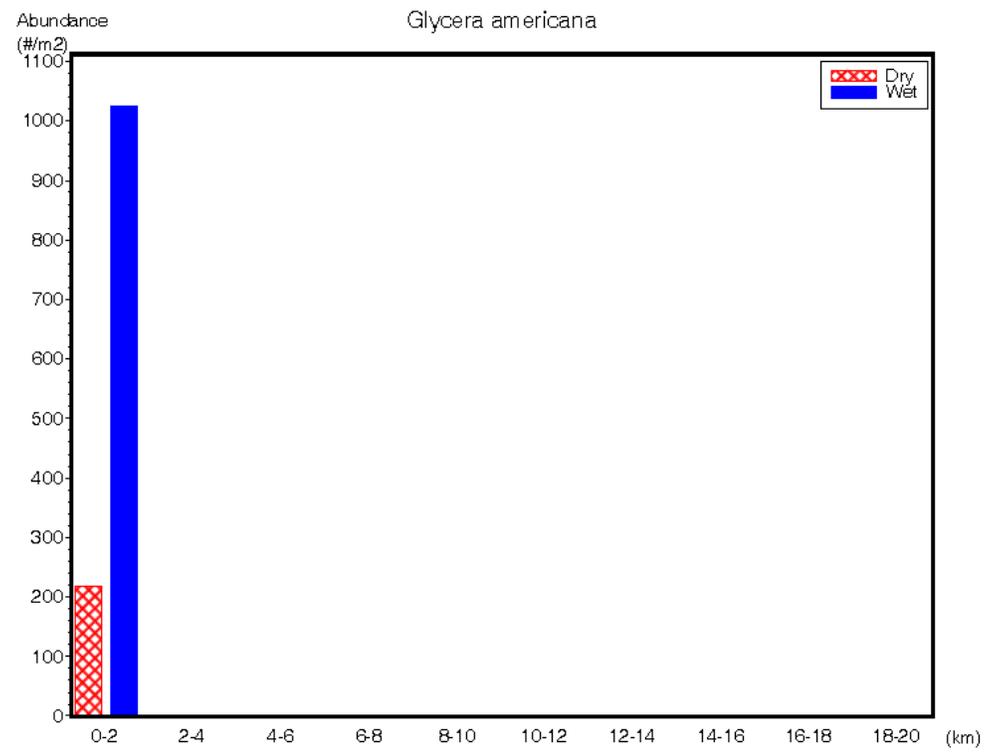
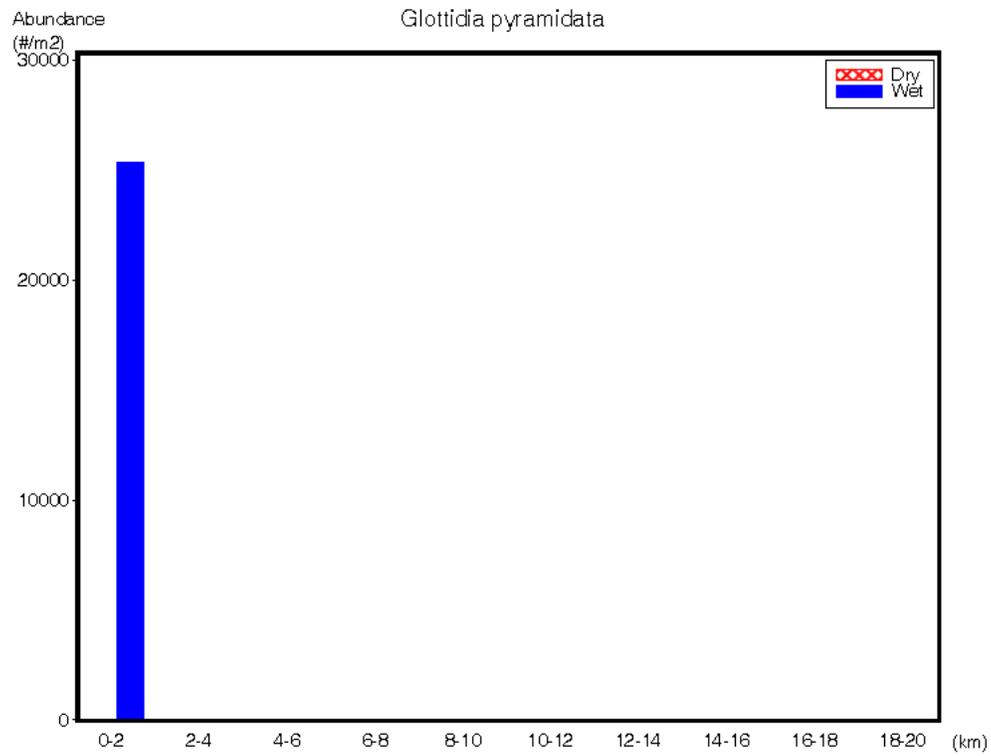


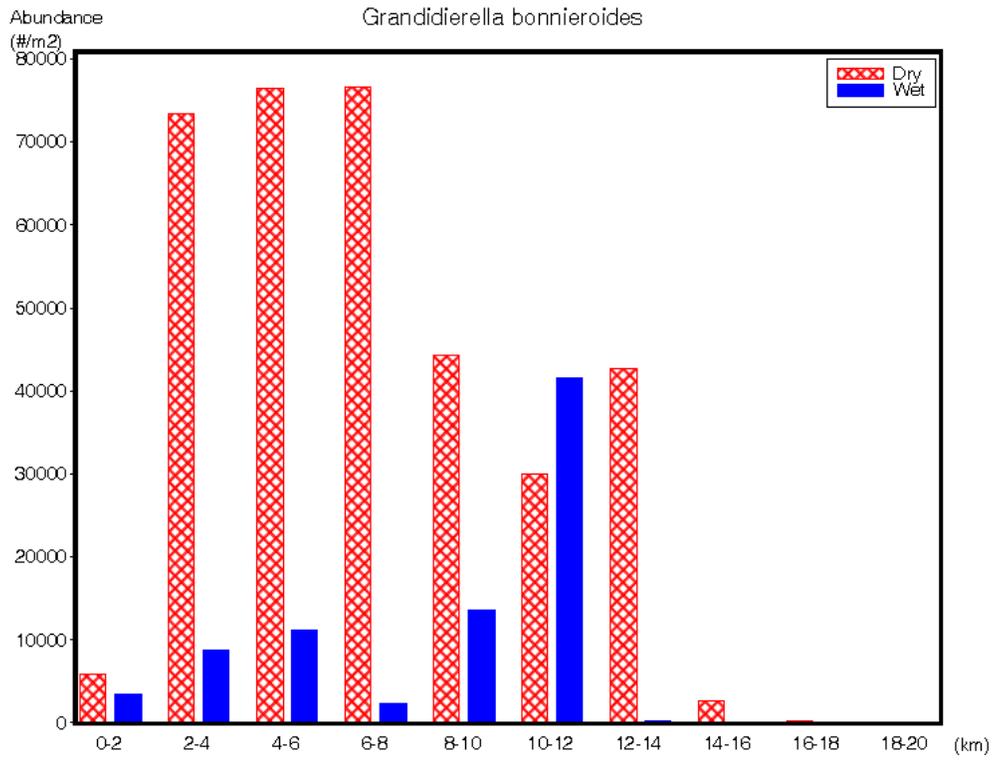
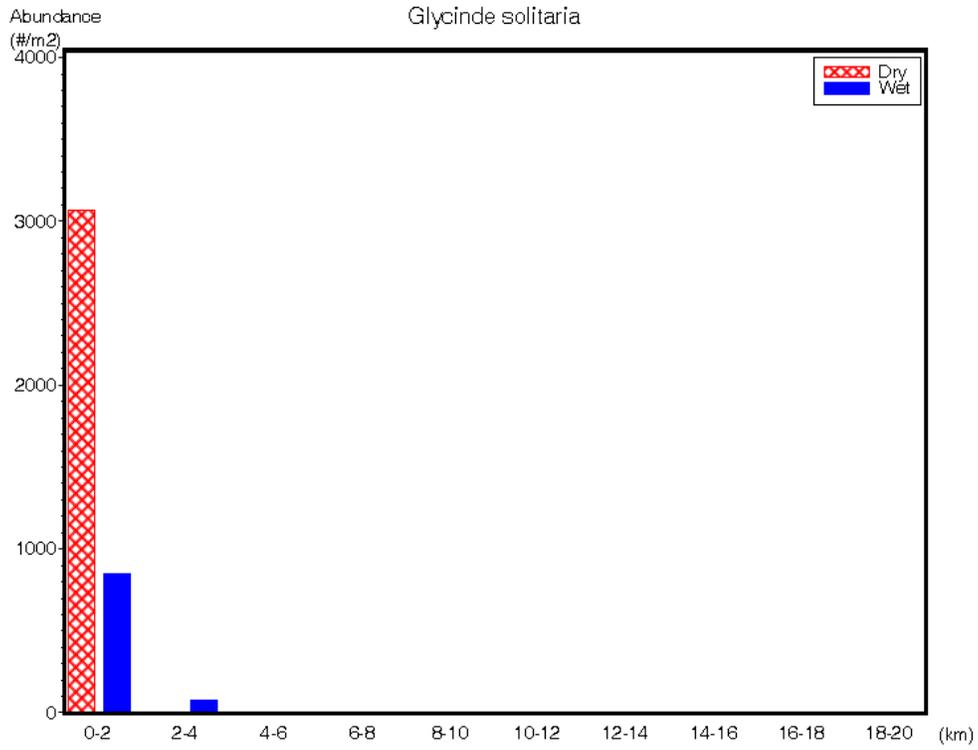


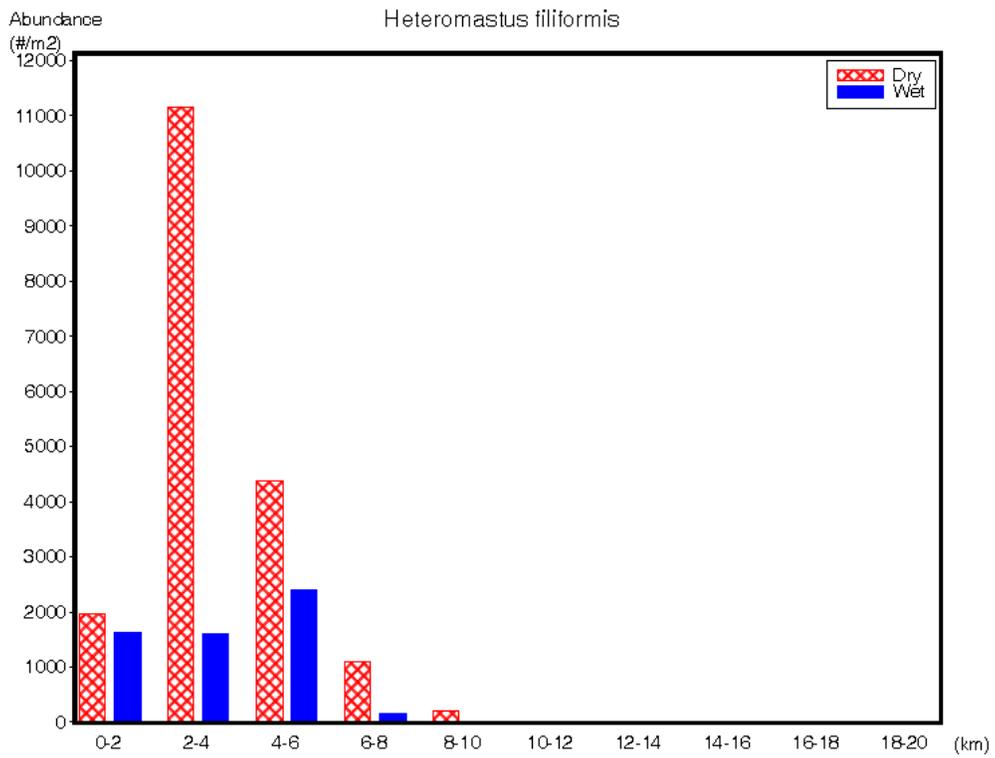
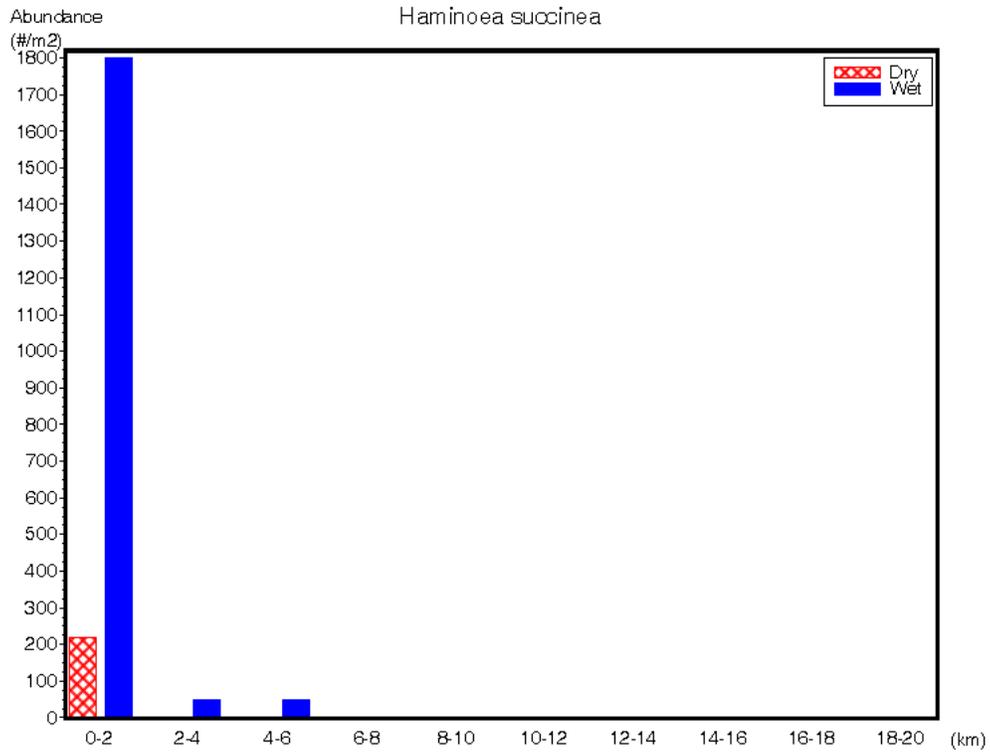


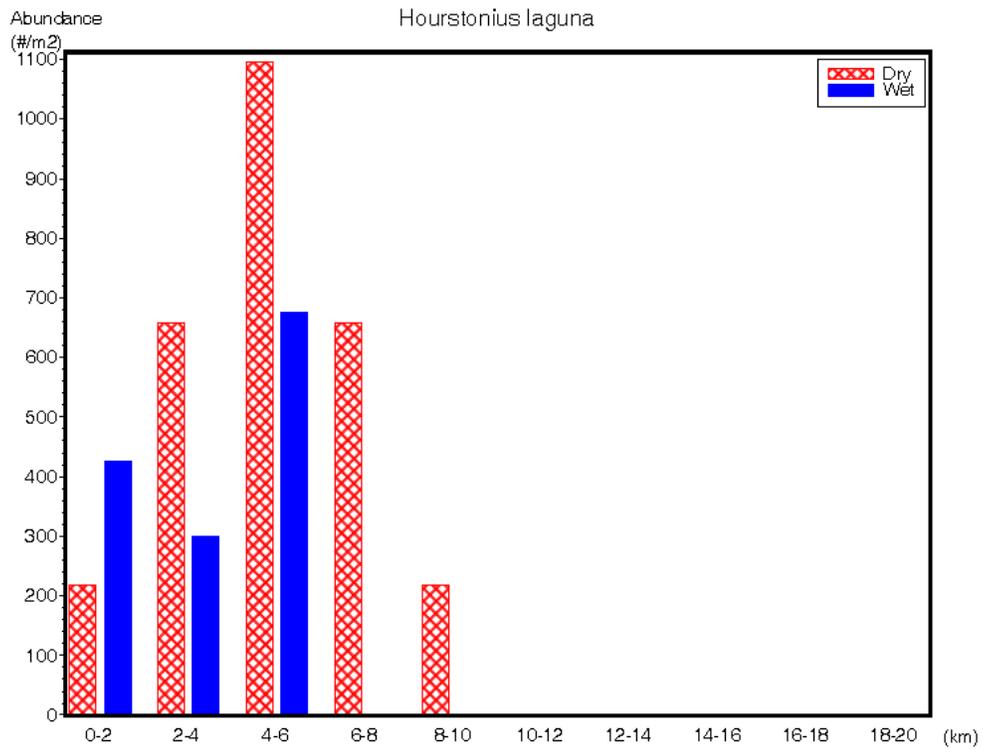
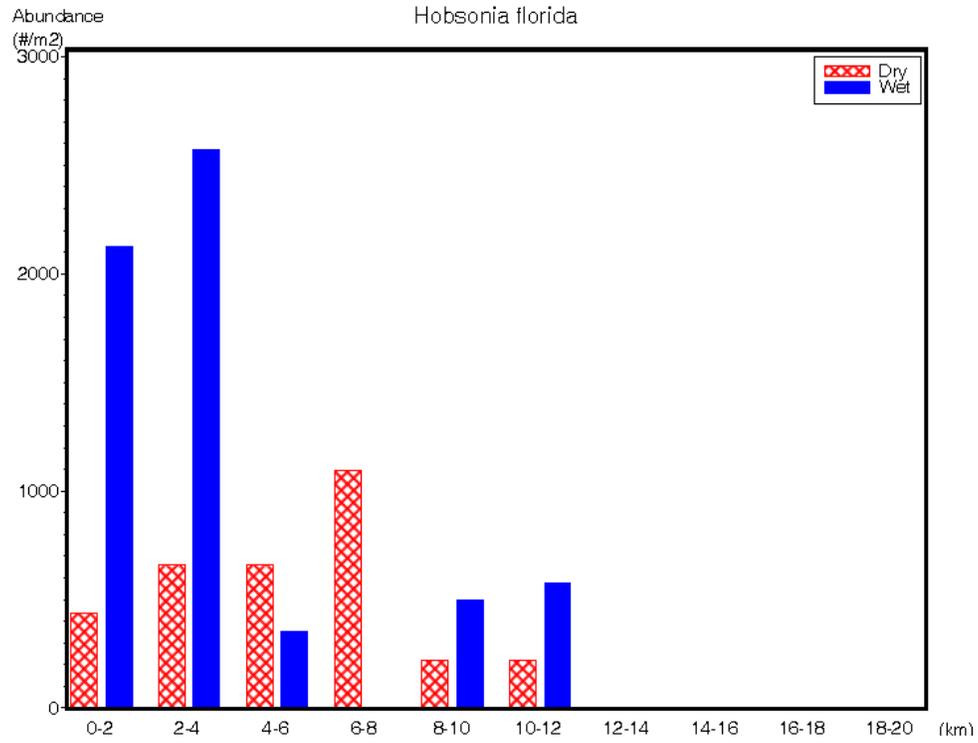


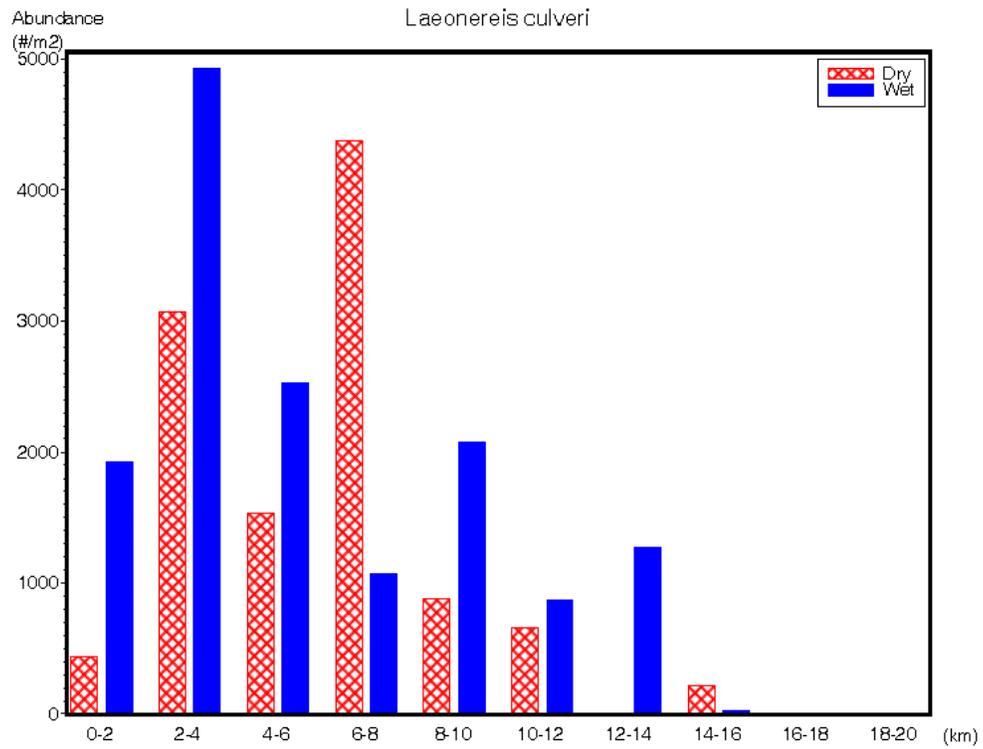
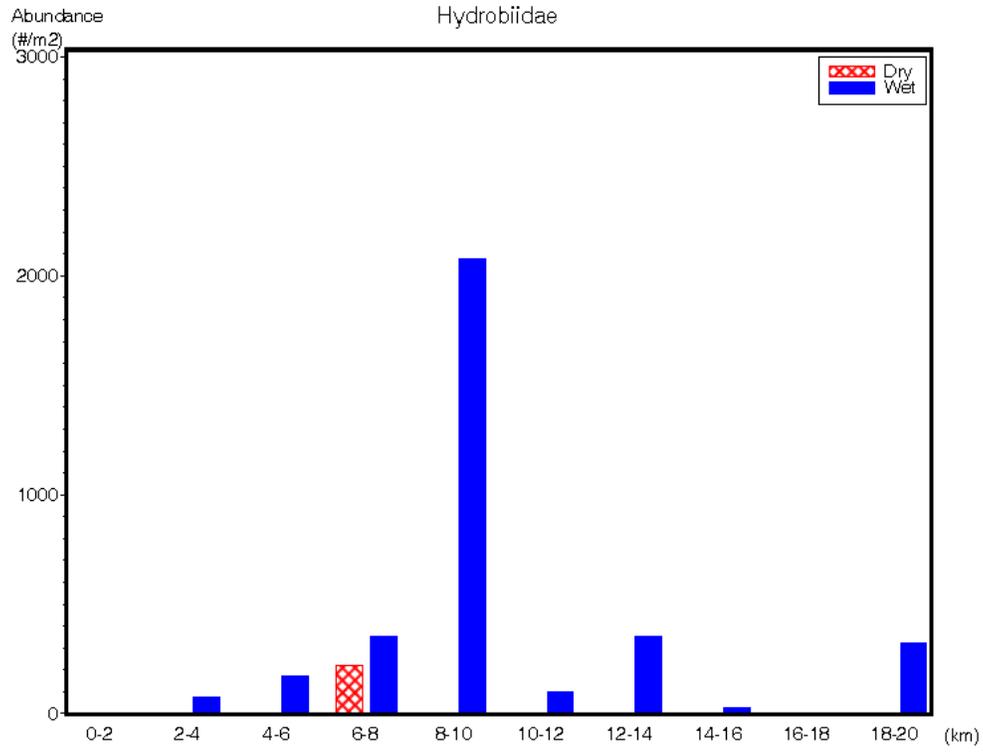


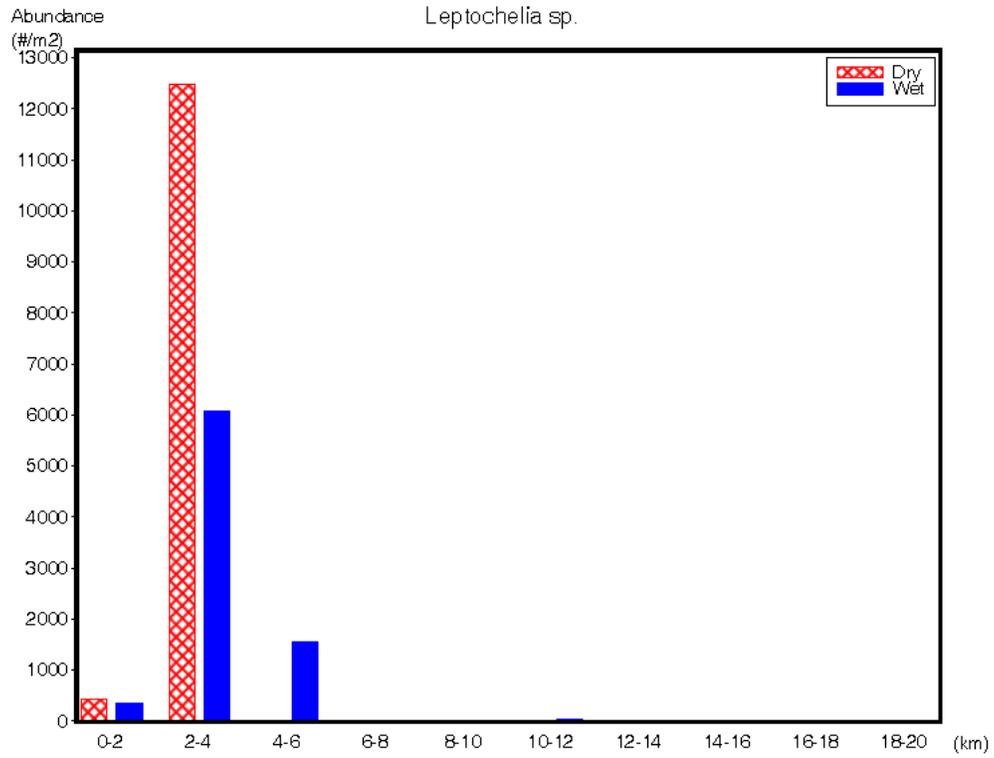
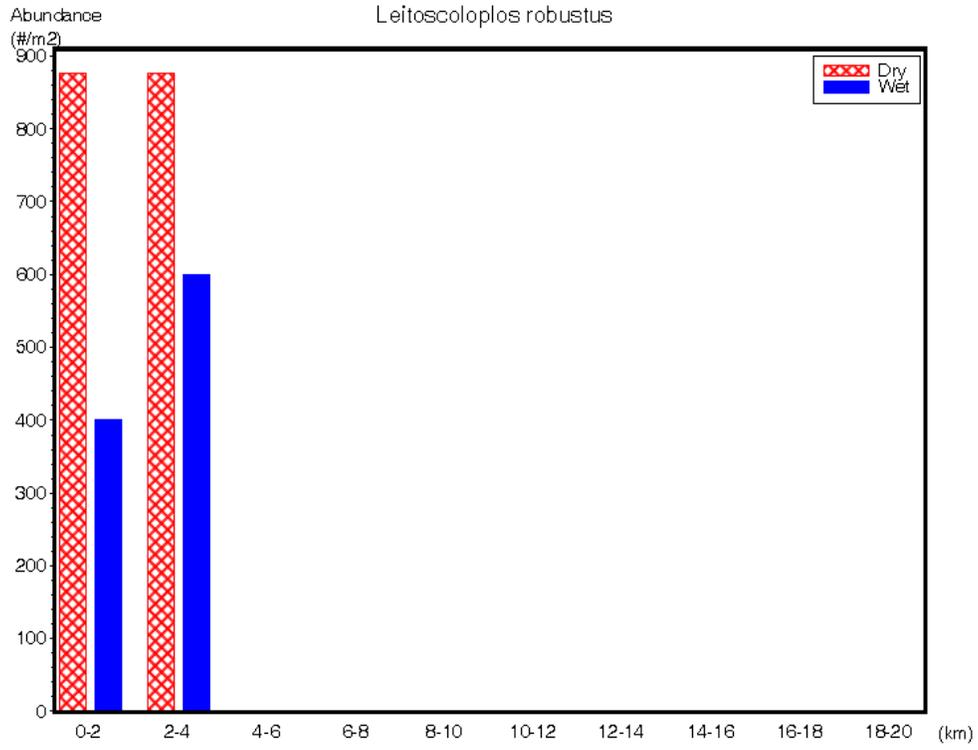


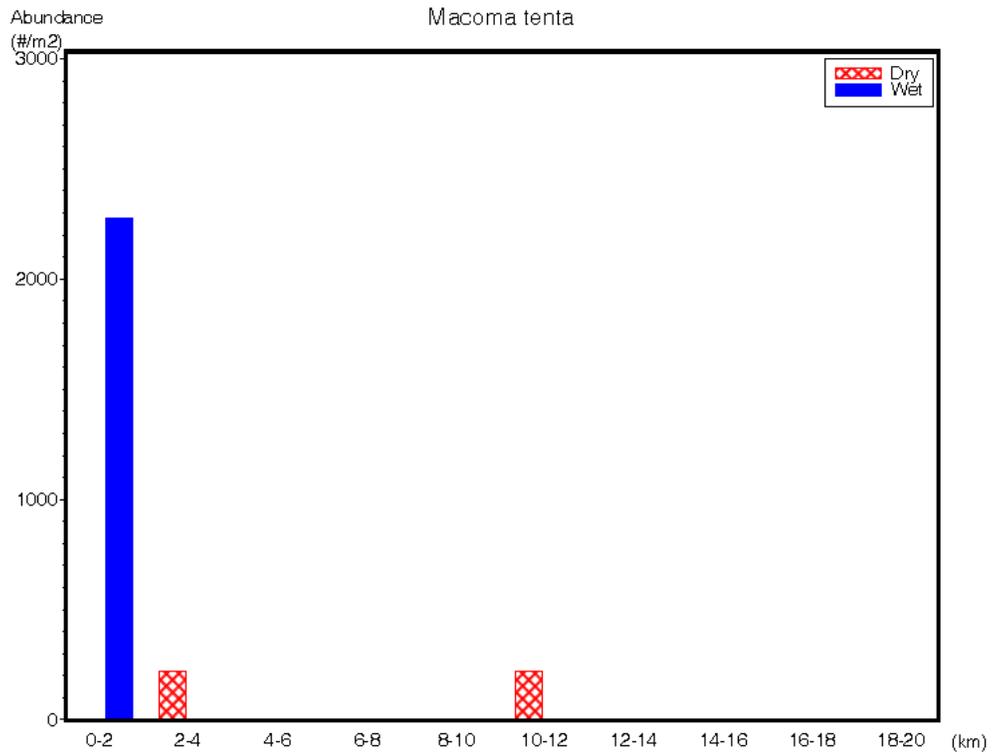
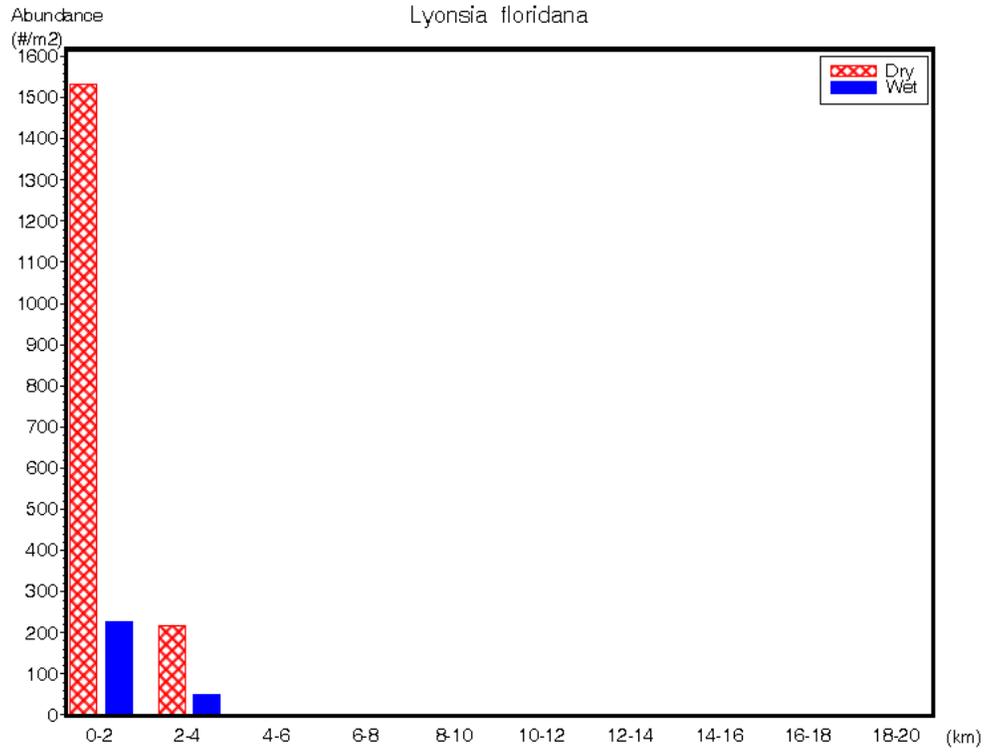


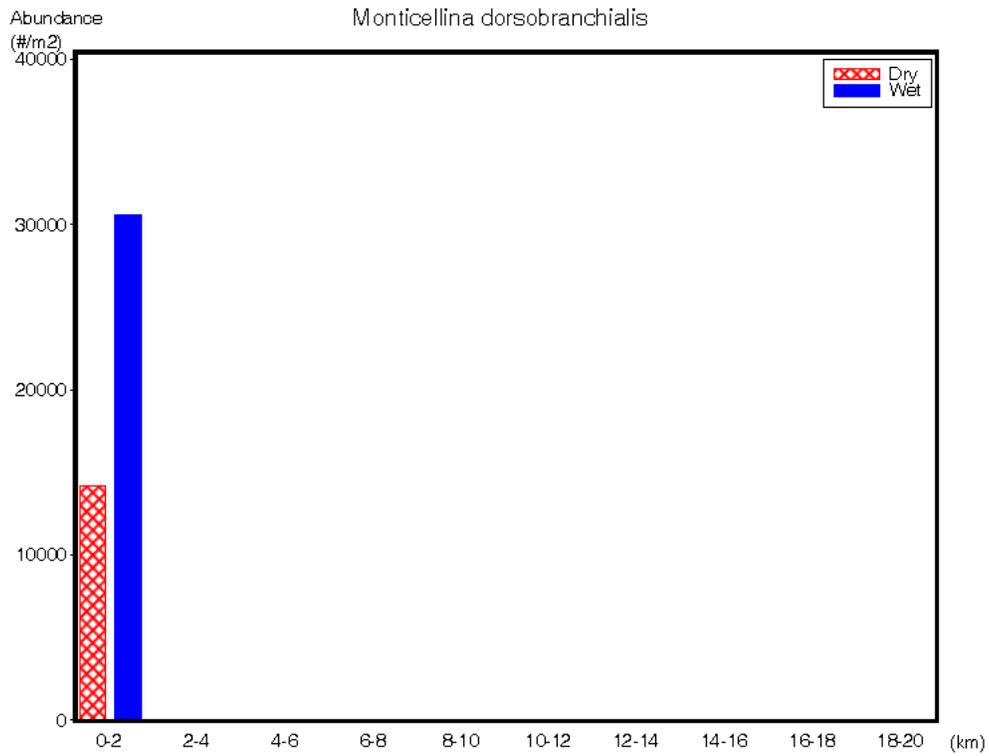
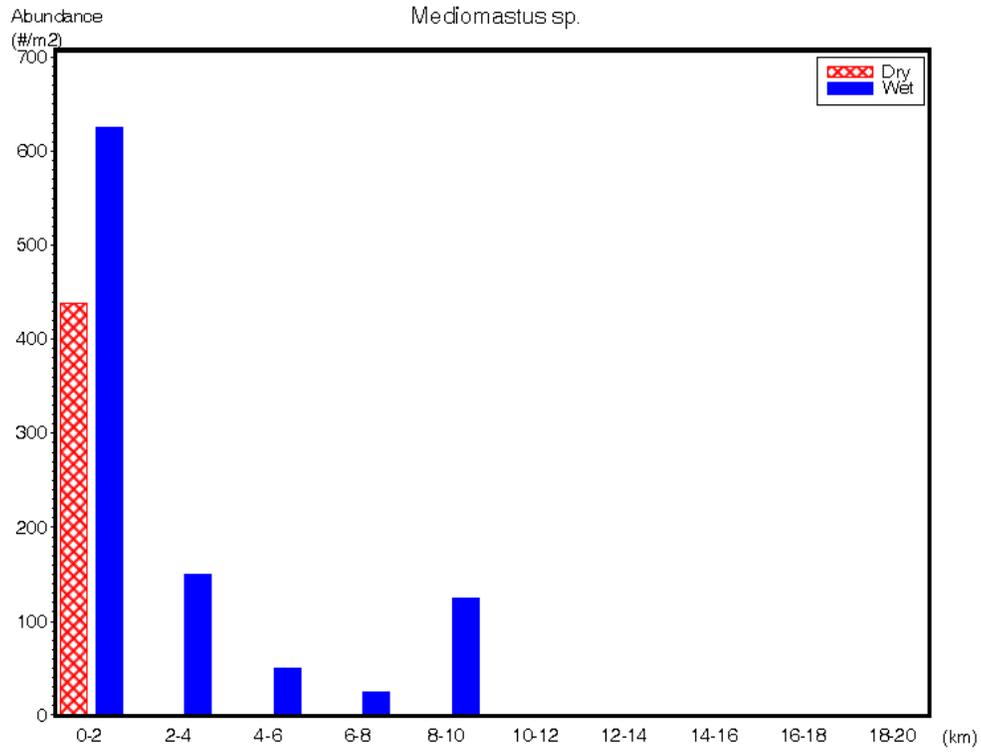


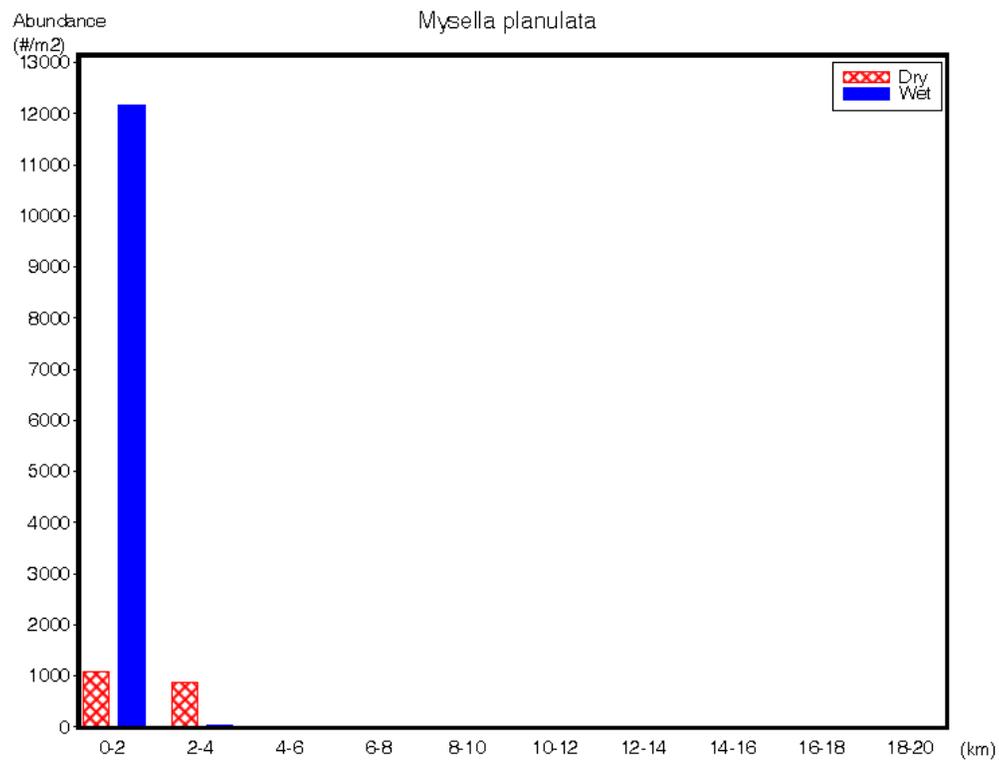
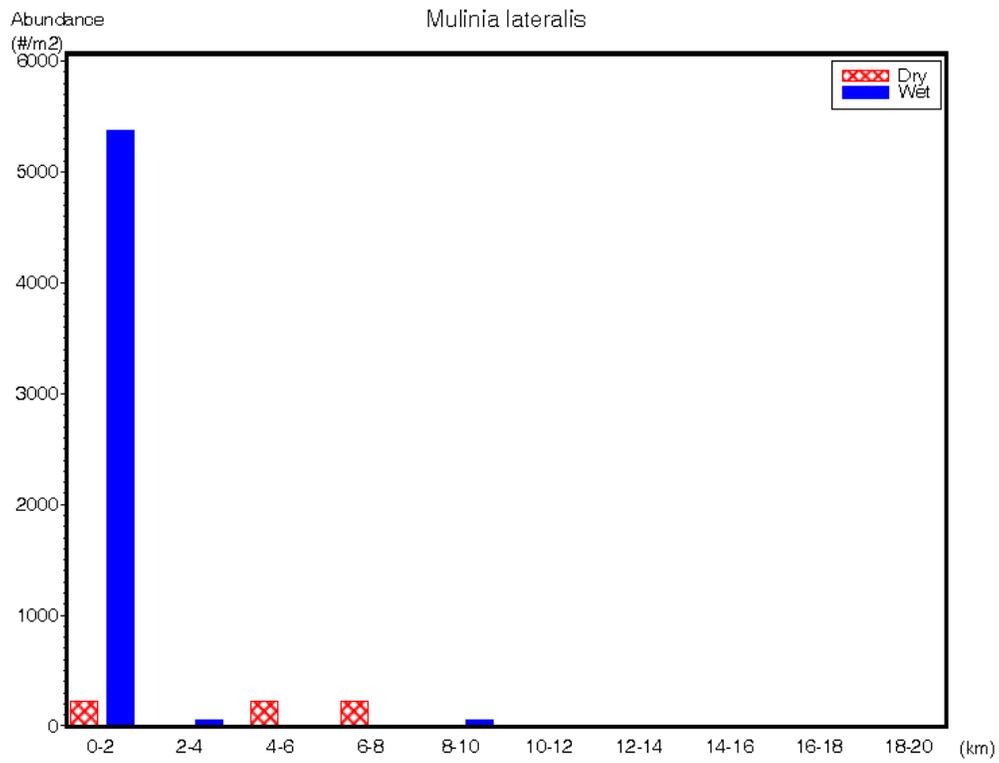


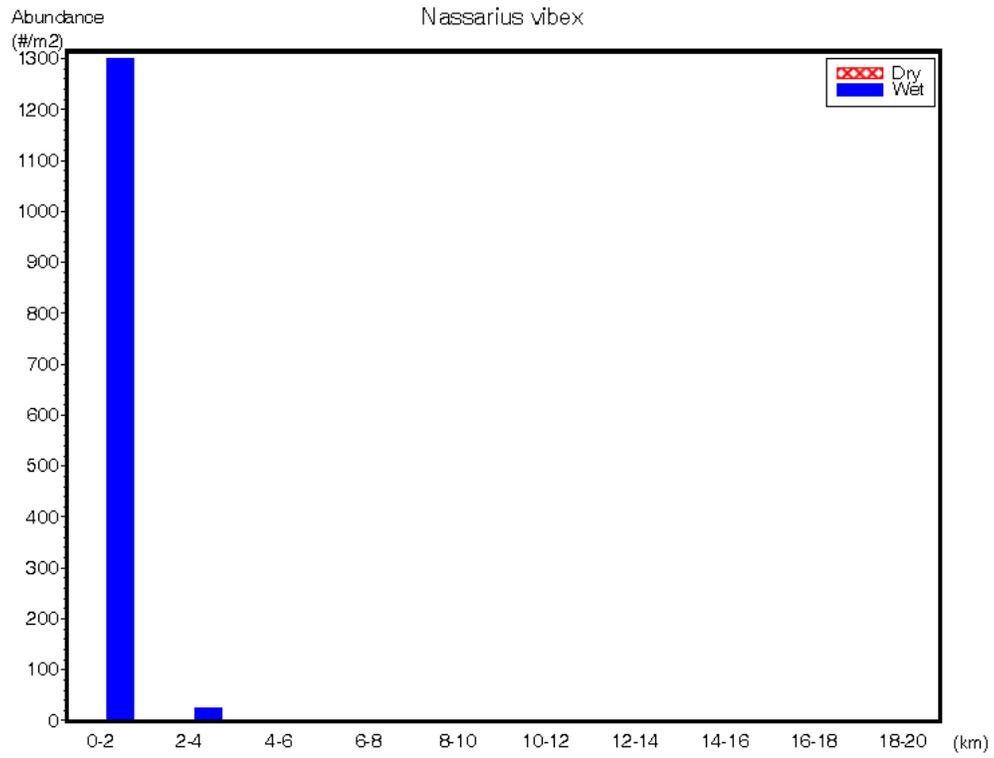
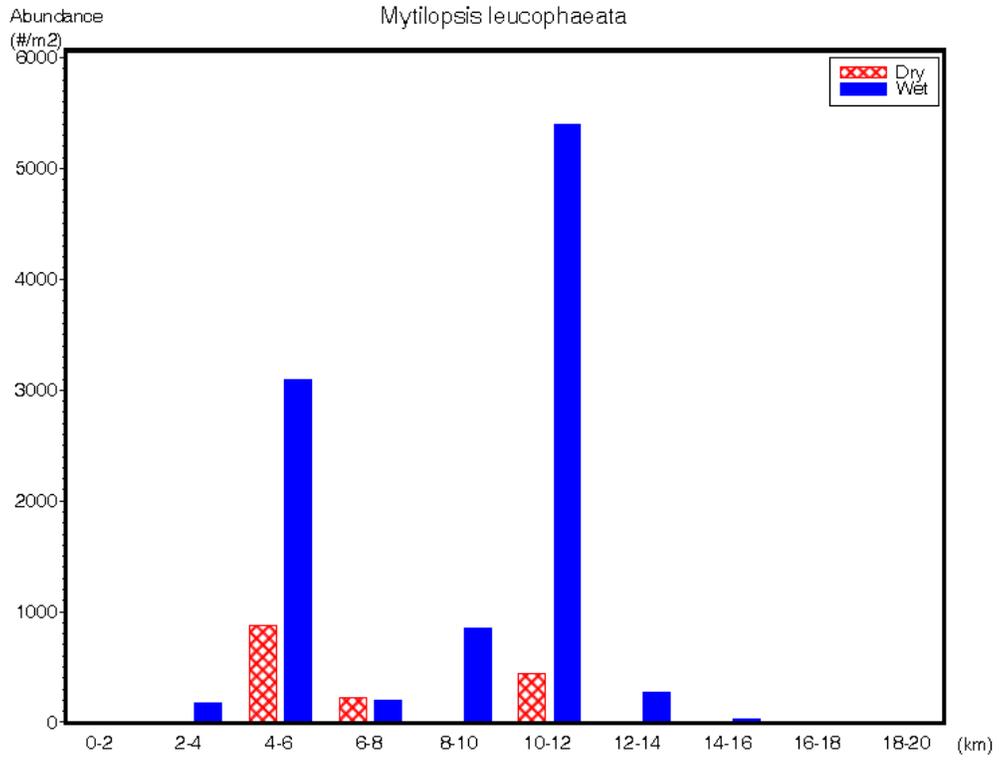


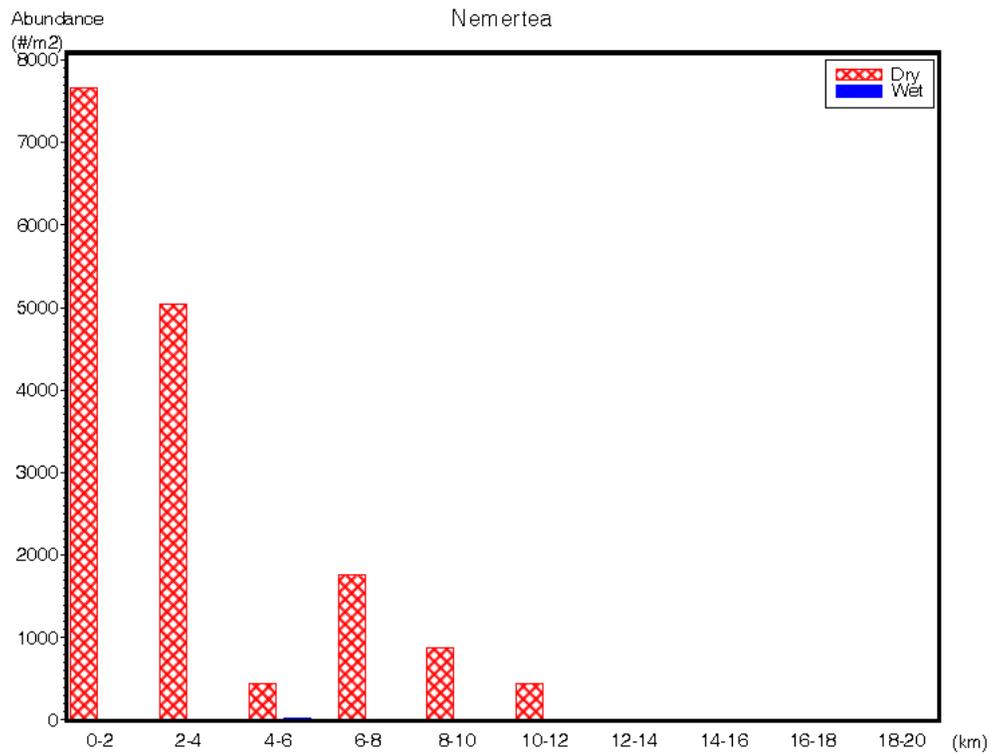
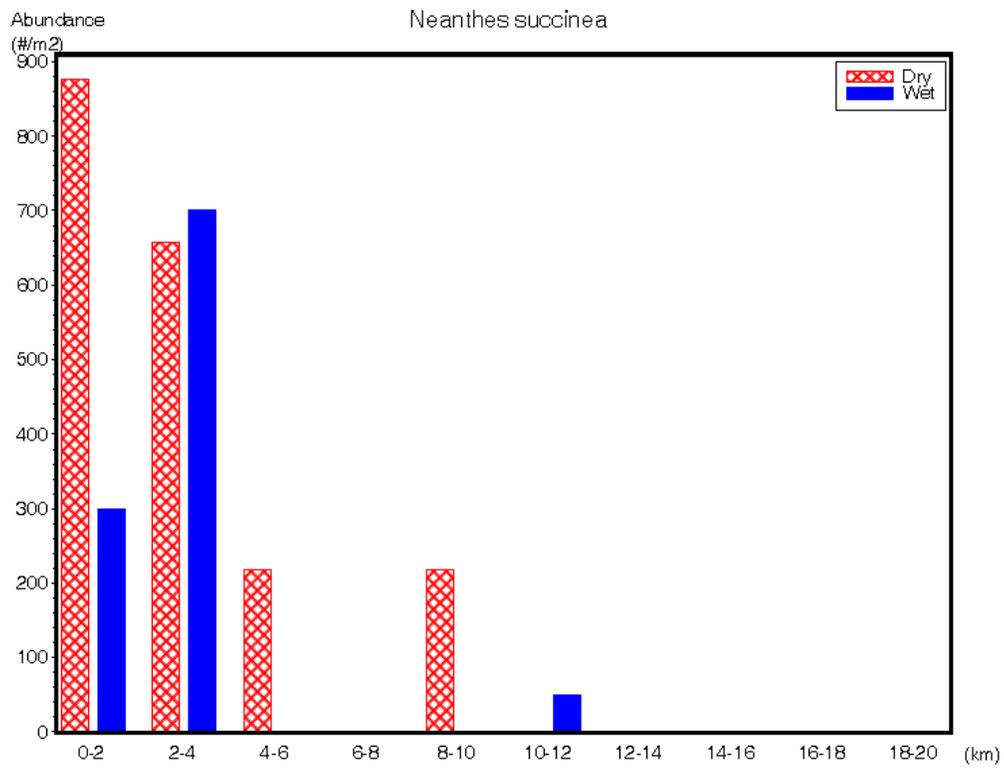


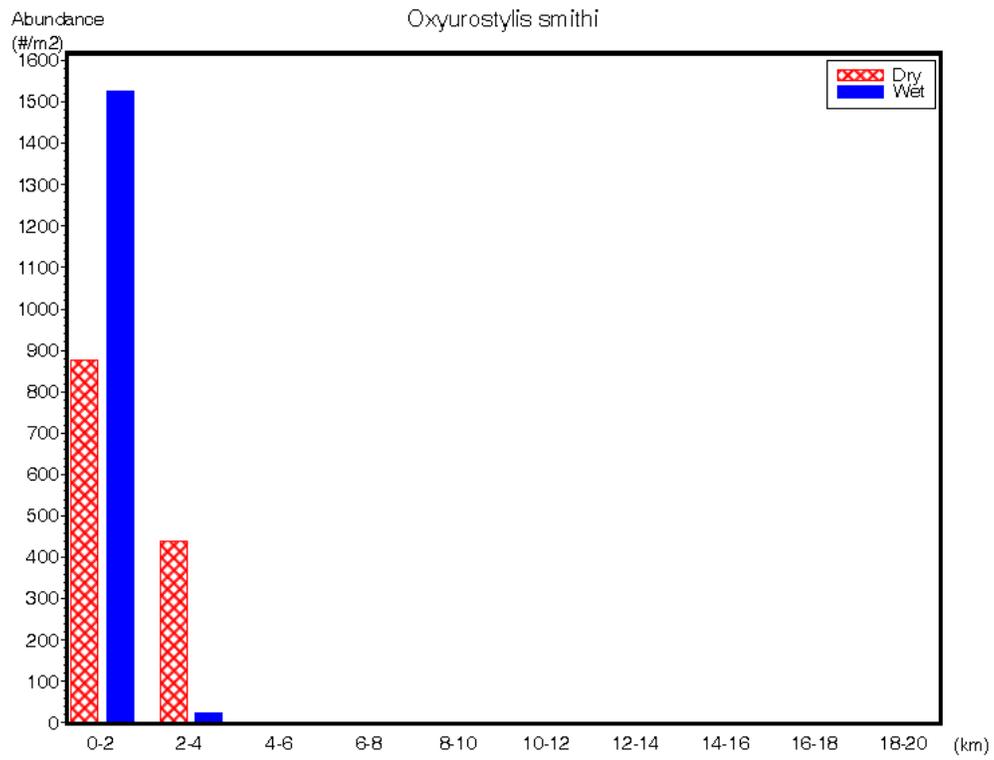
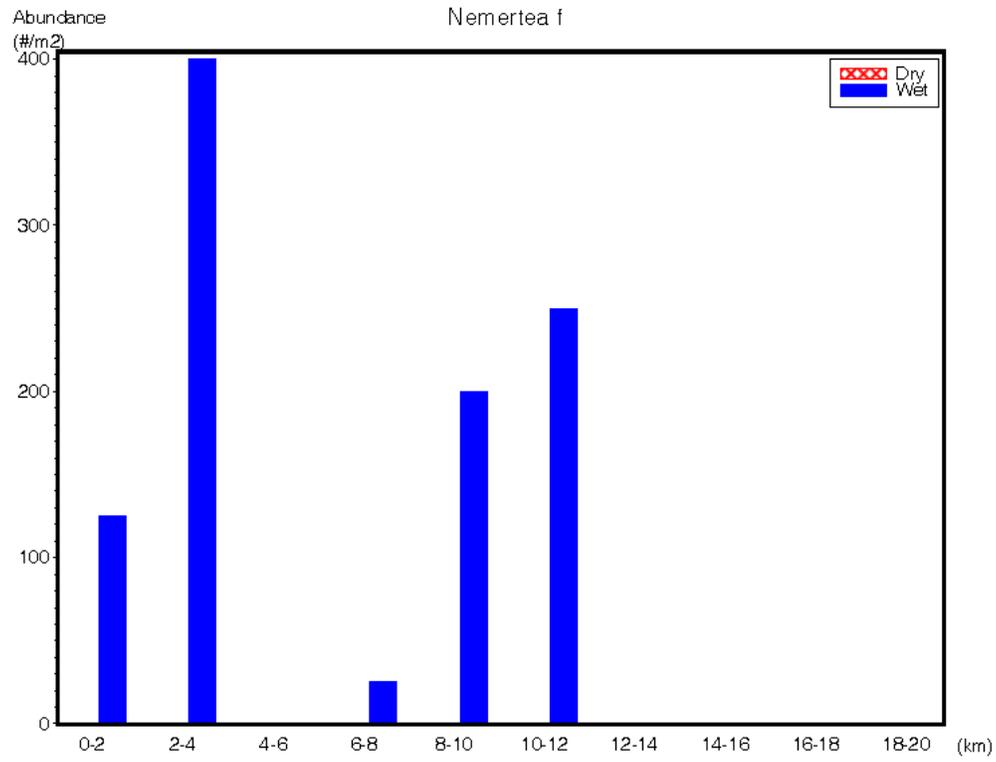


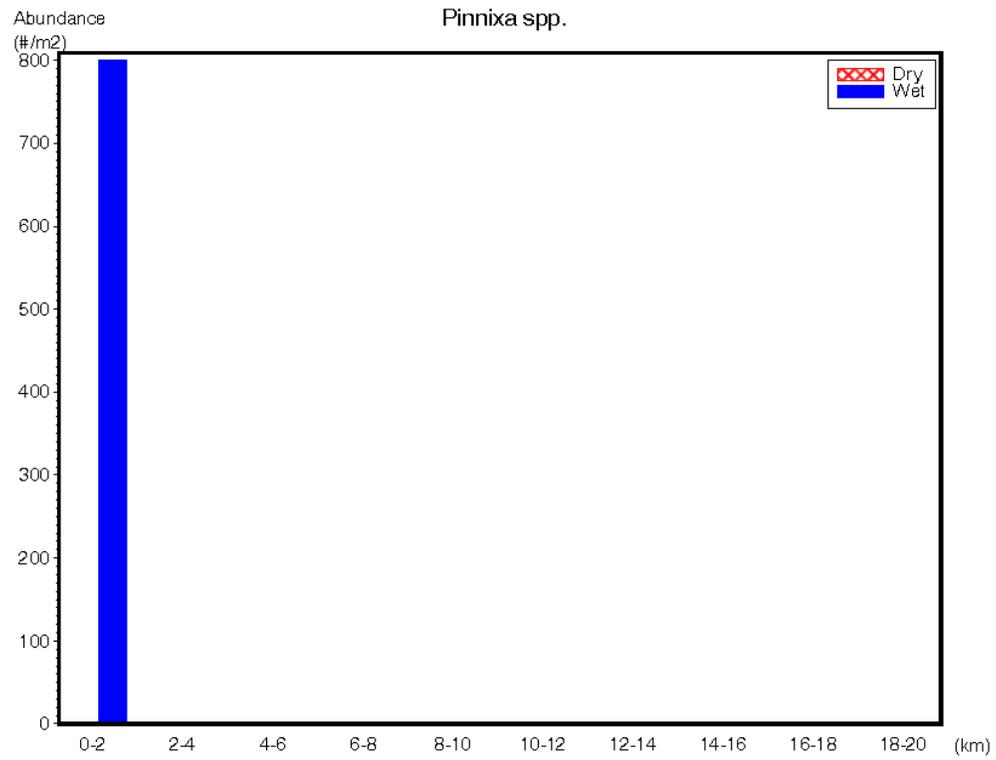
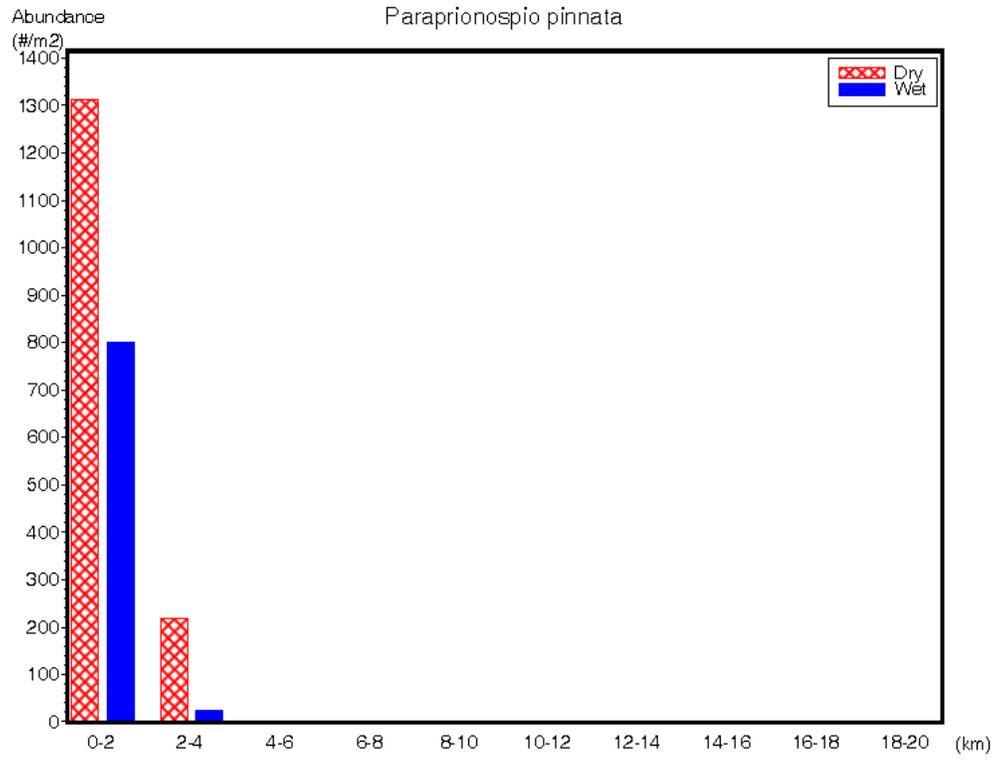


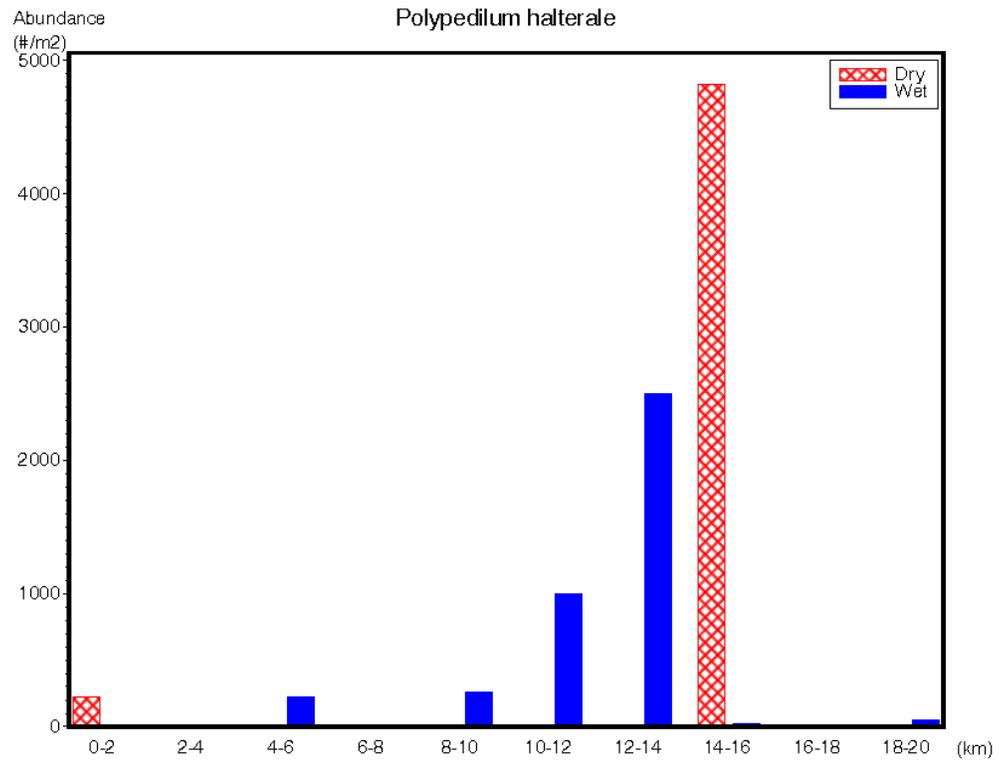
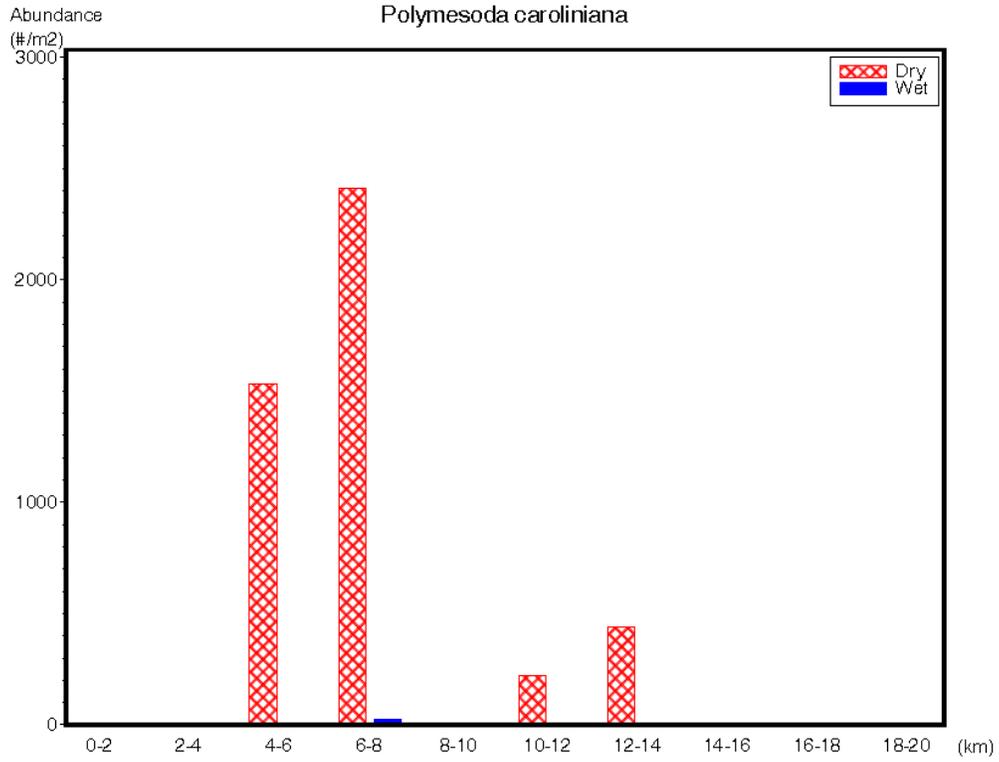


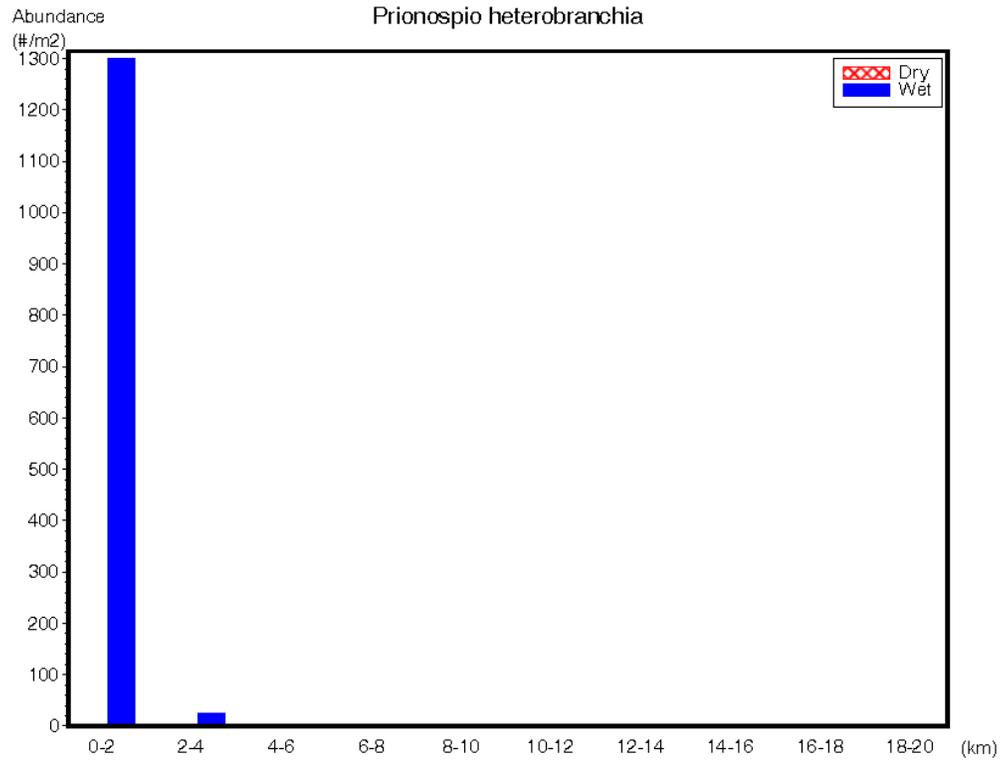
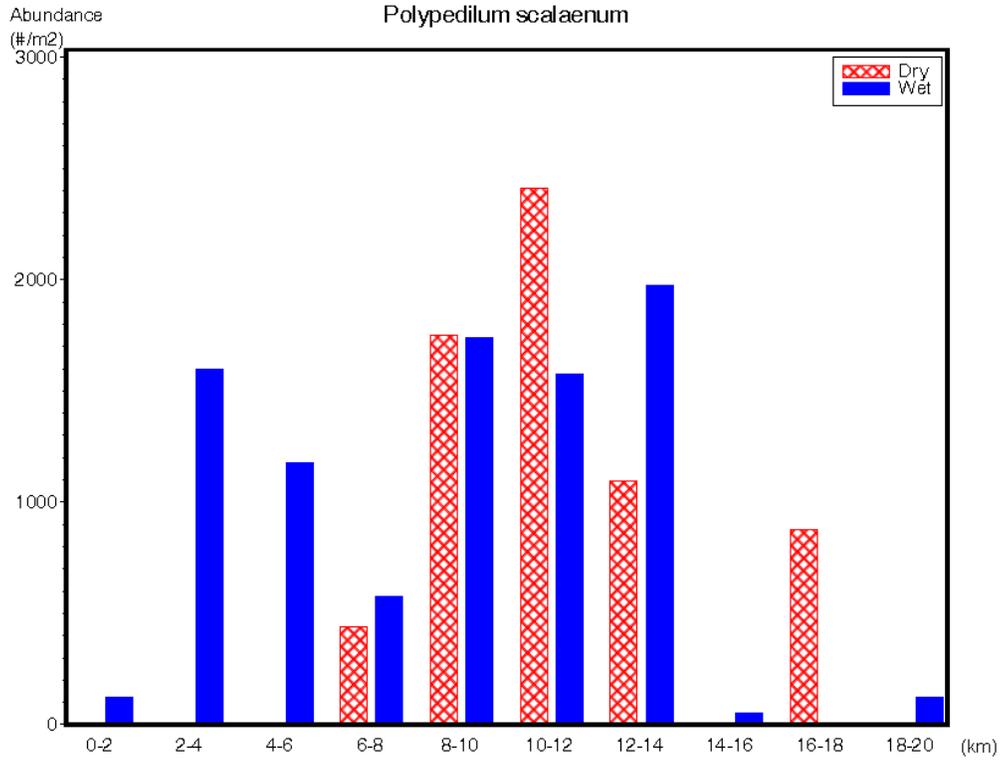


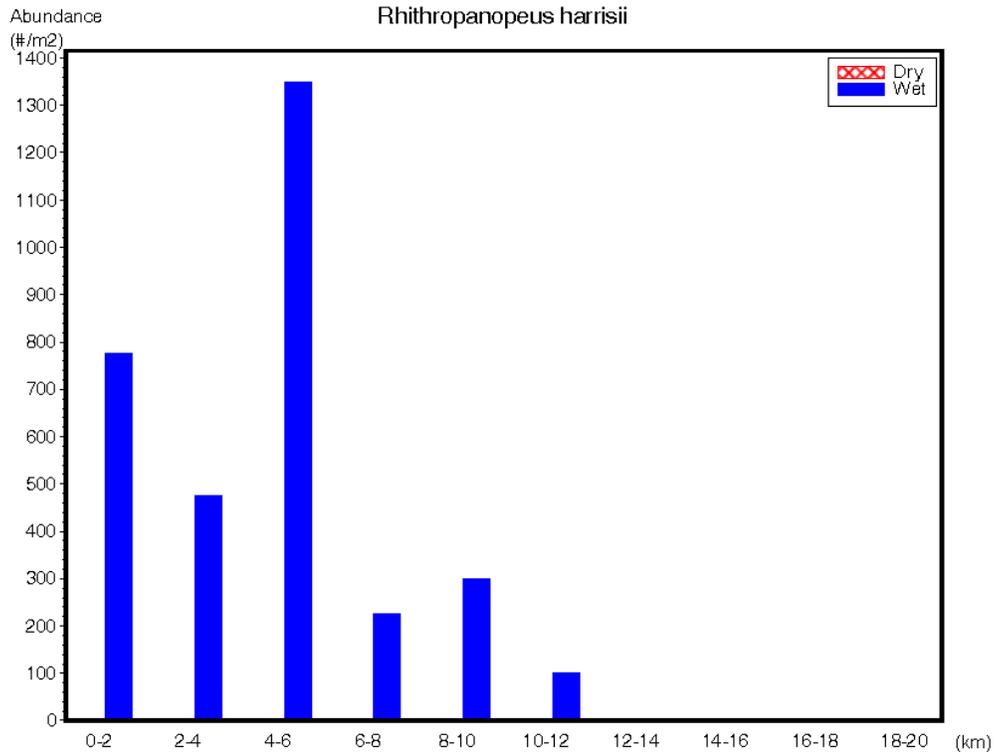
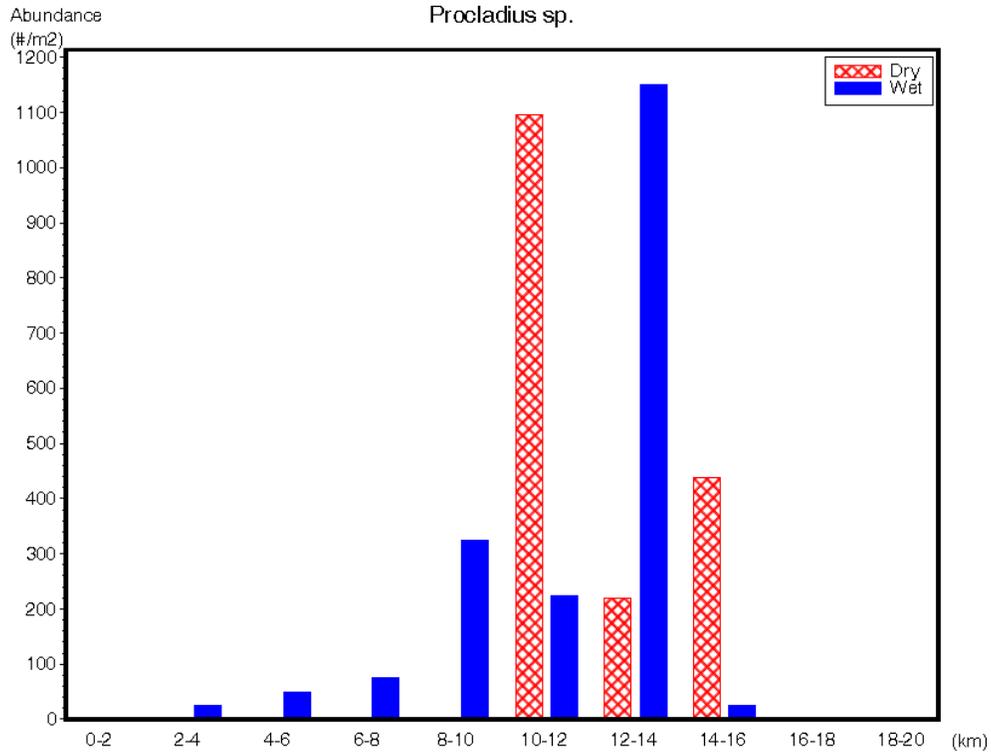


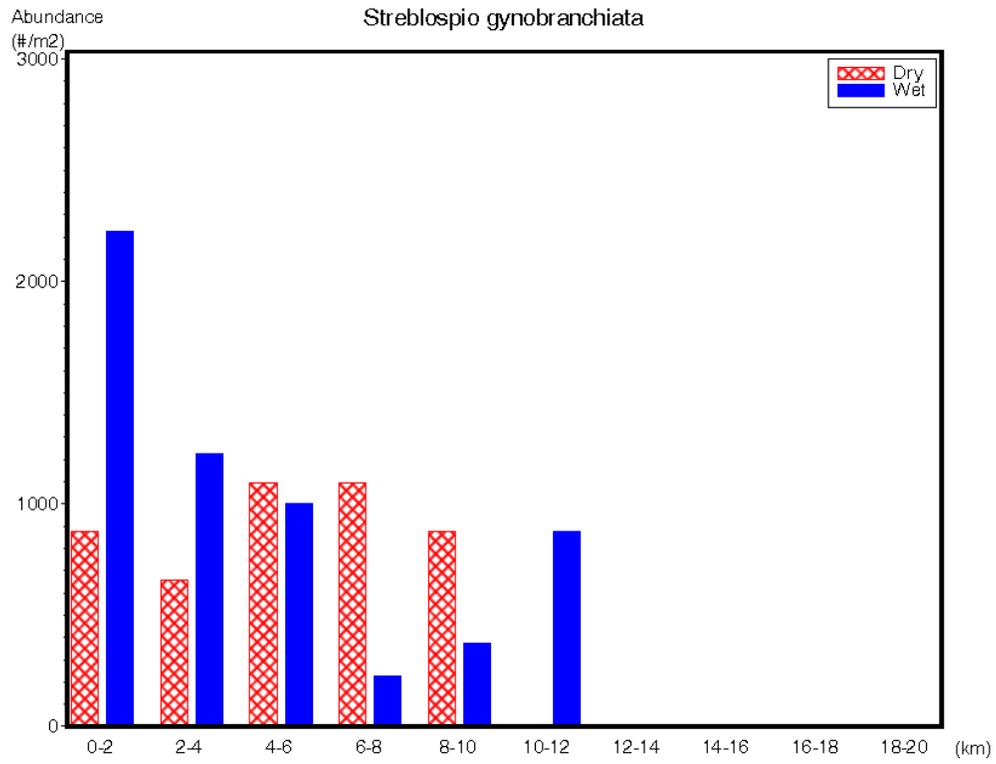
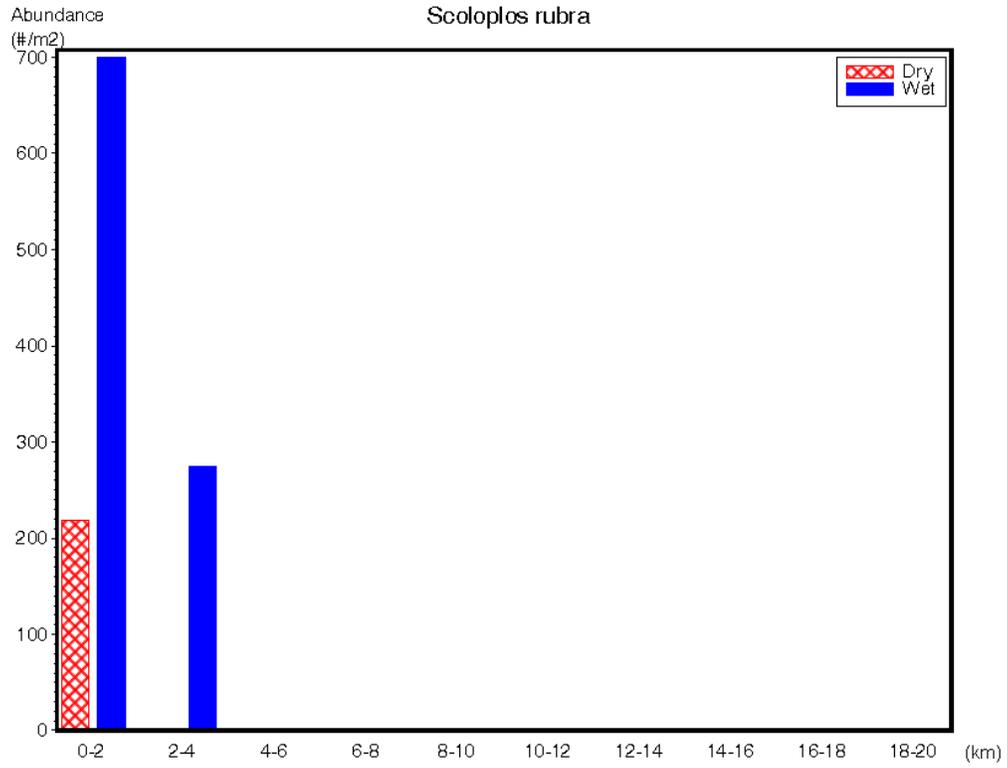


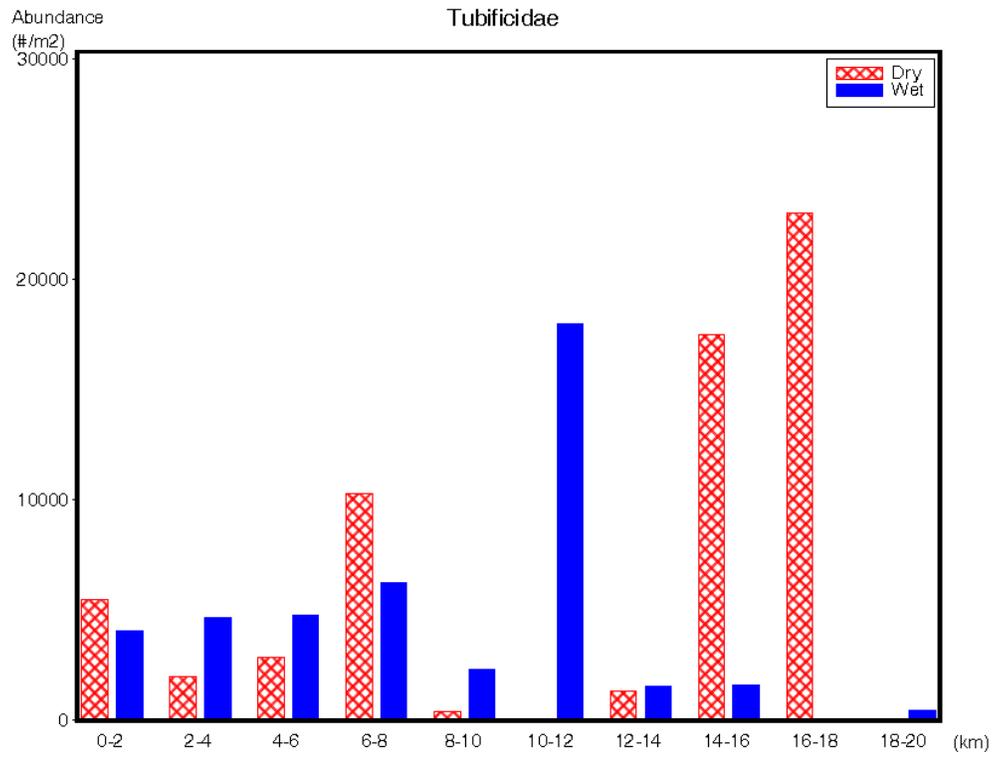
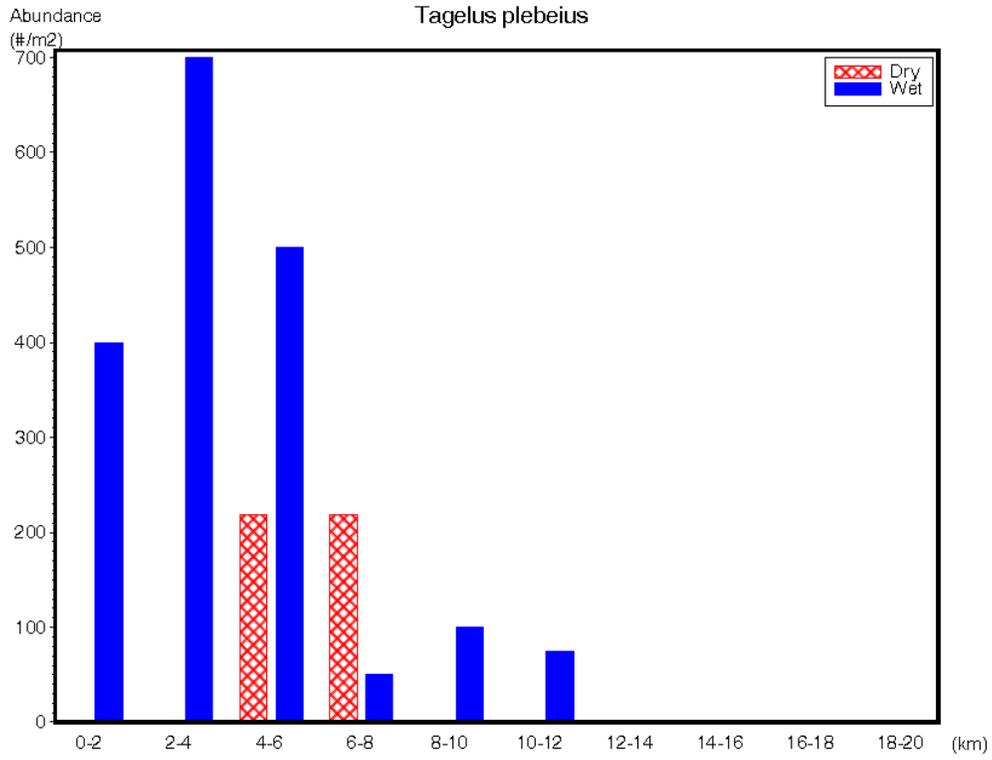


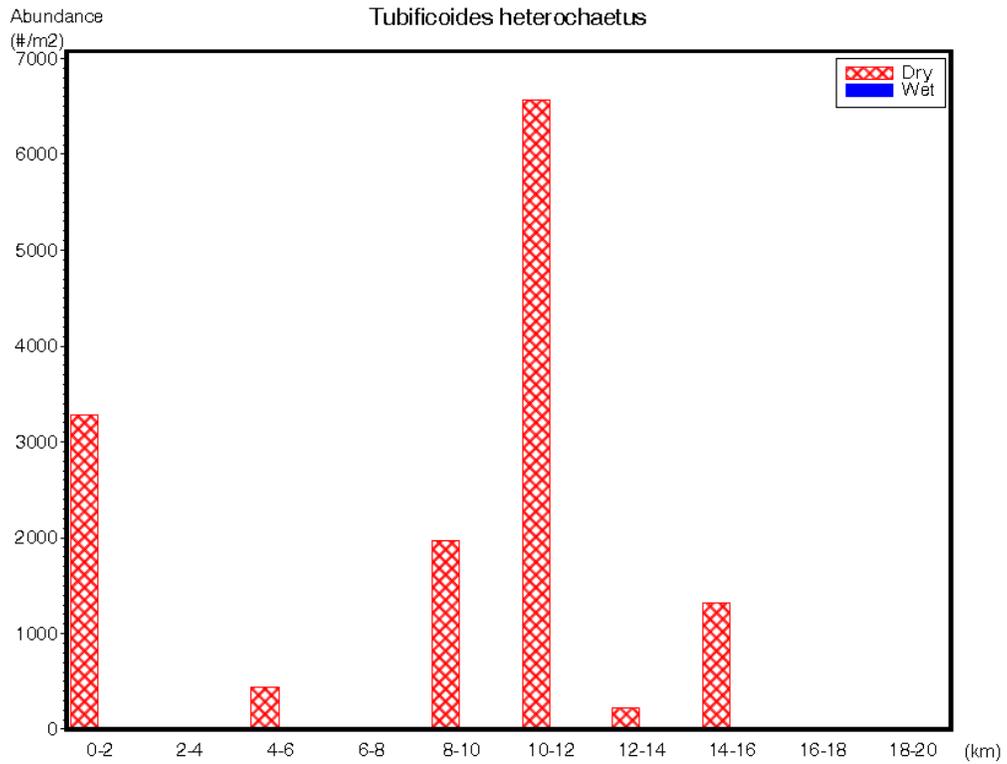
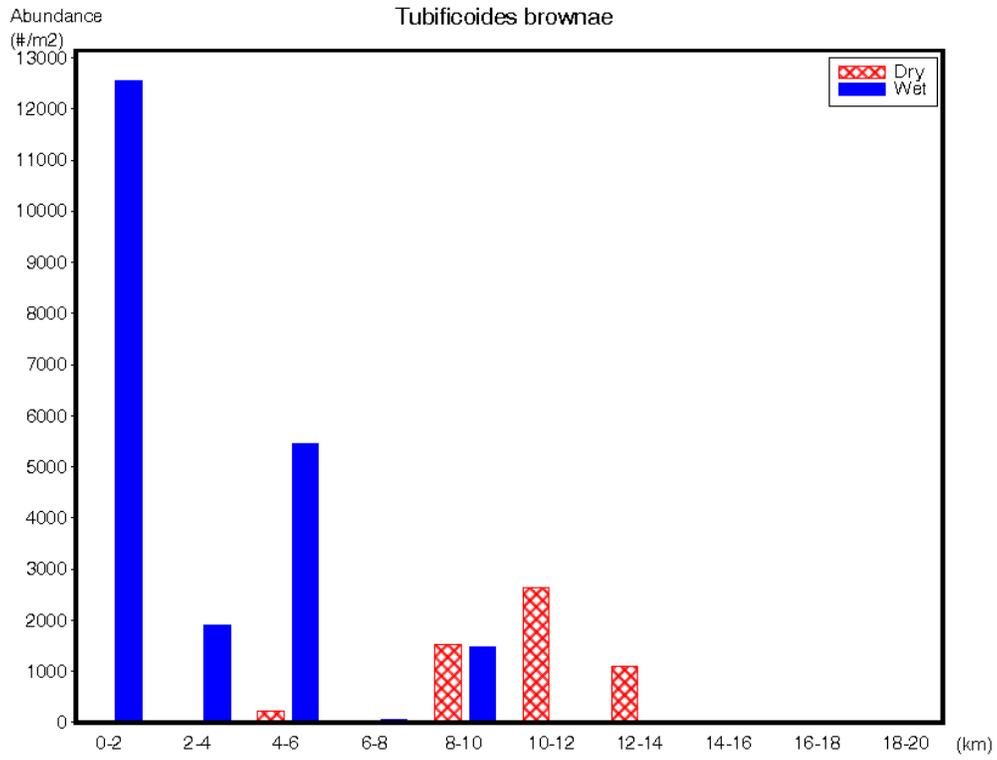


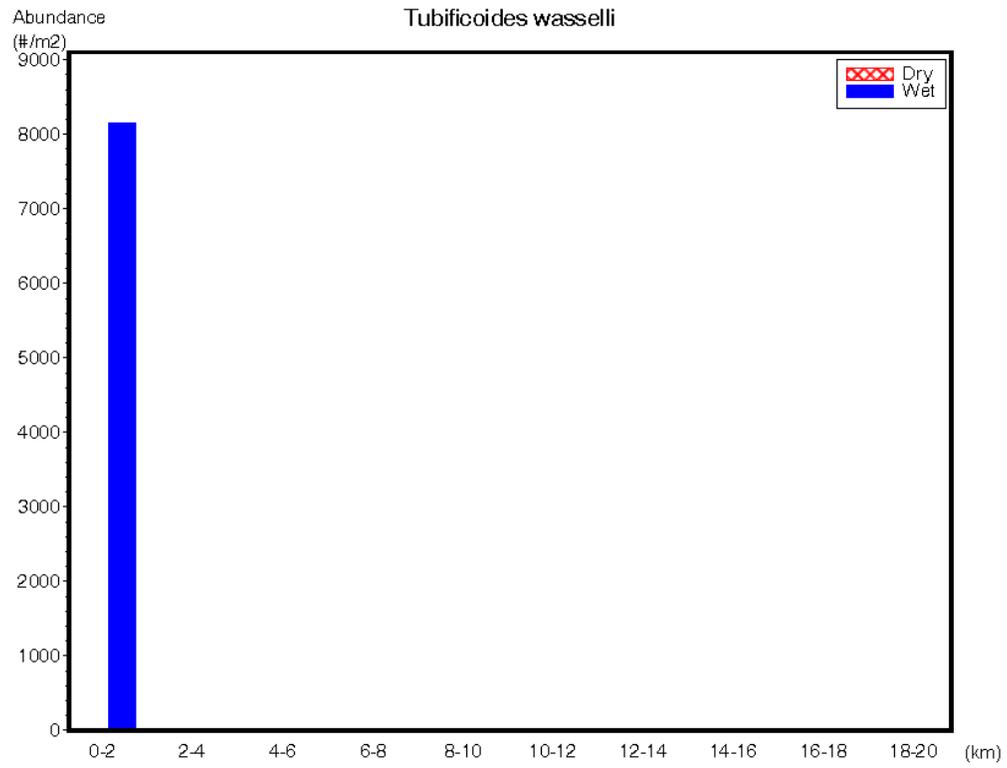
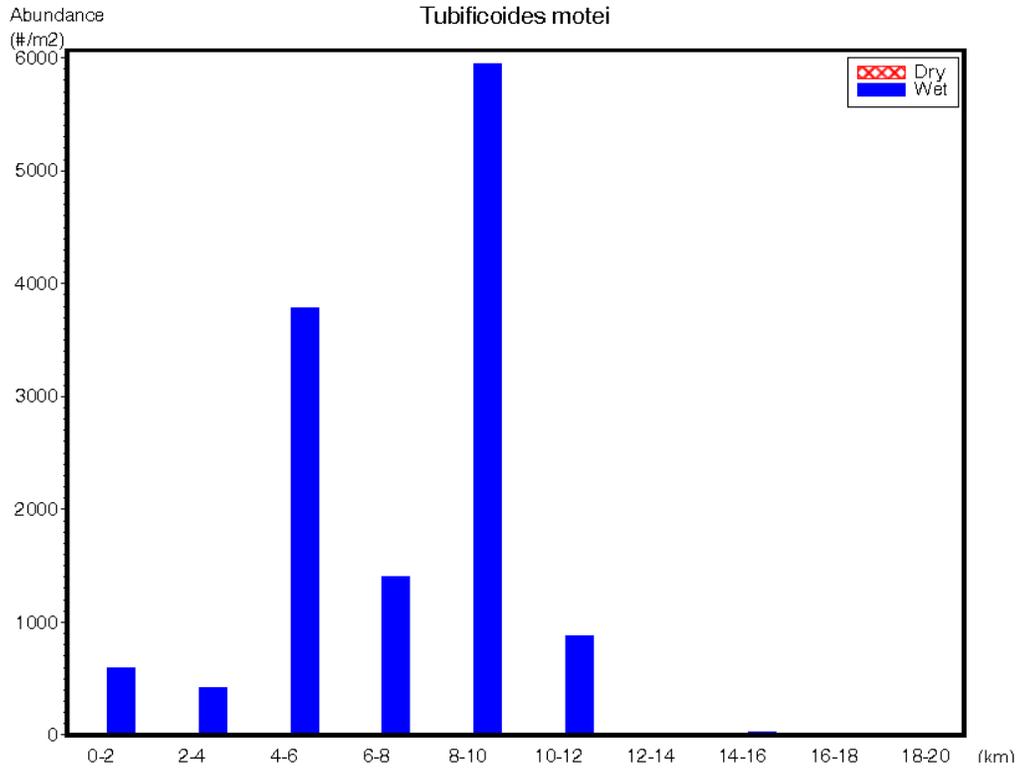


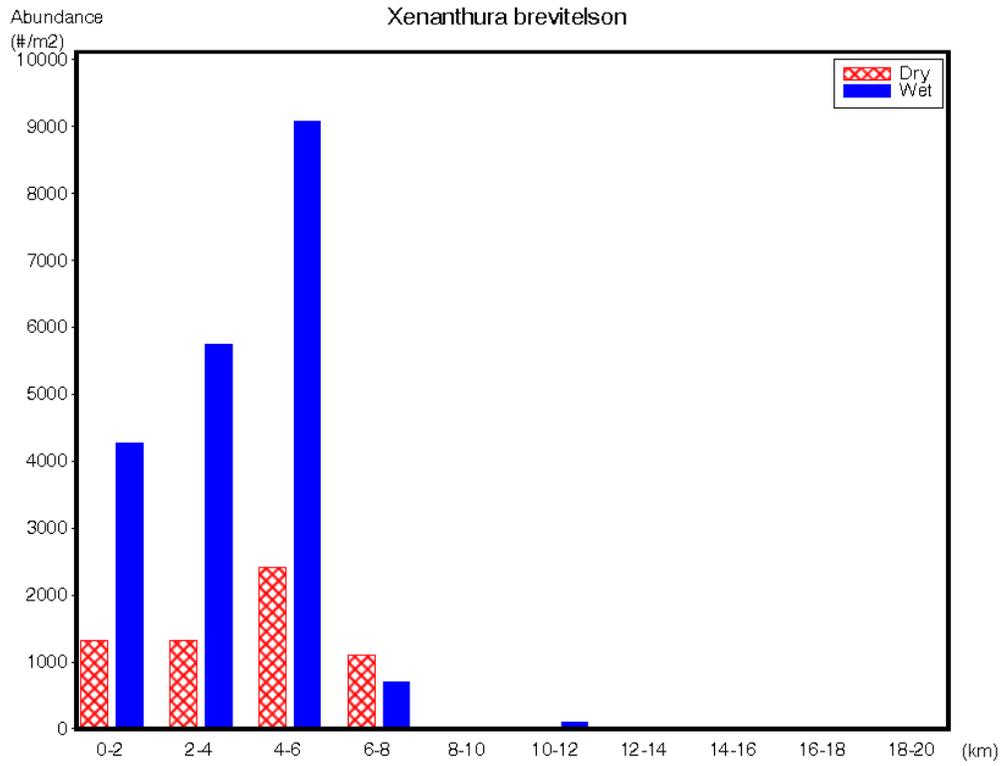












## APPENDIX C: Forward Stepwise Linear Regression Analyses

Data for the following results were selected according to:							
(SEASON\$ = 'D')							
1 case(s) deleted due to missing data.							
Step # 0 R = 0.000 R-Square = 0.000							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
	1 Constant						
Out		Part. Corr.					
	2 RKM	-0.285	.	.	1.000	8.209	0.005
	3 SCLAY	-0.538	.	.	1.000	37.782	0.000
	4 DEPTH	0.083	.	.	1.000	0.651	0.422
	5 DOBOT	0.384	.	.	1.000	16.040	0.000
	6 TEMPBOT	-0.119	.	.	1.000	1.337	0.251
	7 L10FLOW7	0.253	.	.	1.000	6.353	0.013
	8 L10FLOW14	-0.170	.	.	1.000	2.755	0.100
	9 L10FLOW28	-0.271	.	.	1.000	7.360	0.008
	10 L10FLOW56	-0.245	.	.	1.000	5.955	0.017
	11 L10FLOW112	0.310	.	.	1.000	9.869	0.002

Dependent Variable L10ABUND								
Minimum tolerance for entry into model = 0.000000								
Forward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050								
Step # 1 R = 0.537 R-Square = 0.289								
Term entered: SCLAY								
		Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In								
	1	Constant						
	3	SCLAY	-0.021	0.003	-0.538	1.000	37.782	0.000
Out			Part. Corr.					
	2	RKM	-0.546	.	.	0.916	39.070	0.000
	4	DEPTH	-0.030	.	.	0.959	0.085	0.771
	5	DOBOT	0.262	.	.	0.894	6.770	0.011
	6	TEMPBOT	0.122	.	.	0.842	1.399	0.240
	7	L10FLOW7	0.409	.	.	0.974	18.483	0.000
	8	L10FLOW14	0.063	.	.	0.835	0.371	0.544
	9	L10FLOW28	-0.102	.	.	0.875	0.973	0.327
	10	L10FLOW56	-0.057	.	.	0.861	0.303	0.583
	11	L10FLOW112	0.287	.	.	0.983	8.246	0.005

Step # 2 R = 0.708 R-Square = 0.501							
Term entered: RKM							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-0.054	0.009	-0.481	0.916	39.070	0.000
3	SCLAY	-0.026	0.003	-0.677	0.916	77.368	0.000
Out							
		Part. Corr.					
4	DEPTH	-0.052	.	.	0.959	0.248	0.620
5	DOBOT	0.114	.	.	0.806	1.199	0.277
6	TEMPBOT	0.005	.	.	0.802	0.002	0.964
7	L10FLOW7	0.063	.	.	0.526	0.367	0.546
8	L10FLOW14	-0.121	.	.	0.763	1.350	0.248
9	L10FLOW28	-0.122	.	.	0.875	1.377	0.244
10	L10FLOW56	-0.118	.	.	0.856	1.279	0.261
11	L10FLOW112	0.051	.	.	0.779	0.240	0.625

Data for the following results were selected according to:			
(SEASON\$ = 'D')			
1 case(s) deleted due to missing data.			
Eigenvalues of unit scaled X'X			
	1	2.000	3.000
	2.4123	0.488	0.100
Condition indices			
	1	2.000	3.000
	1	2.224	4.912
Variance proportions			
	1	2.000	3.000
CONSTANT	0.0259	0.004	0.970
RKM	0.0348	0.199	0.766
SCLAY	0.0497	0.525	0.426

Dep Var: L10ABUND N: 95 Multiple R: 0.7077 Squared multiple R: 0.5009					
Adjusted squared multiple R: 0.4900 Standard error of estimate: 0.3831					
Effect	Coefficient	Std Error	Std Coef	Tolerance	t
CONSTANT	4.7698	0.098	0.000	.	48.765
RKM	-0.0539	0.009	-0.481	0.916	-6.251
SCLAY	-0.0259	0.003	-0.677	0.916	-8.796
Effect	Coefficient	Lower 95%	Upper 95%		
CONSTANT	4.7698	4.576	4.964		
RKM	-0.0539	-0.071	-0.037		
SCLAY	-0.0259	-0.032	-0.020		
Correlation matrix of regression coefficients					
	CONSTANT	RKM	SCLAY		
CONSTANT	1				
RKM	-0.804	1.000			
SCLAY	-0.6525	0.290	1.000		
Analysis of Variance					

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	13.5474	2.000	6.774	46.159	0.000
Residual	13.5007	92.000	0.147		
Durbin-Watson D Statistic	1.9588				
First Order Autocorrelation	0.0140				

Data for the following results were selected according to:							
(SEASON\$ = 'D')							
1 case(s) deleted due to missing data.							
Step # 0 R = 0.000 R-Square = 0.000							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
Out		Part. Corr.					
2	RKM	-0.613	.	.	1.000	55.832	0.000
3	SCLAY	-0.163	.	.	1.000	2.533	0.115
4	DEPTH	0.035	.	.	1.000	0.113	0.738
5	DOBOT	0.265	.	.	1.000	7.046	0.009
6	TEMPBOT	0.097	.	.	1.000	0.875	0.352
7	L10FLOW7	0.588	.	.	1.000	49.174	0.000
8	L10FLOW14	0.016	.	.	1.000	0.023	0.880
9	L10FLOW28	-0.223	.	.	1.000	4.887	0.030
10	L10FLOW56	-0.163	.	.	1.000	2.542	0.114
11	L10FLOW112	0.528	.	.	1.000	35.957	0.000

Dependent Variable BS							
Minimum tolerance for entry into model = 0.000000							
Forward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050							
Step # 1 R = 0.612 R-Square = 0.375							
Term entered: RKM							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-0.531	0.071	-0.613	1.000	55.832	0.000
Out		Part. Corr.					
3	SCLAY	-0.450	.	.	0.916	23.353	0.000
4	DEPTH	0.072	.	.	0.999	0.477	0.491
5	DOBOT	0.193	.	.	0.964	3.540	0.063
6	TEMPBOT	-0.121	.	.	0.906	1.361	0.246
7	L10FLOW7	0.291	.	.	0.528	8.528	0.004
8	L10FLOW14	-0.291	.	.	0.860	8.531	0.004
9	L10FLOW28	-0.364	.	.	0.989	14.055	0.000
10	L10FLOW56	-0.347	.	.	0.969	12.612	0.001
11	L10FLOW112	0.395	.	.	0.845	16.959	0.000

Step # 2 R = 0.708 R-Square = 0.502							
Term entered: SCLAY							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-0.625	0.067	-0.720	0.916	87.711	0.000
3	SCLAY	-0.110	0.023	-0.372	0.916	23.353	0.000
Out		Part. Corr.					
4	DEPTH	-0.021	.	.	0.959	0.039	0.843
5	DOBOT	0.013	.	.	0.806	0.015	0.902
6	TEMPBOT	0.038	.	.	0.802	0.131	0.718
7	L10FLOW7	0.300	.	.	0.526	9.007	0.004
8	L10FLOW14	-0.167	.	.	0.763	2.603	0.110
9	L10FLOW28	-0.251	.	.	0.875	6.127	0.015
10	L10FLOW56	-0.230	.	.	0.856	5.101	0.026
11	L10FLOW112	0.314	.	.	0.779	9.963	0.002

Step # 3 R = 0.742 R-Square = 0.551							
Term entered: L10FLOW112							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-0.522	0.072	-0.602	0.726	53.277	0.000
3	SCLAY	-0.090	0.023	-0.305	0.845	15.888	0.000
11	L10FLOW112	255.792	81.040	0.251	0.779	9.963	0.002
Out		Part. Corr.					
4	DEPTH	-0.091	.	.	0.919	0.752	0.388
5	DOBOT	0.053	.	.	0.795	0.251	0.618
6	TEMPBOT	0.118	.	.	0.761	1.259	0.265
7	L10FLOW7	0.129	.	.	0.296	1.533	0.219
8	L10FLOW14	0.054	.	.	0.436	0.266	0.607
9	L10FLOW28	0.033	.	.	0.240	0.099	0.754
10	L10FLOW56	0.045	.	.	0.290	0.185	0.669

Data for the following results were selected according to:					
(SEASON\$ = 'D')					
1 case(s) deleted due to missing data.					
Eigenvalues of unit scaled X'X					
	1	2.000	3.000	4.000	
	3.3657	0.492	0.142	0.000	
Condition indices					
	1	2.000	3.000	4.000	
	1	2.615	4.865	3081.428	
Variance proportions					
	1	2.000	3.000	4.000	
CONSTANT	0	0.000	0.000	1.000	
RKM	0.014	0.132	0.646	0.208	
SCLAY	0.0222	0.524	0.377	0.078	
L10FLOW112	0	0.000	0.000	1.000	
Dep Var: BS N: 95 Multiple R: 0.7422 Squared multiple R: 0.5508					
Adjusted squared multiple R: 0.5360 Standard error of estimate: 2.8272					
Effect	Coefficient	Std Error	Std Coef	Tolerance	t
CONSTANT	-1073.7827	344.677	0.000	.	-3.115
RKM	-0.5219	0.072	-0.602	0.726	-7.299
SCLAY	-0.0903	0.023	-0.305	0.845	-3.986
L10FLOW112	255.7922	81.040	0.251	0.779	3.156

Effect	Coefficient	Lower 95%	Upper 95%		
CONSTANT	-1073.7827	-1758.441	-389.124		
RKM	-0.5219	-0.664	-0.380		
SCLAY	-0.0903	-0.135	-0.045		
L10FLOW112	255.7922	94.816	416.768		
Correlation matrix of regression coefficients					
	CONSTANT	RKM	SCLAY	L10FLOW112	
CONSTANT	1				
RKM	-0.4567	1.000			
SCLAY	-0.2792	0.375	1.000		
L10FLOW112	-1	0.455	0.278	1.000	
Analysis of Variance					
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	891.9497	3.000	297.317	37.196	0.000
Residual	727.3766	91.000	7.993		
Durbin-Watson D Statistic 1.7738					
First Order Autocorrelation 0.0917					

Data for the following results were selected according to:								
(SEASON\$ = 'W')								
23 case(s) deleted due to missing data.								
Step # 0 R = 0.000 R-Square = 0.000								
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'	
In								
	1	Constant						
Out		Part. Corr.						
	2	RKM	-0.199	.	.	1.000	4.682	0.033
	3	SCLAY	-0.267	.	.	1.000	8.771	0.004
	4	DEPTH	-0.203	.	.	1.000	4.885	0.029
	5	DOBOT	0.186	.	.	1.000	4.093	0.045
	6	TEMPBOT	0.056	.	.	1.000	0.363	0.548
	7	L10FLOW7	-0.307	.	.	1.000	11.850	0.001
	8	L10FLOW14	-0.325	.	.	1.000	13.498	0.000
	9	L10FLOW28	-0.370	.	.	1.000	18.046	0.000
	10	L10FLOW56	-0.312	.	.	1.000	12.332	0.001
	11	L10FLOW112	-0.271	.	.	1.000	9.045	0.003

Dependent Variable L10ABUND								
Minimum tolerance for entry into model = 0.000000								
Forward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050								
Step # 1 R = 0.370 R-Square = 0.137								
Term entered: L10FLOW28								
		Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In								
	1	Constant						
	9	L10FLOW28	-1.202	0.283	-0.370	1.000	18.046	0.000
Out			Part. Corr.					
	2	RKM	-0.217	.	.	1.000	5.608	0.020
	3	SCLAY	-0.330	.	.	0.990	13.817	0.000
	4	DEPTH	-0.155	.	.	0.973	2.784	0.098
	5	DOBOT	0.177	.	.	0.996	3.641	0.059
	6	TEMPBOT	0.055	.	.	1.000	0.337	0.563
	7	L10FLOW7	-0.036	.	.	0.403	0.147	0.702
	8	L10FLOW14	0.004	.	.	0.216	0.002	0.963
	10	L10FLOW56	0.172	.	.	0.074	3.431	0.067
	11	L10FLOW112	0.130	.	.	0.217	1.930	0.168

Step # 2 R = 0.480 R-Square = 0.231							
Term entered: SCLAY							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
3	SCLAY	-0.038	0.010	-0.308	0.990	13.817	0.000
9	L10FLOW28	-1.305	0.270	-0.401	0.990	23.397	0.000
Out		Part. Corr.					
2	RKM	-0.220	.	.	0.999	5.717	0.019
4	DEPTH	-0.103	.	.	0.942	1.203	0.275
5	DOBOT	0.167	.	.	0.993	3.201	0.076
6	TEMPBOT	0.041	.	.	0.997	0.187	0.666
7	L10FLOW7	-0.028	.	.	0.403	0.087	0.768
8	L10FLOW14	0.021	.	.	0.216	0.049	0.826
10	L10FLOW56	0.152	.	.	0.073	2.636	0.107
11	L10FLOW112	0.115	.	.	0.216	1.510	0.222

Step # 3 R = 0.518 R-Square = 0.268							
Term entered: RKM							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-0.045	0.019	-0.193	0.999	5.717	0.019
3	SCLAY	-0.037	0.010	-0.303	0.989	13.864	0.000
9	L10FLOW28	-1.309	0.264	-0.402	0.990	24.520	0.000
Out							
		Part. Corr.					
4	DEPTH	-0.038	.	.	0.853	0.163	0.687
5	DOBOT	0.192	.	.	0.985	4.264	0.041
6	TEMPBOT	-0.087	.	.	0.733	0.842	0.361
7	L10FLOW7	-0.059	.	.	0.396	0.390	0.534
8	L10FLOW14	-0.026	.	.	0.207	0.072	0.788
10	L10FLOW56	0.133	.	.	0.072	2.007	0.159
11	L10FLOW112	0.115	.	.	0.216	1.482	0.226

Step # 4 R = 0.543 R-Square = 0.295							
Term entered: DOBOT							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-0.048	0.019	-0.209	0.991	6.782	0.011
3	SCLAY	-0.036	0.010	-0.292	0.985	13.259	0.000
5	DOBOT	0.123	0.060	0.166	0.985	4.264	0.041
9	L10FLOW28	-1.273	0.261	-0.392	0.985	23.779	0.000
Out							
		Part. Corr.					
4	DEPTH	-0.063	.	.	0.841	0.437	0.510
6	TEMPBOT	-0.035	.	.	0.676	0.135	0.714
7	L10FLOW7	-0.026	.	.	0.384	0.076	0.783
8	L10FLOW14	-0.003	.	.	0.204	0.001	0.977
10	L10FLOW56	0.184	.	.	0.069	3.859	0.052
11	L10FLOW112	0.075	.	.	0.205	0.619	0.433

Data for the following results were selected according to:					
(SEASON\$ = 'W')					
4 case(s) deleted due to missing data.					
Eigenvalues of unit scaled X'X					
	1	2.000	3.000	4.000	5.000
	3.9646	0.575	0.368	0.088	0.004
Condition indices					
	1	2.000	3.000	4.000	5.000
	1	2.627	3.280	6.716	29.900
Variance proportions					
	1	2.000	3.000	4.000	5.000
CONSTANT	0.0005	0.000	0.001	0.015	0.983
RKM	0.0194	0.009	0.969	0.002	0.000
SCLAY	0.0195	0.910	0.005	0.063	0.003
DOBOT	0.0071	0.017	0.025	0.917	0.034
L10FLOW28	0.0005	0.000	0.001	0.021	0.976

Dep Var: L10ABUND N: 135 Multiple R: 0.5040 Squared multiple R: 0.2540					
Adjusted squared multiple R: 0.2310 Standard error of estimate: 0.9465					
Effect	Coefficient	Std Error	Std Coef	Tolerance	T
CONSTANT	6.2178	0.893	0.000	.	6.961
RKM	-0.0486	0.017	-0.215	0.978	-2.805
SCLAY	-0.0298	0.008	-0.280	0.965	-3.626
DOBOT	0.1151	0.056	0.157	0.971	2.047
L10FLOW28	-0.7786	0.217	-0.273	0.997	-3.595
Effect	Coefficient	Lower 95%	Upper 95%		
CONSTANT	6.2178	4.451	7.985		
RKM	-0.0486	-0.083	-0.014		
SCLAY	-0.0298	-0.046	-0.014		
DOBOT	0.1151	0.004	0.226		
L10FLOW28	-0.7786	-1.207	-0.350		
Correlation matrix of regression coefficients					
	CONSTANT	RKM	SCLAY	DOBOT	L10FLOW28
CONSTANT	1				
RKM	-0.0431	1.000			
SCLAY	-0.0946	-0.130	1.000		
DOBOT	-0.2878	-0.090	0.147	1.000	
L10FLOW28	-0.9598	-0.030	0.002	0.052	1.000

Analysis of Variance					
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	39.6489	4.000	9.912	11.064	0.000
Residual	116.4686	130.000	0.896		
*** WARNING ***					
Case 104 has large leverage (Leverage = 0.3873)					
Case 136 is an outlier (Studentized Residual = -3.9500)					
Case 202 has large leverage (Leverage = 0.1661)					
Case 230 has large leverage (Leverage = 0.1889)					
Durbin-Watson D Statistic	1.6482				
First Order Autocorrelation	0.1730				

Data for the following results were selected according to:							
(SEASON\$ = 'W')							
23 case(s) deleted due to missing data.							
Step # 0 R = 0.000 R-Square = 0.000							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
Out		Part. Corr.					
2	RKM	-0.471	.	.	1.000	32.573	0.000
3	SCLAY	-0.245	.	.	1.000	7.260	0.008
4	DEPTH	-0.311	.	.	1.000	12.189	0.001
5	DOBOT	0.147	.	.	1.000	2.525	0.115
6	TEMPBOT	0.152	.	.	1.000	2.682	0.104
7	L10FLOW7	-0.305	.	.	1.000	11.724	0.001
8	L10FLOW14	-0.289	.	.	1.000	10.418	0.002
9	L10FLOW28	-0.349	.	.	1.000	15.800	0.000
10	L10FLOW56	-0.282	.	.	1.000	9.870	0.002
11	L10FLOW112	-0.337	.	.	1.000	14.562	0.000

Dependent Variable BS								
Minimum tolerance for entry into model = 0.000000								
Forward stepwise with Alpha-to-Enter=0.050 and Alpha-to-Remove=0.050								
Step # 1 R = 0.471 R-Square = 0.222								
Term entered: RKM								
		Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In								
	1	Constant						
	2	RKM	-1.464	0.257	-0.471	1.000	32.573	0.000
Out			Part. Corr.					
	3	SCLAY	-0.262	.	.	0.999	8.311	0.005
	4	DEPTH	-0.201	.	.	0.909	4.751	0.031
	5	DOBOT	0.216	.	.	0.992	5.521	0.021
	6	TEMPBOT	-0.121	.	.	0.735	1.665	0.200
	7	L10FLOW7	-0.397	.	.	0.992	21.081	0.000
	8	L10FLOW14	-0.385	.	.	0.989	19.672	0.000
	9	L10FLOW28	-0.401	.	.	1.000	21.595	0.000
	10	L10FLOW56	-0.340	.	.	0.999	14.777	0.000
	11	L10FLOW112	-0.390	.	.	1.000	20.307	0.000

Step # 2 R = 0.589 R-Square = 0.347							
Term entered: L10FLOW28							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-1.474	0.236	-0.475	1.000	38.988	0.000
9	L10FLOW28	-15.465	3.328	-0.353	1.000	21.595	0.000
Out							
		Part. Corr.					
3	SCLAY	-0.332	.	.	0.989	13.873	0.000
4	DEPTH	-0.145	.	.	0.882	2.407	0.124
5	DOBOT	0.210	.	.	0.988	5.157	0.025
6	TEMPBOT	-0.142	.	.	0.734	2.300	0.132
7	L10FLOW7	-0.149	.	.	0.396	2.533	0.114
8	L10FLOW14	-0.069	.	.	0.207	0.535	0.466
10	L10FLOW56	0.184	.	.	0.073	3.920	0.050
11	L10FLOW112	-0.084	.	.	0.217	0.794	0.375

Step # 3 R = 0.647 R-Square = 0.419							
Term entered: SCLAY							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-1.450	0.224	-0.467	0.999	41.990	0.000
3	SCLAY	-0.449	0.121	-0.270	0.989	13.873	0.000
9	L10FLOW28	-16.669	3.170	-0.381	0.990	27.658	0.000
Out		Part. Corr.					
4	DEPTH	-0.092	.	.	0.853	0.949	0.332
5	DOBOT	0.201	.	.	0.985	4.668	0.033
6	TEMPBOT	-0.164	.	.	0.733	3.083	0.082
7	L10FLOW7	-0.146	.	.	0.396	2.414	0.123
8	L10FLOW14	-0.055	.	.	0.207	0.331	0.566
10	L10FLOW56	0.165	.	.	0.072	3.123	0.080
11	L10FLOW112	-0.111	.	.	0.216	1.393	0.240

Step # 4 R = 0.665 R-Square = 0.442							
Term entered: DOBOT							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-1.494	0.221	-0.481	0.991	45.632	0.000
3	SCLAY	-0.433	0.119	-0.260	0.985	13.273	0.000
5	DOBOT	1.539	0.712	0.154	0.985	4.668	0.033
9	L10FLOW28	-16.224	3.126	-0.371	0.985	26.940	0.000
Out		Part. Corr.					
4	DEPTH	-0.119	.	.	0.841	1.589	0.210
6	TEMPBOT	-0.115	.	.	0.676	1.474	0.227
7	L10FLOW7	-0.115	.	.	0.384	1.468	0.228
8	L10FLOW14	-0.032	.	.	0.204	0.110	0.741
10	L10FLOW56	0.220	.	.	0.069	5.599	0.020
11	L10FLOW112	-0.164	.	.	0.205	3.039	0.084

Step # 5 R = 0.685 R-Square = 0.469							
Term entered: L10FLOW56							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-1.451	0.217	-0.467	0.984	44.543	0.000
3	SCLAY	-0.405	0.117	-0.243	0.975	11.958	0.001
5	DOBOT	1.916	0.716	0.192	0.936	7.163	0.009
9	L10FLOW28	-42.419	11.486	-0.969	0.070	13.638	0.000
10	L10FLOW56	30.376	12.837	0.626	0.069	5.599	0.020
Out		Part. Corr.					
4	DEPTH	-0.024	.	.	0.674	0.064	0.800
6	TEMPBOT	-0.214	.	.	0.588	5.227	0.024
7	L10FLOW7	-0.056	.	.	0.352	0.339	0.562
8	L10FLOW14	0.060	.	.	0.173	0.399	0.529
11	L10FLOW112	-0.345	.	.	0.145	14.699	0.000

Step # 6 R = 0.730 R-Square = 0.532							
Term entered: L10FLOW112							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-1.444	0.205	-0.465	0.984	49.566	0.000
3	SCLAY	-0.402	0.110	-0.242	0.975	13.280	0.000
5	DOBOT	2.979	0.730	0.299	0.801	16.659	0.000
9	L10FLOW28	-42.477	10.832	-0.970	0.070	15.379	0.000
10	L10FLOW56	60.192	14.389	1.241	0.049	17.500	0.000
11	L10FLOW112	-55.281	14.419	-0.659	0.145	14.699	0.000
Out		Part. Corr.					
4	DEPTH	0.119	.	.	0.581	1.547	0.216
6	TEMPBOT	-0.350	.	.	0.538	15.103	0.000
7	L10FLOW7	-0.041	.	.	0.352	0.185	0.668
8	L10FLOW14	0.033	.	.	0.172	0.118	0.732

Step # 7 R = 0.768 R-Square = 0.590							
Term entered: TEMPBOT							
	Effect	Coefficient	Std Error	Std Coef	Tol.	F	'P'
In							
1	Constant						
2	RKM	-1.916	0.228	-0.617	0.705	70.598	0.000
3	SCLAY	-0.411	0.104	-0.247	0.974	15.690	0.000
5	DOBOT	2.724	0.690	0.273	0.794	15.592	0.000
6	TEMPBOT	-2.930	0.754	-0.327	0.538	15.103	0.000
9	L10FLOW28	-58.535	10.998	-1.337	0.060	28.327	0.000
10	L10FLOW56	86.811	15.173	1.789	0.039	32.733	0.000
11	L10FLOW112	-71.365	14.185	-0.851	0.133	25.310	0.000
Out							
		Part. Corr.					
4	DEPTH	0.013	.	.	0.526	0.017	0.898
7	L10FLOW7	-0.018	.	.	0.350	0.035	0.851
8	L10FLOW14	-0.017	.	.	0.168	0.031	0.860

Data for the following results were selected according to:					
(SEASON\$ = 'W')					
4 case(s) deleted due to missing data.					
Eigenvalues of unit scaled X'X					
	1	2.000	3.000	4.000	5.000
	6.8667	0.604	0.406	0.112	0.009
	6	7.000	8.000		
	0.0011	0.000	0.000		
Condition indices					
	1	2.000	3.000	4.000	5.000
	1	3.371	4.114	7.821	27.282
	6	7.000	8.000		
	78.8806	133.123	209.214		
Variance proportions					
	1	2.000	3.000	4.000	5.000
CONSTANT	0	0.000	0.000	0.000	0.016
RKM	0.0045	0.004	0.745	0.004	0.020
SCLAY	0.0055	0.874	0.037	0.045	0.000
DOBOT	0.0021	0.007	0.001	0.824	0.005
TEMPBOT	0	0.000	0.000	0.001	0.079
L10FLOW28	0	0.000	0.000	0.000	0.013
L10FLOW56	0	0.000	0.000	0.000	0.003
L10FLOW112	0	0.000	0.000	0.000	0.001

	6	7.000	8.000		
CONSTANT	0.29	0.639	0.056		
RKM	0.1565	0.039	0.028		
SCLAY	0.0233	0.003	0.013		
DOBOT	0.133	0.001	0.027		
TEMPBOT	0.5406	0.149	0.230		
L10FLOW28	0.0168	0.157	0.814		
L10FLOW56	0.011	0.000	0.986		
L10FLOW112	0.1061	0.767	0.126		
Dep Var: BS N: 135 Multiple R: 0.6709 Squared multiple R: 0.4501					
Adjusted squared multiple R: 0.4198 Standard error of estimate: 11.0255					
Effect	Coefficient	Std Error	Std Coef	Tolerance	T
CONSTANT	111.3355	31.901	0.000	.	3.490
RKM	-1.6521	0.231	-0.545	0.747	-7.156
SCLAY	-0.2612	0.098	-0.183	0.930	-2.677
DOBOT	1.1852	0.701	0.121	0.847	1.691
TEMPBOT	-1.9791	0.779	-0.221	0.572	-2.541
L10FLOW28	-46.2918	11.964	-1.209	0.044	-3.869
L10FLOW56	43.5282	14.607	1.002	0.038	2.980
L10FLOW112	-6.9464	9.334	-0.123	0.160	-0.744

Effect	Coefficient	Lower 95%	Upper 95%		
CONSTANT	111.3355	48.210	174.461		
RKM	-1.6521	-2.109	-1.195		
SCLAY	-0.2612	-0.454	-0.068		
DOBOT	1.1852	-0.202	2.572		
TEMPBOT	-1.9791	-3.520	-0.438		
L10FLOW28	-46.2918	-69.966	-22.618		
L10FLOW56	43.5282	14.623	72.434		
L10FLOW112	-6.9464	-25.418	11.525		
Correlation matrix of regression coefficients					
	CONSTANT	RKM	SCLAY	DOBOT	TEMPBOT
CONSTANT	1				
RKM	-0.3961	1.000			
SCLAY	-0.0192	-0.088	1.000		
DOBOT	-0.1567	0.015	0.200	1.000	
TEMPBOT	-0.7821	0.480	0.024	0.138	1.000
L10FLOW28	0.0199	0.104	-0.065	-0.094	0.344
L10FLOW56	0.171	-0.133	0.127	0.198	-0.415
L10FLOW112	-0.6124	0.095	-0.141	-0.207	0.259
	L10FLOW28	L10FLOW56	L10FLOW112		
L10FLOW28	1				
L10FLOW56	-0.8753	1.000			
L10FLOW112	-0.0648	-0.384	1.000		

Analysis of Variance					
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Regression	12636.6491	7.000	1805.236	14.850	0.000
Residual	15438.4324	127.000	121.563		
*** WARNING ***					
Case 104 has large leverage (Leverage = 0.4016)					
Case 230 has large leverage (Leverage = 0.2088)					
Durbin-Watson D Statistic 1.0345					
First Order Autocorrelation 0.4816					

## APPENDIX D: Logistic Regression Intercepts & Coefficients Based on Data from 5 Tampa Bay Area Tidal Rivers (Adapted From: Janicki Environmental, Inc., 2007a)

Logistic Regression was used by Janicki Environmental, Inc. (2007a) to model relationships between salinity and the probability of occurrence for selected benthic species from five Tampa Bay area tidal rivers (including the Little Manatee River). Several of the dominant species in the Little Manatee River had significant relationships with salinity. A summary of the regression intercepts and coefficients are tabulated below.

Samples were coded as presence/absence for each species of interest. Using the Logit function:

$$g(y) = \log \left[ \frac{p(y)}{1-p(y)} \right] = \beta_0 + \beta_1 x + \beta_2 x^2$$

where

x = salinity

p(y) = probability of a species being present, as a function of x

g(y) = transformation of the odds of species occurrence

$\beta_0$ ,  $\beta_1$ , and  $\beta_2$  regression coefficients

Estimates of the log odds of occurrence based on linear regression coefficients for salinity were developed. The log odds can be equated to a probability of occurrence as follows:

$$P_{(y)} = \frac{1}{1 + \exp(-\alpha - \beta_1 X_1 - \beta_2 X_2 \dots - \beta_k X_k)}$$

<b>Species</b>	<b>Variable</b>	<b>Intercept</b>	<b>salinity</b>	<b>salinity2</b>
<i>AMPELISCA ABDITA</i>	Intercept	-2.7579		
	xvar		0.1868	
	xvar2			-0.00362
<i>AMPELISCA HOLMESI</i>	Intercept	-3.4044		
	xvar		0.2359	
	xvar2			-0.00488
<i>AMYGDALUM PAPYRIUM</i>	Intercept	-3.2831		
	xvar		0.3048	
	xvar2			-0.00786
<i>APOCOROPHIUM LOUISIANUM</i>	Intercept	-3.3526		
	xvar		0.2178	
	xvar2			-0.00862
<i>CORBICULA FLUMINEA</i>	Intercept	-1.0758		
	xvar		-0.4218	
	xvar2			0.00664
<i>CYATHURA POLITA</i>	Intercept	-1.2595		
	xvar		0.1169	
	xvar2			-0.00513
<i>GRANDIDIERELLA BONNIEROIDES</i>	Intercept	-1.0539		
	xvar		0.1184	
	xvar2			-0.00391
<i>LAONEREIS CULVERI</i>	Intercept	-0.2737		
	xvar		0.0509	
	xvar2			-0.00345
<i>MONTICELLINA DORSOBRANCHIALIS</i>	Intercept	-4.2183		
	xvar		0.1983	
	xvar2			-0.00236
<i>XENANTHURA BREVITELSON</i>	Intercept	-3.9028		
	xvar		0.2798	
	xvar2			-0.00719