Appendix L

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:

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Cover photographs:
Top:http://www.lib.usf.edu/ldsu/browsephotograph.html?size=1andidx=47and
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. Tubiculous and fossorial benthic organisms may fulfill an important role in reworking sediments. In this role as bioturbators, they may bring suspended sediments into contact with the water column thereby translocating nutrients and pollutants and oxygenating sediments.

1.3 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).

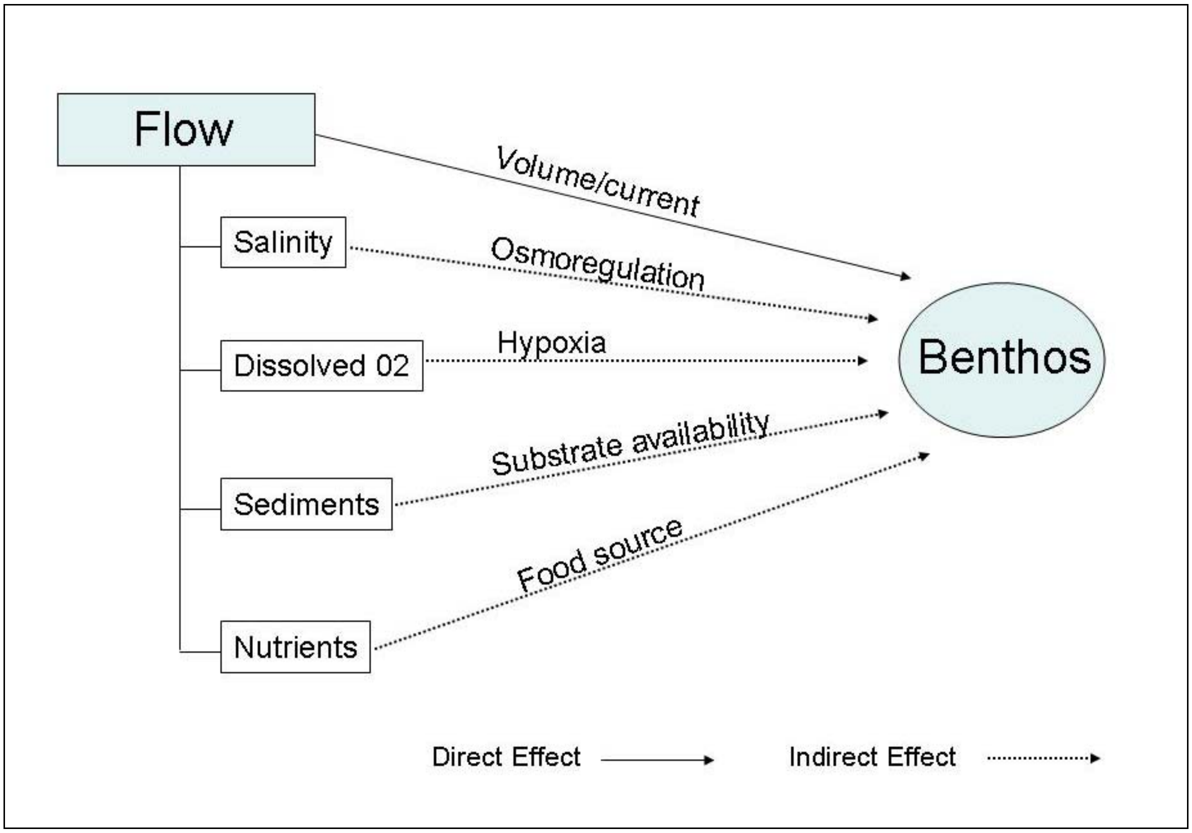


Figure 1-1. Conceptual diagram showing the direct (solid line) and indirect (dashed line) effects of low on benthos.

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^2 (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).

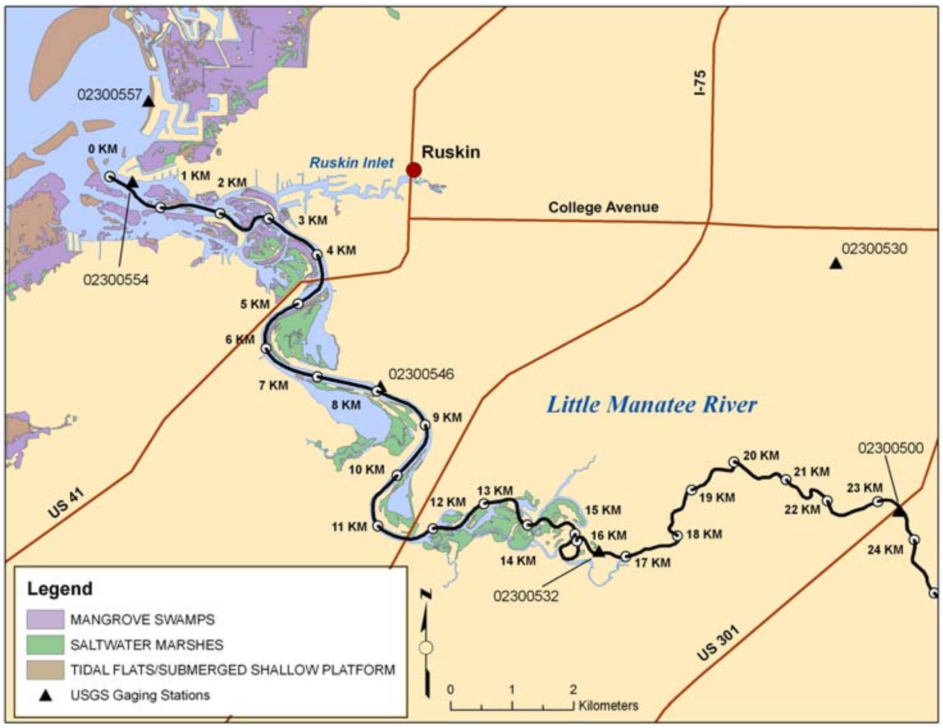


Figure 1-2. The Little Manatee River study area.

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^2). The 2005 survey for the District employed a 7.62 cm diameter hand core (area= 45.6 cm^2) 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

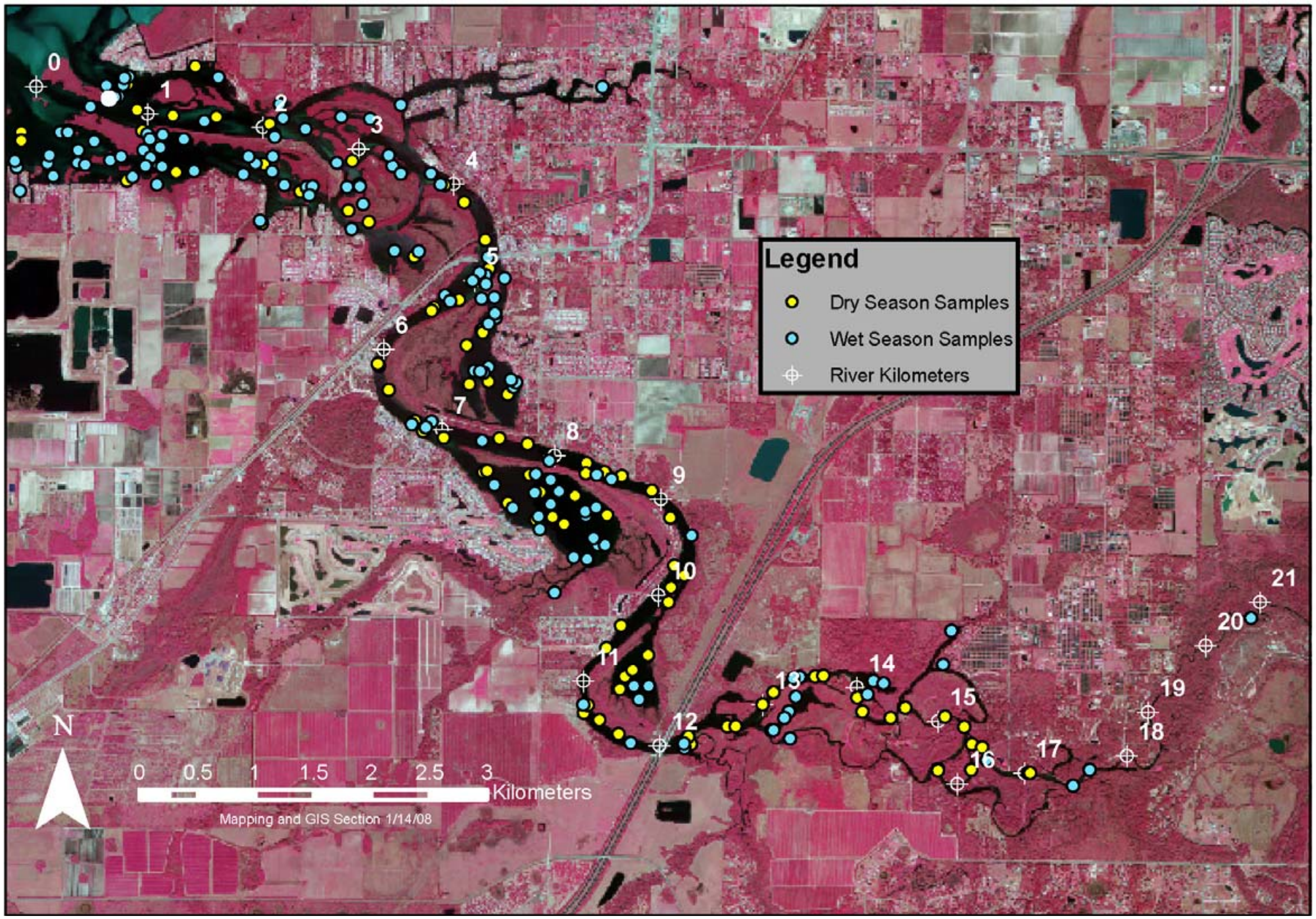


Figure 2-1. Location of benthic sampling stations in the Little Manatee River, 1996-2003 and 2005 (EPCHC unpublished data; map prepared by SWFWMD). Numbers indicate river kilometers along the centerline.

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^{-2}) is an indicator of the standing crop of the benthic community. Extremely high or extremely low abundance can be indicative of a perturbed environment.

2.4.2 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 4th root transformed for all multivariate community analyses. The 4th root transformation in multivariate analyses permits a greater number of taxa to influence the results (Clarke and Warwick, 2001). The use of untransformed data yields results strongly influenced by the most abundant taxa. Cao *et al*. (1998) argue that "rare" taxa may be more sensitive to environmental perturbation than common species. Therefore, an analytical approach that is more responsive to the "community" rather than to only a few, numerically abundant taxa was desirable. Thorne *et al*. (1999) have also demonstrated that the 4th root transformation is preferred in multivariate community analyses because it represents a "good compromise between untransformed and binary data". Therefore, the 4th root transformation was employed in the multivariate analyses.

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 ≥ 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 pair-wise 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 perfomed 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 RKMs. 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).

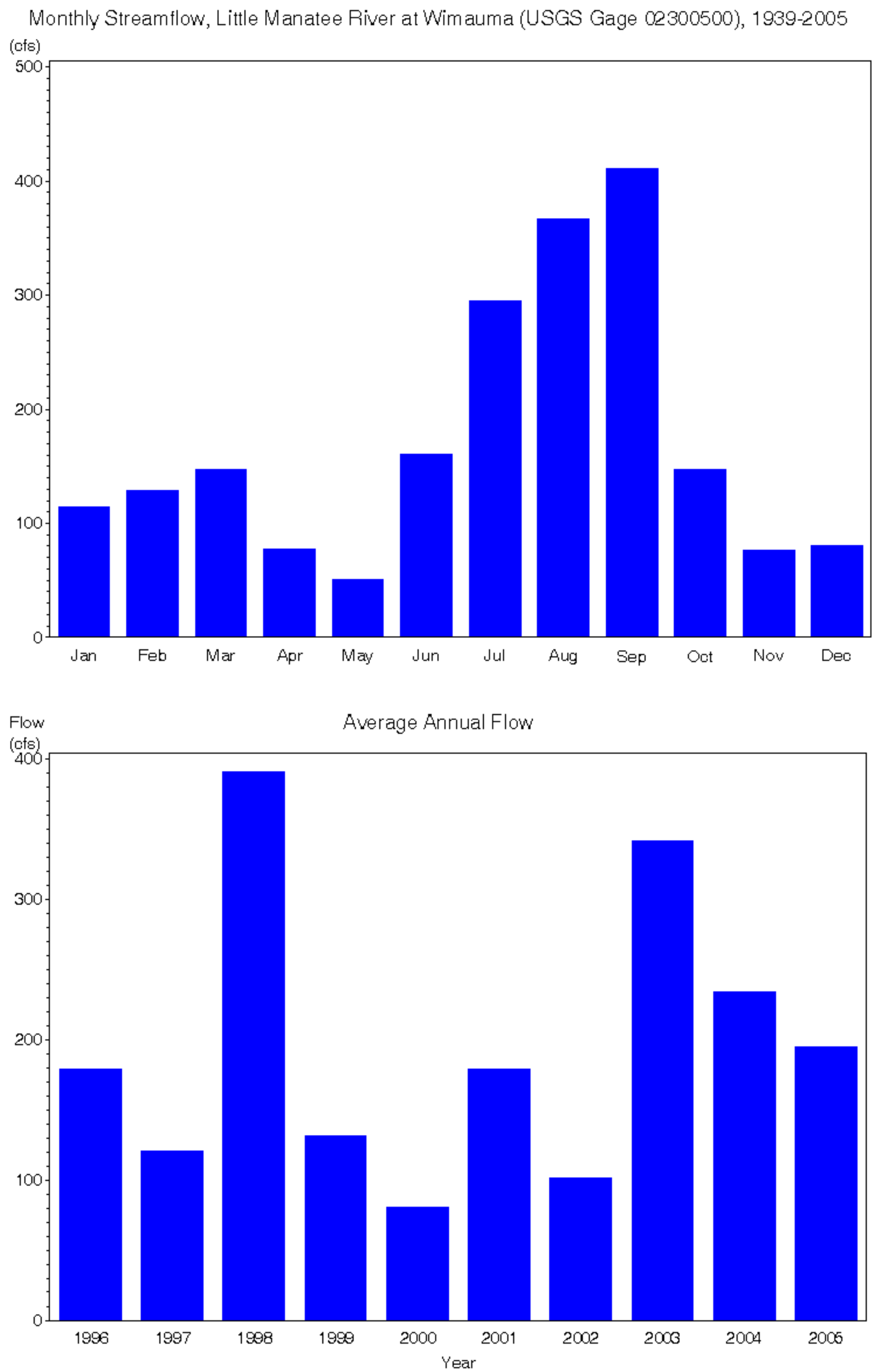


Figure 3-1. **Monthly and annual flows (cfs) in the Little Manatee River at USGS Gage 02300500 near Wimauma.**

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.		
Variable	**Wet Seasons 1996-2004 (n=116)**	**Dry Season 2005 (n=95)**
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^{-1})	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)

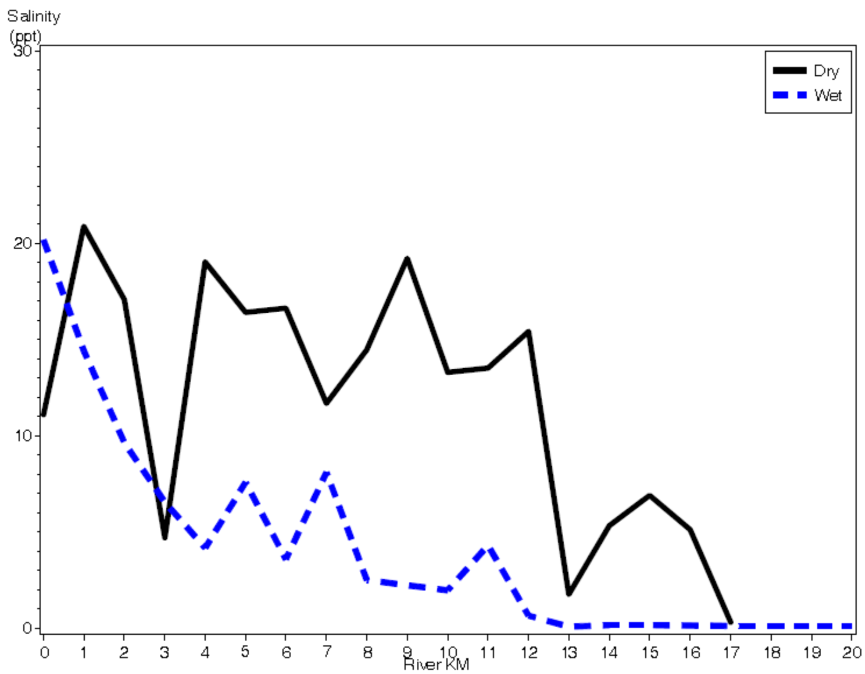


Figure 3-2. Mean near-bottom salinity by river kilometer and season in the Little Manatee River. Dry season= 2005; Wet season= 1996-2004.

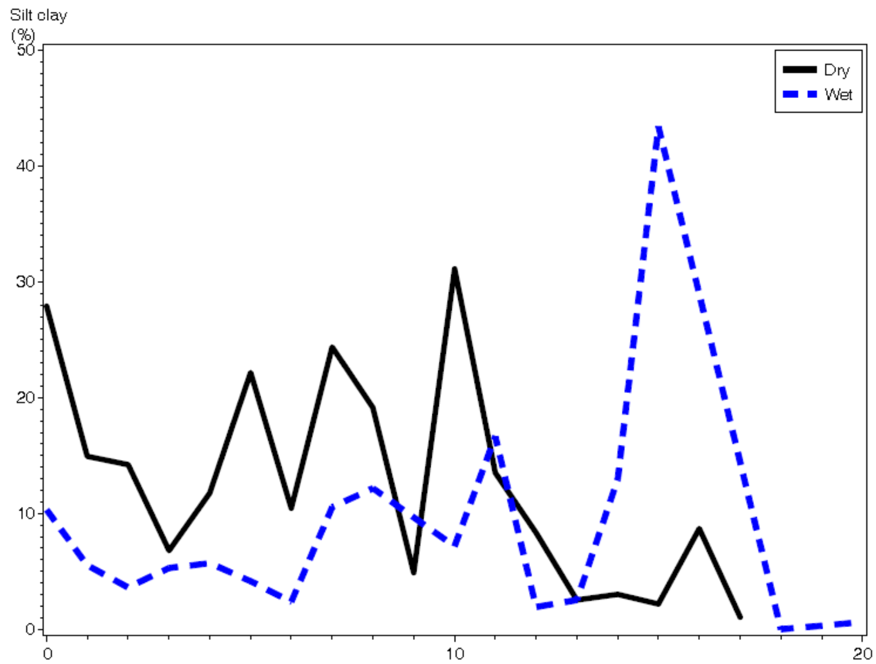


Figure 3-3. **Mean sediment percent silt+clay by river kilometer and season in the Little Manatee River. Dry season= 2005; Wet season= 1996-2004. *Note: sample analysis methods are not comparable for the two seasons.* The sand-mud demarcation is 20.2% silt+clay in the 1996-2004 wet season samples and 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.					
Wet Season (1996-2004)					
Taxon	**Frequency of Occurrence**	**Mean Density (#/m^2)**	**Dominance**	**Mean Salinity at Capture (ppt)**	**Mean Center of Abundance (RKm)**
Apocorophium louisianum	32	1,550	23.52	7.1	5.0
Grandidierella bonnieroides	53	586	18.61	8.0	8.1
Tubificidae	64	315	14.98	8.2	7.8
Ampelisca holmesi	39	376	12.80	15.2	0.7
Cerapus spp.	28	441	11.74	16.3	1.7
Cyathura polita	63	194	11.68	8.1	5.8
Xenanthura brevitelson	42	143	8.19	12.5	3.5
Monticellina dorsobranchialis	26	220	7.99	21.0	0.4
Laeonereis culveri	49	106	7.60	8.1	5.0
Amygdalum papyrium	37	132	7.38	16.2	1.1
Glottidia pyramidata	20	182	6.38	19.4	0.0
Tubificoides brownae	23	154	6.29	15.4	1.9
Aricidea philbinae	33	106	6.24	17.9	0.9
Ampelisca abdita	36	77	5.55	12.2	1.8
Polypedilum scalaenum	43	64	5.55	4.7	8.0
Mysella planulata	22	88	4.65	19.4	0.5
Leptochelia sp.	29	58	4.34	12.8	3.0
Tubificoides motei	17	94	4.22	7.0	6.5
Mytilopsis leucophaeata	21	72	4.11	7.3	8.7
Heteromastus filiformis	35	42	4.04	10.2	2.9
Fabricinuda triloba	18	79	3.99	18.9	1.1
Hobsonia florida	28	44	3.71	12.0	3.3
Streblospio gynobranchiata	28	43	3.65	11.4	4.0
Edotea triloba	37	30	3.49	12.4	2.1
Cirripedia	7	145	3.37	12.5	0.1
Acteocina canaliculata	24	42	3.35	18.9	0.4
Cyclaspis cf. varians	20	50	3.34	18.3	0.5
Ampelisca vadorum	23	43	3.31	17.7	2.6
Tubificoides wasselli	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.					
Wet Season (1996-2004)					
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Dominance**	**Mean Salinity at Capture (ppt)**	**Mean Center of Abundance (RKm)**
Rhithropanopeus harrisii	34	23	2.97	11.5	4.1
Mulinia lateralis	17	39	2.73	17.8	0.4
Aricidea taylori	16	37	2.57	19.9	0.8
Amphiporus bioculatus	17	32	2.45	17.1	0.6
Bivalvia	29	15	2.21	8.7	5.4
Polypedilum halterale	15	29	2.21	0.9	11.6
Hydrobiidae	17	25	2.18	4.6	9.2
Tagelus plebeius	30	13	2.10	9.4	3.4
Chironomus sp.	16	19	1.84	3.3	6.2
Capitella capitata	19	15	1.78	13.8	1.5
Corbicula fluminea	5	57	1.78	0.1	17.2
Haminoea succinea	16	14	1.56	15.7	0.4
Nassarius vibex	22	10	1.53	20.4	0.4
Macoma tenta	12	16	1.48	18.6	0.3
Procladius sp.	14	14	1.45	1.10	11.0
Archinemertea sp. A	20	9	1.37	10.1	3.4
Nemertea K	11	15	1.36	14.7	1.0
Oxyurostylis smithi	12	11	1.22	18.8	0.1
Pyrgophorus platyrachus	6	21	1.19	0.3	13.0
Glycera americana	17	7	1.18	20.7	0.3
Anomalocardia auberiana	14	9	1.17	17.4	1.0
Dry Season (2005)					
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Dominance**	**Mean Salinity at Capture (ppt)**	**Mean Center of Abundance (RKm)**
Grandidierella bonnieroides	76	3,668	42.96	14.9	6.5
Apocorophium louisianum	48	3,552	33.59	14.6	6.9
Ampelisca abdita	43	2,135	24.65	15.3	3.0
Cyathura polita	61	657	16.29	14.5	6.9
Amygdalum papyrium	27	954	13.05	15.0	1.8
Tubificidae	35	655	12.32	11.9	11.9
Gammarus tigrinus	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.					
Dry Season (2005)					
Taxon	**Frequency of Occurrence**	**Mean Density (#/m^2)**	**Dominance**	**Mean Salinity at Capture (ppt)**	**Mean Center of Abundance (RKm)**
Corbicula fluminea	20	315	6.46	6.0	14.4
Heteromastus filiformis	24	196	5.58	14.7	2.7
Nemertea	27	169	5.49	16.9	2.6
Laeonereis culveri	29	116	4.73	15.7	5.5
Euplana gracilis	18	123	3.83	14.3	3.8
Tubificoides heterochaetus	13	144	3.52	14.3	7.7
Aricidea philbinae	7	256	3.44	15.5	0.9
Ampelisca holmesi	6	267	3.26	14.4	1.7
Monticellina dorsobranchialis	8	148	2.80	16.7	0.2
Athenaria	3	335	2.58	15.5	2.1
Polypedilum scalaenum	13	68	2.43	10.1	10.8
Cryptochironomus sp.	13	62	2.30	15.2	11.6
Xenanthura brevitelson	11	64	2.16	15.9	3.5
Leptochelia sp.	5	135	2.11	14.3	2.0
Streblospio gynobranchiata	13	48	2.03	14.1	4.6
Polymesoda caroliniana	12	48	1.95	12.4	6.4
Apocorophium lacustre	4	132	1.87	5.4	14.0
Bivalvia	10	50	1.82	12.0	5.7
Hobsonia florida	14	34	1.78	17.3	5.0
Cladotanytarsus sp.	6	50	1.41	7.2	15.5
Hourstonius laguna	9	30	1.33	14.4	4.3
Tubificoides brownae	4	57	1.23	12.1	10.1
Eteone heteropoda	6	37	1.20	17.0	1.9
Cyclaspis cf. varians	8	25	1.15	16.2	2.6
Capitella capitata	7	27	1.13	10.1	2.7
Glycinde solitaria	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^2)**	**Dominance**	**Mean Salinity at Capture (ppt)**	**Mean Center of Abundance (RKm)**
Ameroculodes miltoni	5	27	0.95	16.3	2.3
Phyllodoce arenae	5	25	0.91	21.0	1.1
Edotea triloba	6	21	0.90	10.8	8.8
Neanthes succinea	6	21	0.90	19.6	2.4
Lyonsia floridana	6	18	0.85	22.6	0.9
Melita elongata	3	37	0.85	23.7	1.4
Polypedilum halterale	2	53	0.83	18.8	14.3
Paraprionospio pinnata	6	16	0.80	16.7	0.7
Fabricinuda triloba	5	18	0.78	16.1	0.6
Leitoscoloplos robustus	5	18	0.78	18.4	1.5
Procladius sp.	5	18	0.78	18.7	11.9
Mysella planulata	4	21	0.74	14.2	1.0
Mytilopsis leucophaeata	5	16	0.73	16.3	6.9
Oxyurostylis smithi	4	14	0.60	19.3	1.0
Tectidrilus wasselli	2	25	0.58	10.4	0.0
Mactra fragilis	3	14	0.52	17.2	0.8
Prionospio sp.	2	14	0.43	14.4	0.0

Thirty-four of the ranked dominants were most abundant in RKMs 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 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^{-2}).

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^{-2}) 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 seasone (*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
Nemertea										
Amphiporus bioculatus	Blue									
Archinemertea sp. A	Blue									
Nemertea sp. F		Blue								
Turbellaria										
Euplana gracilis		Red	Blue							
Polychaeta										
Aricidea philbinae	Gray									
Aricidea taylori	Gray									
Capitella capitata		Gray								
Eteone heteropoda	Blue	Red								
Fabricinuda triloba	Gray									
Glycera americana	Gray									
Glycinde solitaria	Gray									
Heteromastus filiformis		Red	Blue							
Hobsonia florida		Blue		Red						
Laeonereis culveri		Blue		Red						
Mediomastus sp.	Gray									
Monticellina cf. dorsobranchialis	Gray									
Neanthes succinea	Red	Blue								
Paraprionospio pinnata	Gray									
Prionospio heterobranchiata	Blue									
Scoloplos rubra	Gray									
Streblospio gynobranchiata	Blue		Red	Red						
Tubificidae										
Tubificoides brownae	Blue					Red				
Tubificoides heterochaetus						Red				
Tubificoides motei					Blue					
Tubificoides wasselli	Blue									
Gastropoda										
Acteocina canaliculata	Gray									
Haminoe succinea	Gray									
Nassarius vibex	Blue									
Bivalvia										
Amygdalum papyrium	Gray									
Anomalocardia auberniana	Gray									
Corbicula fluminea								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 seasone (*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
Lyonsia floridana	Gray									
Macoma tenta	Blue	Red				Red				
Mulinia lateralis	Gray									
Mysella planulata	Gray		Red	Red						
Mytilopsis leucophaeata			Red			Blue				
Polymesoda caroliniana				Gray						
Tagelus plebeius		Blue	Red	Red						
Cumacea										
Almyracuma cf. proximoculi							Blue			
Cyclaspis cf. varians	Gray									
Oxyurostylis smithi	Gray									
Isopoda										
Cyathura polita			Blue	Red						
Edotea triloba	Blue				Red					
Xenanthura brevitelson			Gray							
Tanaidacea										
Leptochelia sp.		Gray								
Amphipoda										
Ampelisca abdita	Red	Blue								
Ampelisca holmesi	Red	Blue								
Ampelisca vadorum			Gray							
Apocorophium louisianum			Blue		Red					
Cerapus spp.	Blue									
Gammarus cf. tigrinus								Red		
Grandidierella bonnieroides			Red	Red		Blue				
Hourstonius laguna			Gray							
Decapoda										
Pinnixa spp.	Blue									
Rhithropanopeus harrisii			Blue							
Chironomidae										
Chironomus sp.			Blue							
Cryptochironomus			Blue						Red	
Polypedilum halterale Group							Blue	Red		
Polypedilum scalaenum Group						Red	Blue			
Branchiopoda										
Glottidia pyramidata	Blue									

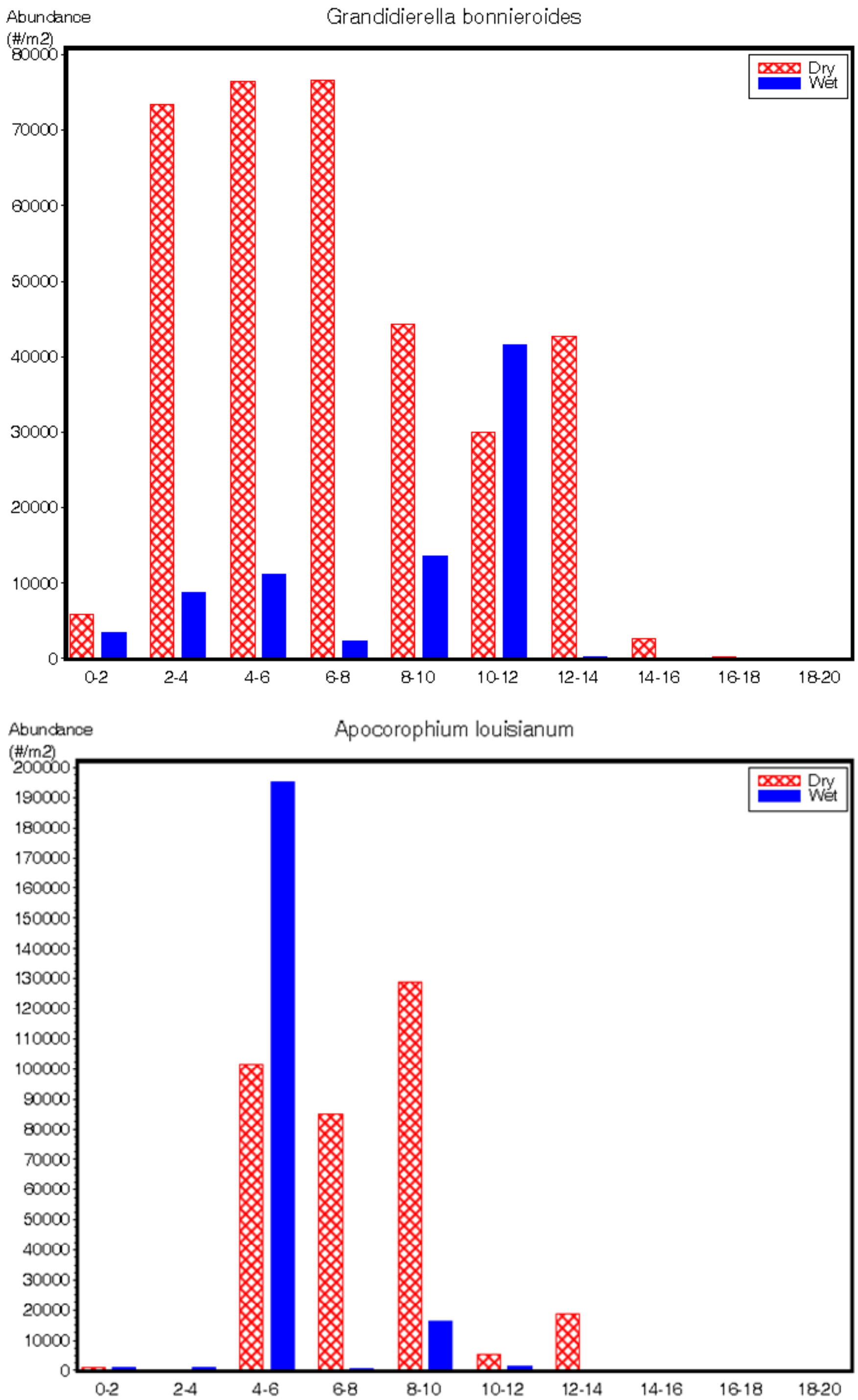


Figure 3-4. **Longitudinal distribution, by season, of the eight taxa with the highest overall Dominance Scores, Little Manatee River, 1996-2005.**

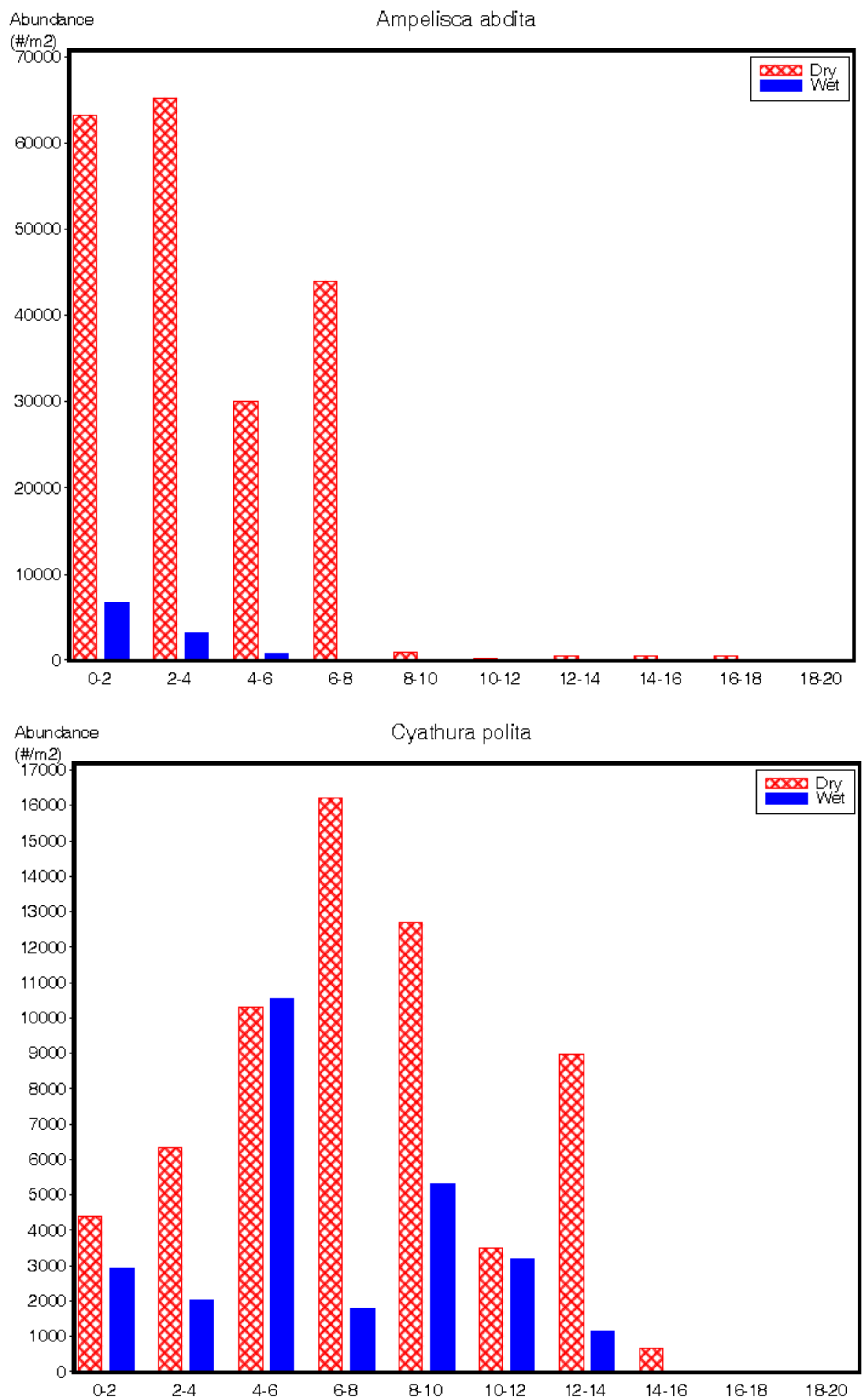
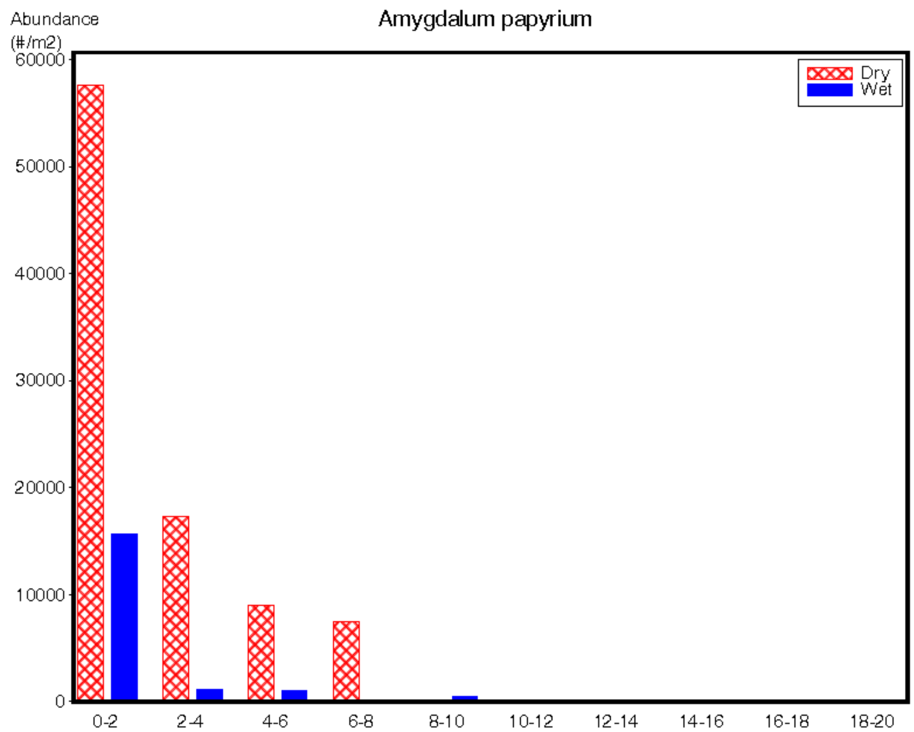


Figure 3-4. **continued.**



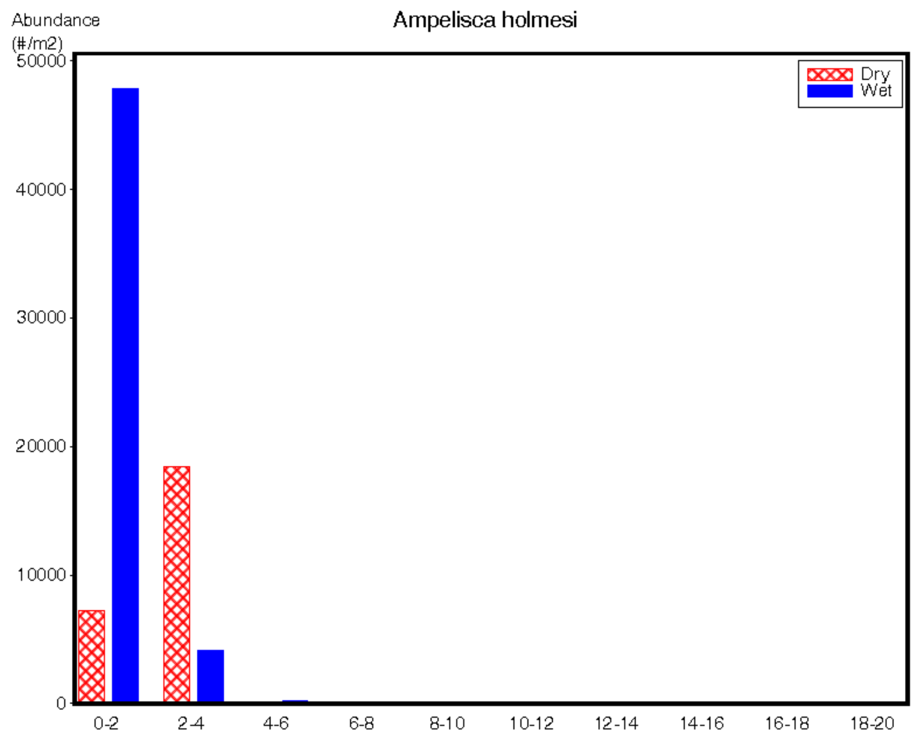
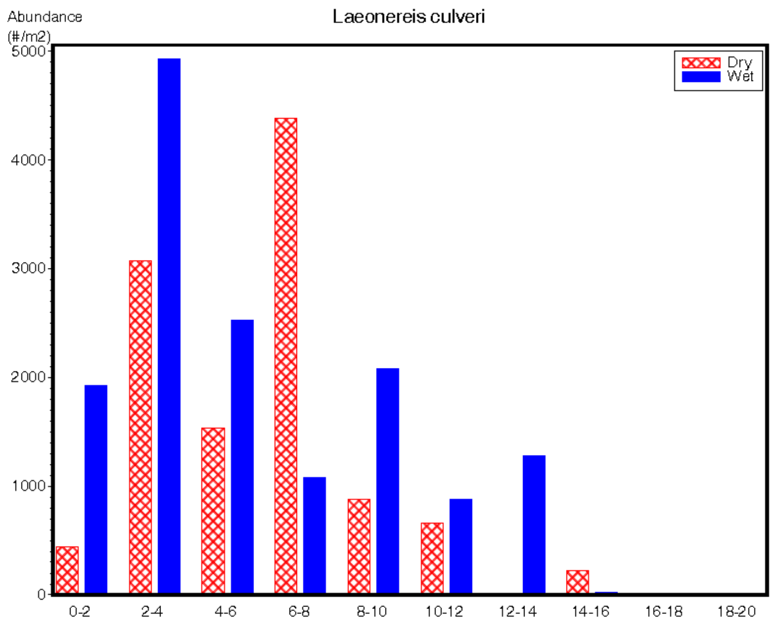


Figure 3-4. continued.



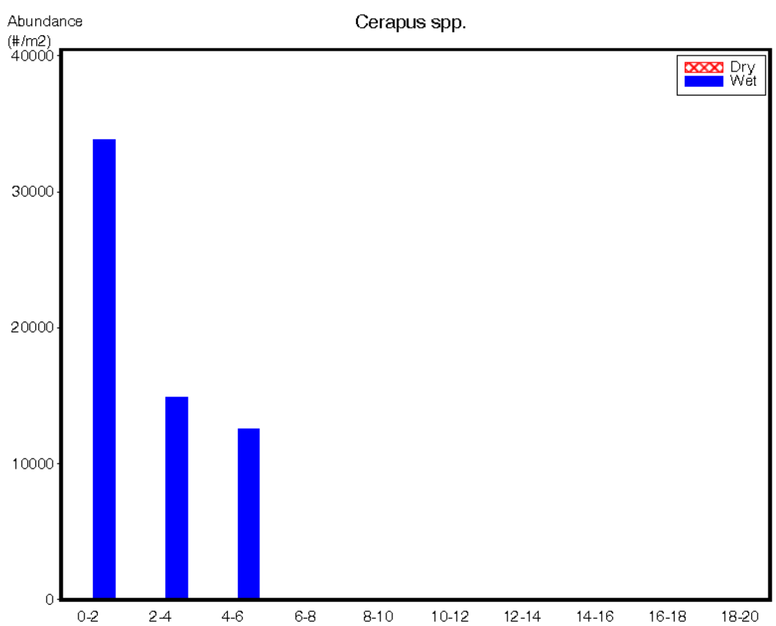


Figure 3-4. **continued.**

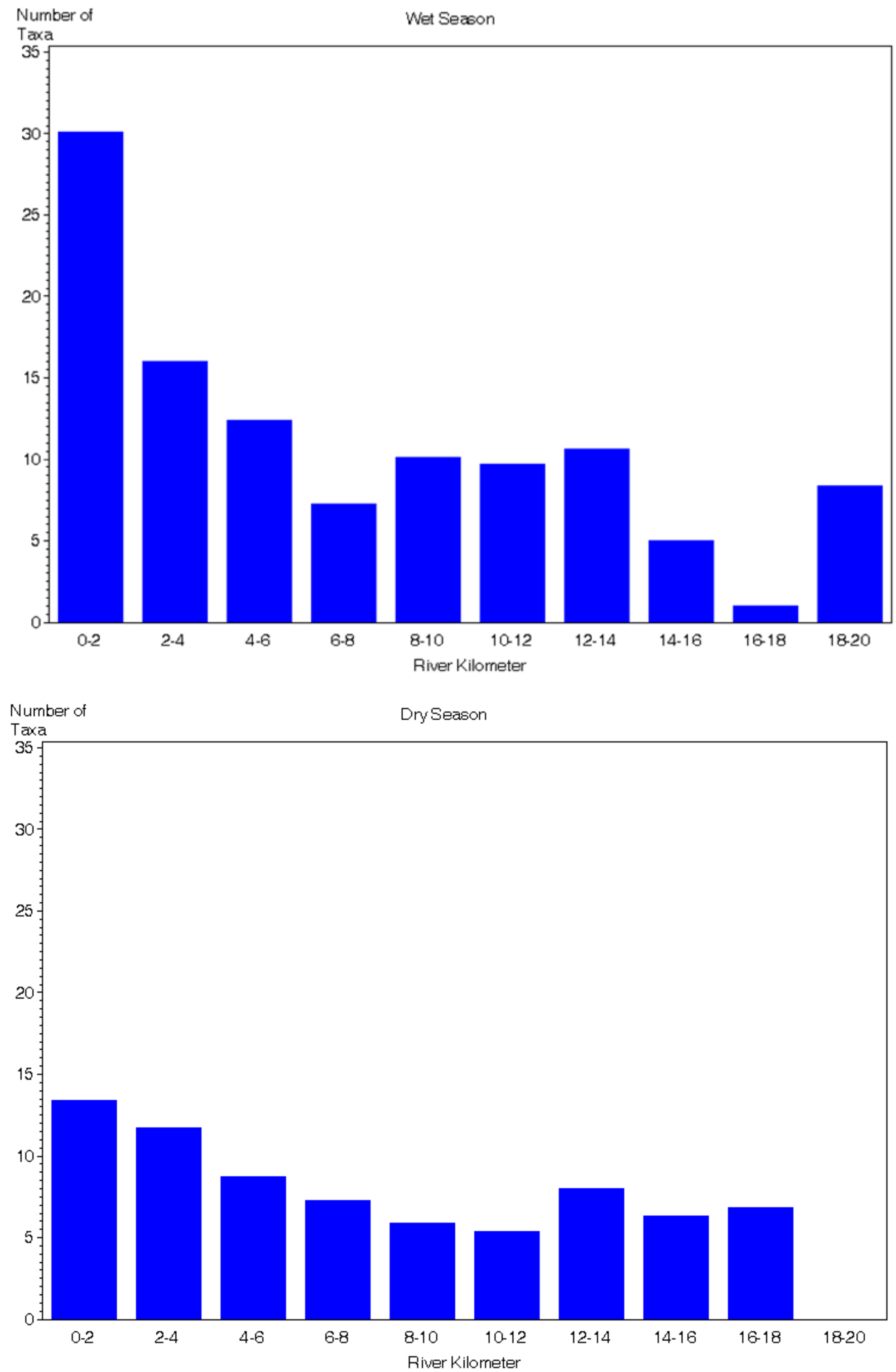


Figure 3-5. **Longitudinal distribution of the numbers of benthic taxa in the Little Manatee River, by season.** ***Wet and dry season numbers are <u>not</u> comparable the sampling gears used in each season sample different areas.***

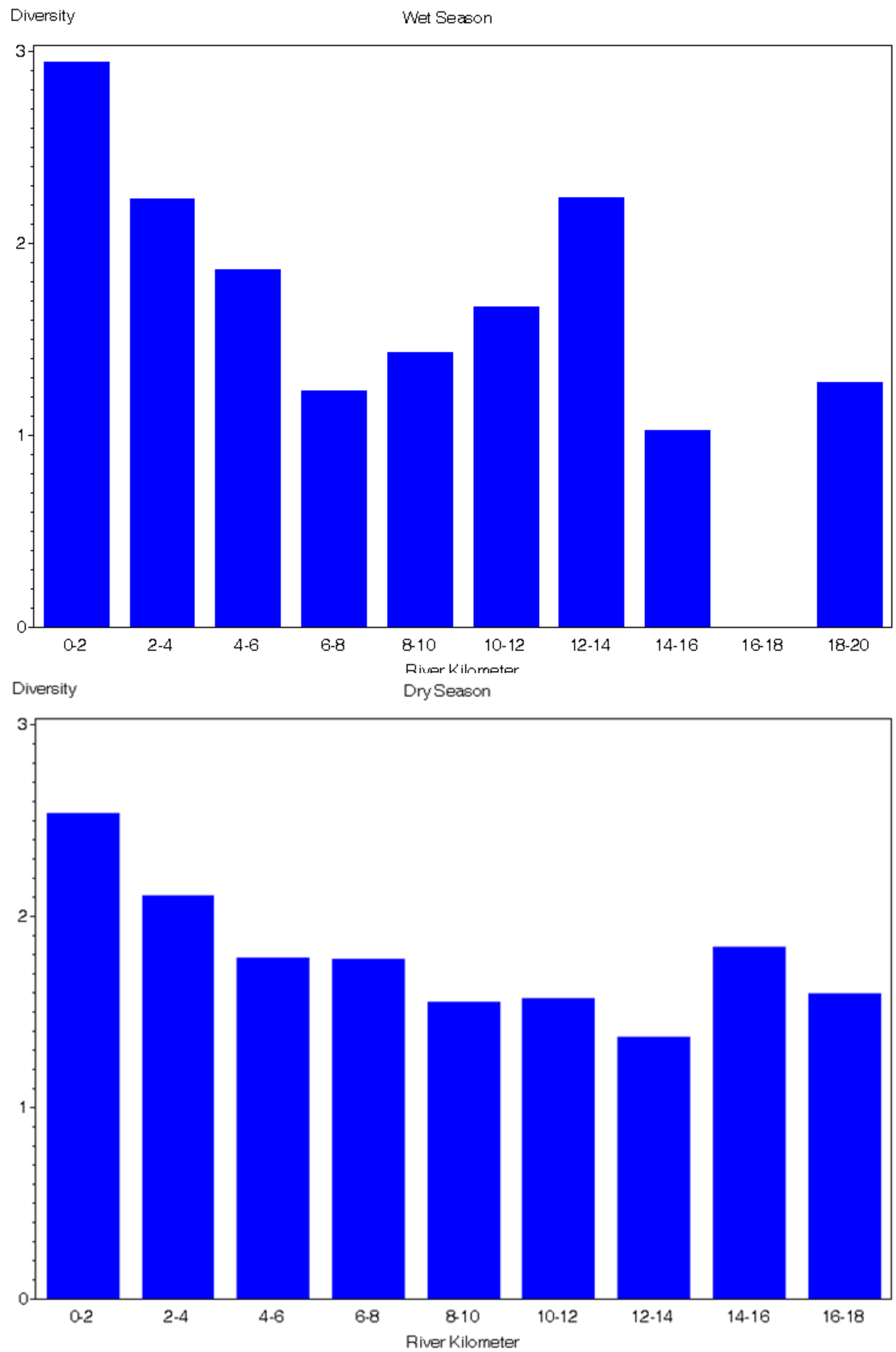


Figure 3-6. **Longitudinal distribution of Shannon-Wiener diversity in the Little Manatee River, by season.** ***Wet and dry season numbers are not comparable because the sampling gears used in each season sample different areas.***

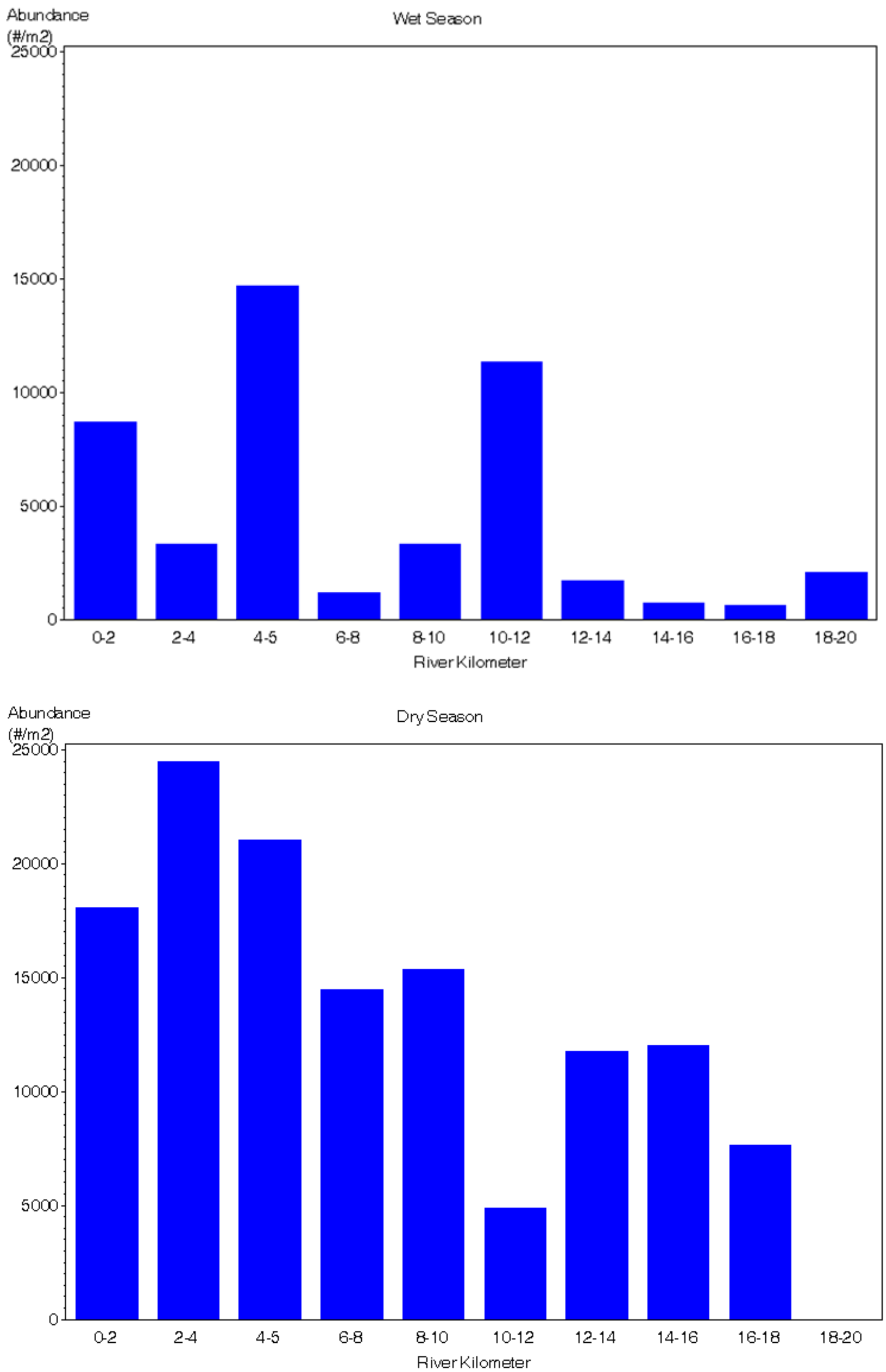


Figure 3-7. Longitudinal distribution of benthic abundance in the Little Manatee River, by season.

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^{-2}).

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^{-2}) did not appear to exhibit any longitudinal trend (Figure 3-7).

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 *p*<0.05 to be included.

Wet Season	R^2
Numbers of Taxa	
Y= 111.34 – (1.65*RKM) –(0.26*% silt+clay) + (1.18*DO) – (1.98*Temperature) – (46.3*Log_{10} 28-Day Flow) + (43.5*Log_{10} 56-Day Flow) - (6.95*Log_{10} 112-Day Flow)	0.42
Log_{10} Abundance	
Y= 6.22 – (0.05*RKM) – (0.03*% silt+clay) + (0.12*DO) - (0.78*Log_{10} 28-Day Flow)	0.23
Dry Season	
Numbers of Taxa	
Y= -107.38 – (0.52*RKM) – (0.09*% silt+clay) + (255.7*Log_{10} 112-Day Flow)	0.54
Log_{10} Abundance	
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.

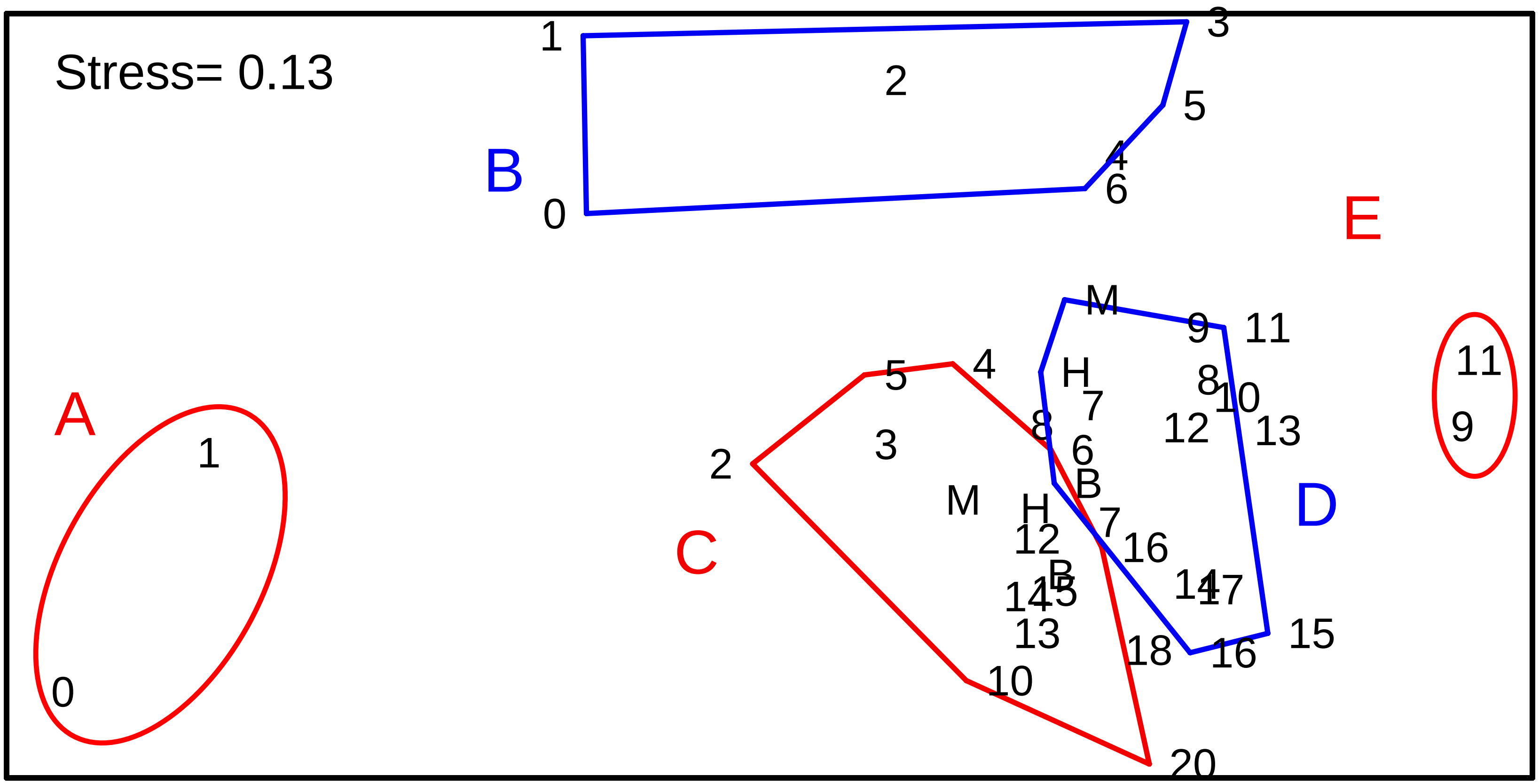


Figure 3-8. **MDS plot showing the similarity of the Little Manatee River benthos by season (dry and wet), river kilometer (0-20) and bayou (B = Bolster; H = Hayes; M = Mill) within the 1996-2004 wet seasons and the May 2005 dry season surveys. Subjectively identified Season-RKM groups are designated 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 (**)
Polychaeta										
Aricidea philbinae		A								
Monticellina dorsobranchialis		A	A							
Oligochaeta										
Tubificidae		B	D					D		E
Bivalvia										
Amygdalum papyrium	B	A			B	B				
Mysella planulata		A								
Isopoda										
Cyathura polita	B		D							
Amphipoda										
Ampelisca abdita	B				B	B				
Ampelisca holmesi	A	A	A							
Apocorophium louisianum	B		D			D		D		E
Cerapus spp.		A								
Gammarus cf. tigrinus			D							
Grandidierella bonnieroides	B	E	D		B			D		E
Brachiopoda										
Glottidia pyramidata		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 ρ_s is not established.*

This analysis showed that, in the 1996-2004 wet seasons, each of the ρ_s values for between one and five variables was <0.1 (Table 3-6). The ρ_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 ρ_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 ρ_s. The decline in ρ_s values with increasing numbers of variable shows that variables such as temperature (ρ_s=0.8), depth (ρ_s=0.11), *et al*. have little influence on community structure.

Table 3-6. Association (Spearman rank correlations, ρ_s) between benthic community structure in the Little Manatee River, 1996-2004 (wet seasons) and 2005 (dry season), and selected abiotic variables. Benthic abundances 4th root transformed; abiotic variables normalized; Euclidean distance. *Salinity measured at time of collection was excluded.*

1996-2004 Wet Seasons

Number of Variables	ρ_s	Log_{10} 56-day Cumulative Flow	Log_{10} 28-day Cumulative Flow	Log_{10} 112-day Cumulative Flow	River Kilometer	Log_{10} 14-day Cumulative Flow
1	0.09					
2	0.09					
3	0.07					
4	0.06					
5	0.03					

2005 Dry Season

Number of Variables	ρ_s	River Kilometer	Temperature	Depth	Dissolved Oxygen	% Silt + Clay
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:

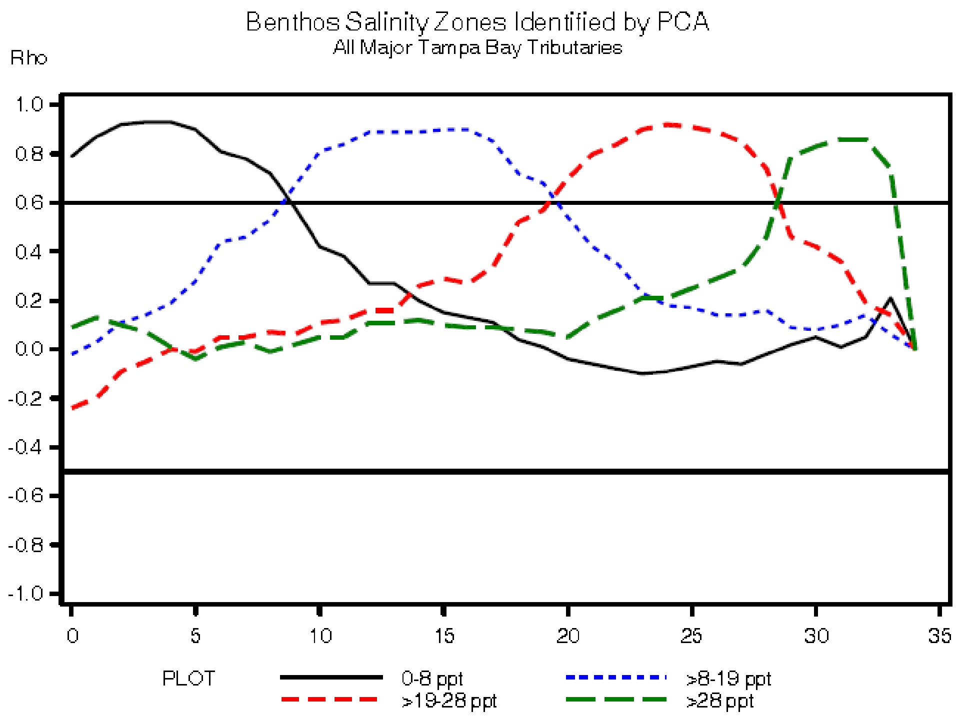
- ~0-8 ppt (Varimax rotated); and
- ~0-7 ppt (unrotated).

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.



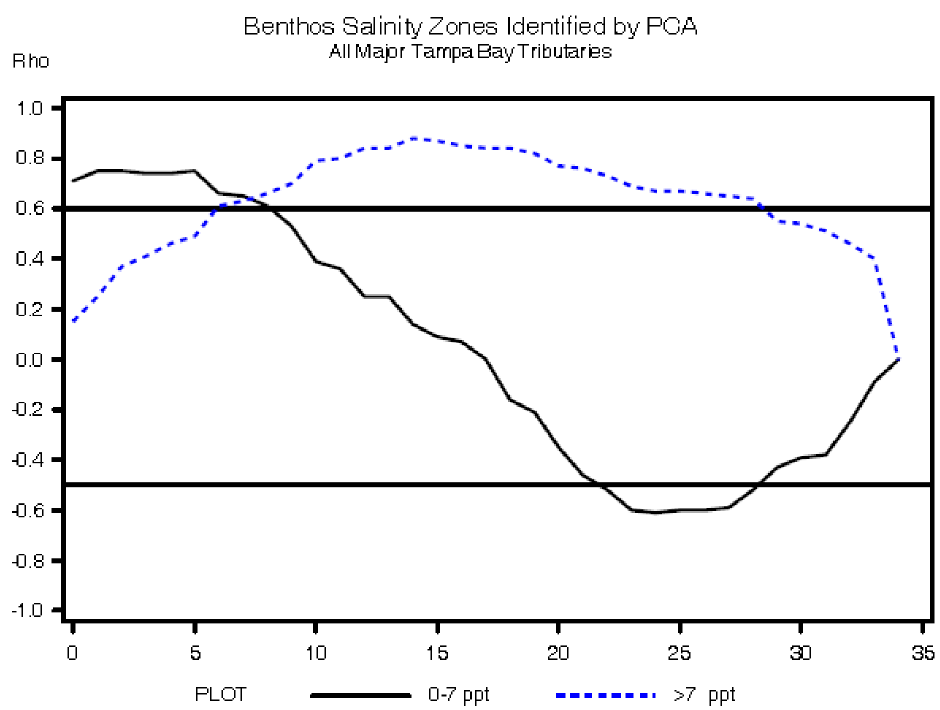


Figure 3-9. **Salinity classes based upon the distribution of the benthos from five Tampa Bay area tidal rivers (From Janicki Environmental, Inc., 2007a). Top: Varimax rotation; Bottom: not rotated.**

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	*Apocorophium louisianum*	*Amygdalum papyrium*
Cyathura polita	*Grandidierella bonnieroides*	*Cyathura polita*
Grandidierella bonnieroides		*Ampelisca abdita*
		Grandidierella bonnieroides

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 (***)
Annelida							
Aricidea philbinae						P	
Laeonereis culveri		O					
Monticellina dorsobranchialis						P	
Tubificidae		O				M	
Bivalvia							
Amygdalum papyrium						P	
Corbicula fluminea	D						
Isopoda							
Cyathura polita		O		D		M	D
Xenanthura brevitelson		M					
Amphipoda							
Ampelisca abdita				D			D
Ampelisca holmesi						P	W
Apocorophium louisianum		M		D		P	D
Cerapus sp.						P	
Gammarus cf. tigrinus	D						
Grandidierella bonnieroides	D	O		D		M	D
Chironomidae							
Polypedilum scalaenum Group		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.

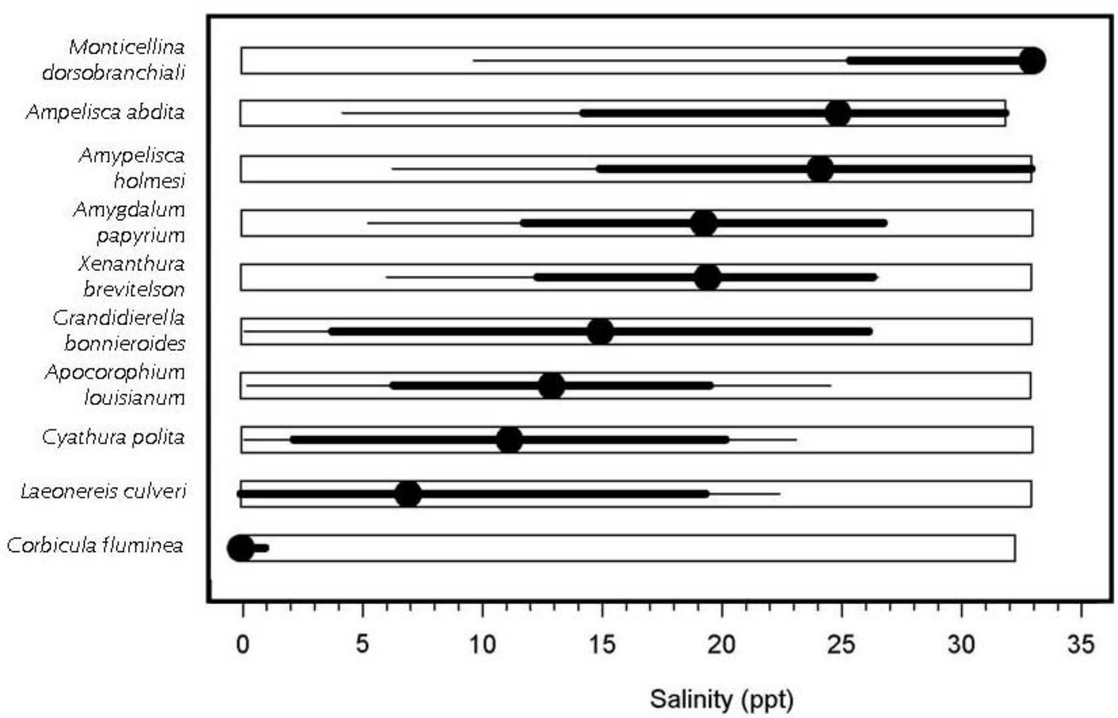


Figure 3-10. Summary of salinity optimum (circle), optimal habitat range (solid bar), 10th to 90th percentile probability of occurrence (thin line), and model domain (open bar) of salinity for ten selected benthic taxa derived from 12 southwest Florida tidal rivers (wet and dry seasons) by Janicki Environmental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

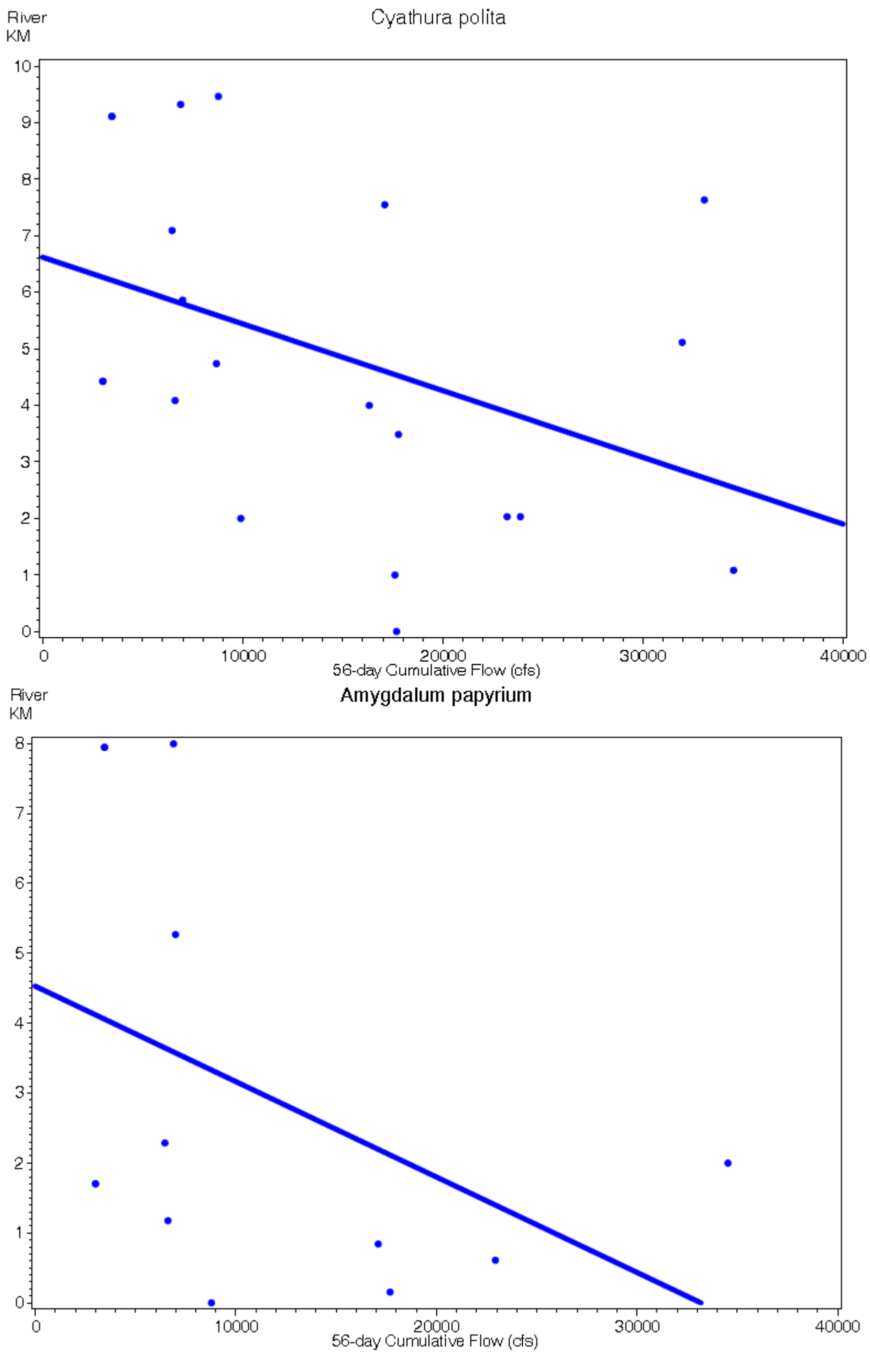


Figure 3-11. Relationship between the Center of Abundance (as RKM) for *Cyathura polita* and *Amygdalum papyrium* in the Little Manatee River, 1996-2005, and different flow regimes (as the cumulative flow over 56-days).

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 acgue 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*. 2nd 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 unimpounded 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)

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

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Archinemertea sp. A	20	59	50	175
Cyclaspis cf. varians	20	348	150	1625
Glottidia pyramidata	20	1,268	288	11,775
Capitella capitata	19	109	50	800
Fabricinuda triloba	18	611	238	3,575
Glycinde solitaria	18	51	25	175
Amphiporus bioculatus	17	259	175	850
Glycera americana	17	60	50	150
Hydrobiidae	17	204	50	1,925
Mulinia lateralis	17	322	175	1,925
Scoloplos rubra	17	57	25	175
Tubificoides motei	17	768	275	5,650
Aricidea taylori	16	322	113	1,500
Chironomus sp.	16	166	75	1,150
Cryptochironomus sp.	16	66	50	200
Gastropoda	16	53	25	175
Haminoea succinea	16	119	63	450
Mediomastus sp.	15	65	25	200
Polypedilum halterale	15	271	75	1,675
Tubificoides wasselli	15	543	125	2,850
Anomalocardia auberiana	14	88	75	325
Procladius sp.	14	134	50	750
Almyracuma proximoculi	13	71	50	200
Leitoscoloplos robustus	13	77	50	175
Nemertea F	13	77	50	250
Macoma tenta	12	190	75	1,075
Oxyurostylis smithi	12	129	38	525
Pinnixa spp.	12	67	38	325
Prionospio heterobranchia	12	110	88	375
Hourstonius laguna	11	127	75	350
Nemertea K	11	191	100	675
Paraprionospio pinnata	11	75	50	325
Sphenia antillensis	11	80	50	275

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Tellina cf. versicolor	11	141	100	475
Abra aequalis	10	103	25	325
Chironomidae	10	50	38	125
Magelona pettiboneae	10	75	50	150
Phascolion cryptum	10	48	38	125
Rangia cuneata	10	60	38	200
Astyris lunata	9	36	25	75
Gammarus mucronatus	9	50	25	200
Podarkeopsis levifuscina	9	89	50	225
Sabaco americanus	9	31	25	50
Eteone heteropoda	8	31	25	50
Prionospio perkinsi	8	219	150	525
Stenoninereis martini	8	97	63	275
Thenaria E	8	88	38	375
Apoprionospio pygmaea	7	89	50	175
Bowmaniella floridana	7	39	25	75
Cirripedia	7	2,882	50	19,000
Macoma constricta	7	50	50	100
Neanthes succinea	7	150	50	650
Nereiphylla castanea	7	86	75	200
Scolelepis texana	7	39	25	75
Tagelus divisus	7	50	50	100
Tubulanus pellucidus	7	43	25	100
Dipolydora socialis	6	146	88	500
Erpobdella punctata	6	46	25	150
Lyonsia floridana	6	46	25	125
Melinna maculata	6	33	25	50
Notomastus hemipodus	6	54	25	175
Phyllodoce arenae	6	54	50	100
Polydora cornuta	6	133	100	375
Pyrgophorus platyrachus	6	488	363	1,250
Tellina tampaensis	6	46	38	75

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Amphilocidae	5	110	75	300
Caecum pulchellum	5	60	50	100
Carazziella hobsonae	5	45	25	125
Corbicula fluminea	5	1,580	1,175	3,725
Enteropneusta	5	70	75	125
Gammarus tigrinus	5	35	25	75
Littoridinops palustris	5	305	50	950
Lucinisca nassula	5	85	25	200
Mediomastus californiensis	5	225	50	925
Odostomia spp.	5	85	100	150
Ophiuroidea	5	70	75	125
Paramphinome sp. B	5	60	50	100
Sigambra tentaculata	5	60	25	150
Teinostoma biscaynense	5	60	75	100
Tellina sp.	5	35	25	75
Veneroida	5	120	25	475
Ambidexter symmetricus	4	56	25	150
Cladotanytarsus daviesi	4	300	288	550
Dicrotendipes sp.	4	31	25	50
Euplana gracilis	4	119	88	275
Eustylochus meridianalis	4	50	50	75
Hemipholis elongata	4	200	125	500
Holothuroidea C	4	31	25	50
Laevicardium mortoni	4	69	63	125
Littoridinops 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
Paracladopelma doris	4	31	25	50
Phoronis sp.	4	50	38	100
Rudilemboides naglei	4	100	88	200
Tanytarsus sp.	4	256	25	950

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Tectonatica pusilla	4	44	25	100
Tellina iris	4	163	100	425
Tellina tenella	4	31	25	50
Bittiolum varium	3	67	75	100
Ceratopogonidae	3	58	25	125
Cladotanytarsus sp.	3	233	50	600
Cymadusa compta	3	33	25	50
Diopatra cuprea	3	25	25	25
Diplodonta semiaspera	3	25	25	25
Erichsonella attenuata	3	158	200	250
Glyptotendipes sp.	3	58	25	125
Hartmanodes nyei	3	25	25	25
Kinbergonuphis simoni	3	25	25	25
Leitoscoloplos fragilis	3	83	50	175
Mediomastus ambiseta	3	108	125	175
Melita elongata	3	25	25	25
Micrura leidyi	3	75	25	175
Nais communis sp	3	108	75	225
Nemertea B	3	25	25	25
Nereiphylla fragilis	3	25	25	25
Onobops sp.	3	25	25	25
Ophiodromus obscura	3	75	50	125
Ophiophragmus filograneus	3	25	25	25
Parahesione luteola	3	58	75	75
Parastarte triquetra	3	592	25	1,725
Sayella hemphillii	3	33	25	50
Synaptidae sp. A	3	42	50	50
Tanypus stellatus	3	50	50	75
Tanytarsus H	3	50	50	75
Tubulanus sp. B	3	33	25	50
Zygeupolia cf. rubens	3	25	25	25
Amphioplus thrombodes	2	150	150	150
Asthenothaerus hemphilli	2	25	25	25
Athenaria	2	225	225	350
Branchiostoma floridae	2	25	25	25

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

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
punctostriatus				
Sigambra bassi	2	38	38	50
Sphaerium sp.	2	25	25	25
Sphaerosyllis longicauda	2	25	25	25
Spio pettiboneae	2	38	38	50
Spiochaetopterus costarum	2	25	25	25
Syllis gracilis	2	25	25	25
Tagelus sp.	2	25	25	25
Thalassodrilides sp.	2	25	25	25
Thenaria G	2	25	25	25
Turbellaria C	2	50	50	75
Turbonilla dalli	2	25	25	25
Vitrinella floridana	2	88	88	100
Ablabesmyia rhamphe	1	25	25	25
Alpheidae	1	50	50	50
Americamysis almyra	1	25	25	25
Americamysis stucki	1	25	25	25
Ampharetidae	1	50	50	50
Amphioplus sepultus	1	25	25	25
Amphipholis atra	1	25	25	25
Amphipholis gracillima	1	25	25	25
Anisoptera sp.	1	25	25	25
Anthozoa sp. A	1	25	25	25
Bhawania heteroseta	1	75	75	75
Busycotypus spiratus	1	25	25	25
Cabira incerta	1	25	25	25
Carinoma cf. tremaphoros	1	25	25	25
Cephalocardida	1	25	25	25
Cerebratulus lacteus	1	25	25	25
Chaoborus sp.	1	25	25	25
Chione elevata	1	25	25	25
Chironomini sp.	1	25	25	25
Cirrophorus sp.	1	25	25	25
Cladopelma sp.	1	75	75	75
Cladotanytarsus sp. A	1	50	50	50

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Cladotanytarsus sp. F	1	50	50	50
Collembola	1	25	25	25
Cumacea	1	25	25	25
Cyclinella tenuis	1	50	50	50
Cyrenoida floridana	1	125	125	125
Dasybranchus lumbricoides	1	25	25	25
Dicrotendipes lobus	1	25	25	25
Einfeldia natchitocheae	1	400	400	400
Einfeldia sp. A	1	575	575	575
Elysiidae	1	25	25	25
Eobrolgus spinosus	1	25	25	25
Eudevenopus honduranus	1	75	75	75
Exogone dispar	1	25	25	25
Fargoa gibbosa	1	25	25	25
Gemma gemma	1	50	50	50
Goniadidae	1	25	25	25
Grubeosyllis clavata	1	25	25	25
Gyptis crypta	1	25	25	25
Halacaridae	1	275	275	275
Haminoea sp.	1	50	50	50
Harrieta faxoni	1	25	25	25
Hexapanopeus sp.	1	25	25	25
Hutchinsoniella sp.	1	25	25	25
Isopoda	1	175	175	175
Kalliapseudes macsweenyi	1	25	25	25
Laseidae	1	150	150	150
Leitoscoloplos sp.	1	50	50	50
Limnodriloides baculatus	1	100	100	100
Littoridinops monroensis	1	75	75	75
Loimia medusa	1	50	50	50
Macoma sp. A	1	25	25	25
Micropthalmus sp A	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

Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Neverita duplicata	1	25	25	25
Notomastus americanus	1	25	25	25
Notomastus cf. tenuis	1	25	25	25
Notomastus n. sp	1	25	25	25
Notomastus sp.	1	75	75	75
Olivella pusilla	1	50	50	50
Ophiophragmus wurdemanii	1	25	25	25
Orobitella floridana	1	25	25	25
Pagurus sp.	1	25	25	25
Panopeus sp.	1	25	25	25
Paradoneis lyra	1	125	125	125
Parakiefferiella sp. F	1	50	50	50
Parvilucina multilineata	1	50	50	50
Petitilla crosseana	1	25	25	25
Phascolion cf. caupo	1	50	50	50
Phoronida *B*	1	25	25	25
Phyllodoce mucosa	1	25	25	25
Pinnixa A	1	100	100	100
Pinnixa D	1	100	100	100
Pinnixa pearsei	1	175	175	175
Pisidium punctiferum	1	50	50	50
Polymesoda caroliniana	1	25	25	25
Pseudochironomus sp.	1	25	25	25
Pyramidellidae	1	75	75	75
Pyrgocythara plicosa	1	100	100	100
Rheosmittia arcuata	1	175	175	175
Rissoidae	1	25	25	25
Sayella laevigata	1	175	175	175
Scolelepis squamata	1	25	25	25
Sinelobus stanfordi	1	25	25	25
Sinum perspectivum	1	25	25	25
Sipuncula	1	25	25	25
Sphaerosyllis	1	25	25	25

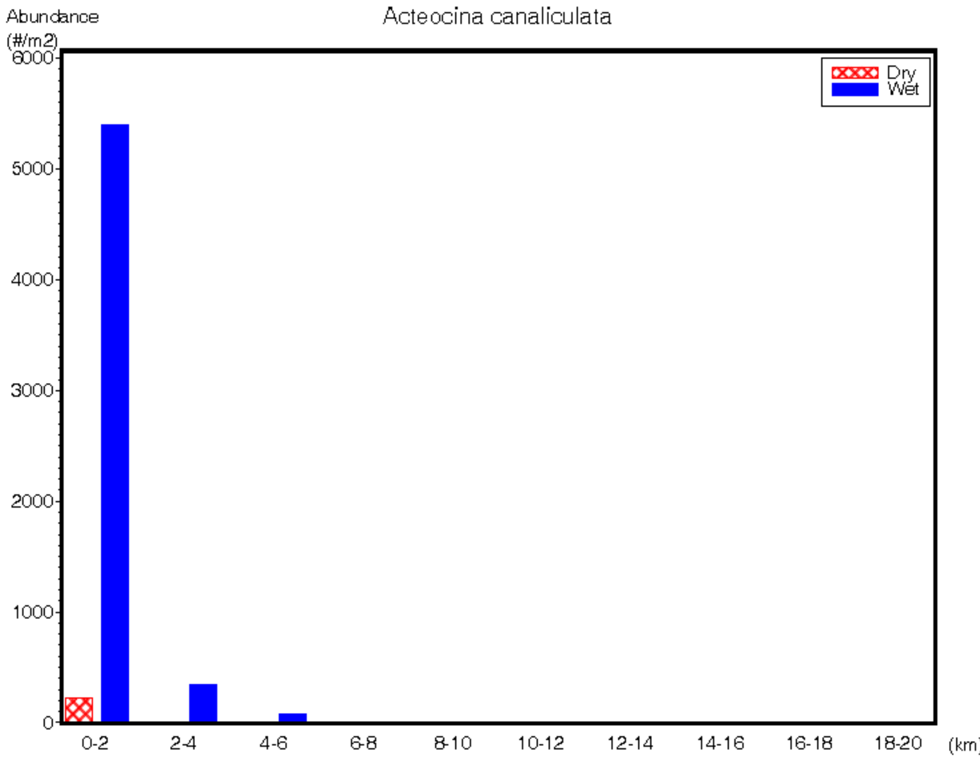
Wet Seasons (1996-2004)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m^2)**	**Median Density (#/m^2)**	**Maximum Density (#/m^2)**
labyrinthophila				
Stephensonia trivandrana	1	350	350	350
Syllidae	1	25	25	25
Syllis (typosyllis) tortugaensi	1	25	25	25
Syllis sp.	1	100	100	100
Synalpheus sp.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

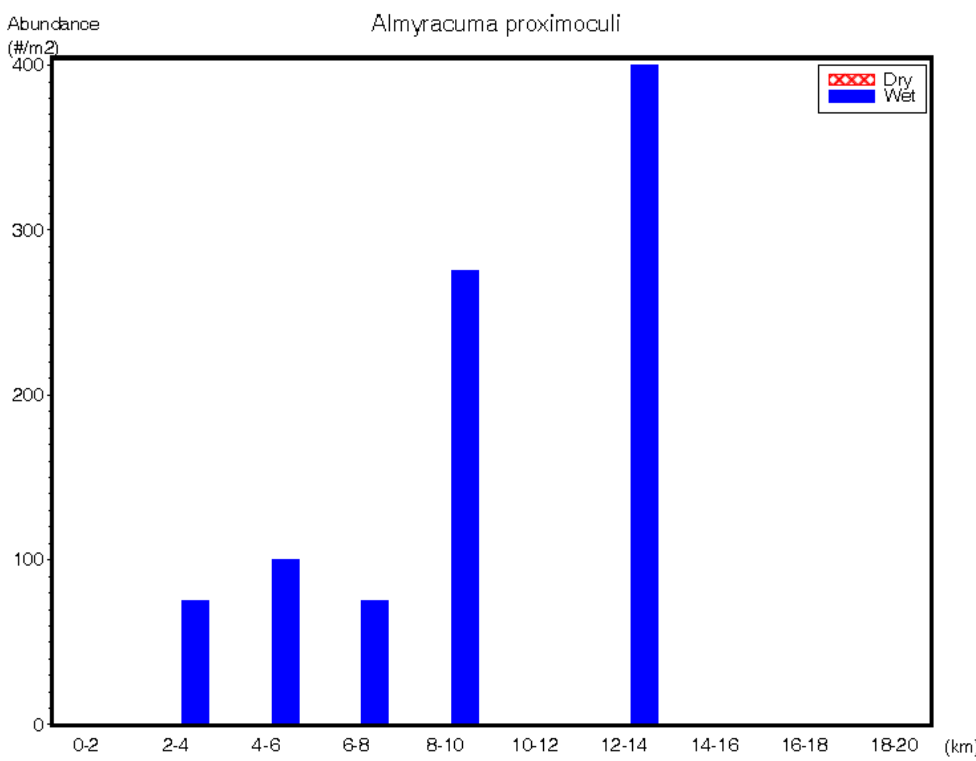
Dry Season (2005)				
Taxon	**Frequency of Occurrence**	**Mean Density (#/m²)**	**Median Density (#/m²)**	**Maximum Density (#/m²)**
Grandidierella bonnieroides	76	4,634	2,409	26,280
Cyathura polita	61	1,034	876	3,723
Apocorophium louisianum	48	7,104	1,971	63,291
Ampelisca abdita	43	4,767	1,971	28,470
Tubificidae	35	1,796	876	8,322
Laeonereis culveri	29	385	219	1,095
Amygdalum papyrium	27	3,390	1,752	15,111
Nemertea	27	600	219	3,285
Gammarus tigrinus	26	2,190	767	18,396
Heteromastus filiformis	24	785	438	2,847
Corbicula fluminea	20	1,511	986	5,256
Euplana gracilis	18	657	329	4,380
Hobsonia florida	14	235	219	438
Cryptochironomus sp.	13	455	219	1,533
Polypedilum scalaenum	13	505	438	1,752
Streblospio gynobranchiata	13	354	219	657
Tubificoides heterochaetus	13	1,061	438	5,037
Polymesoda caroliniana	12	383	219	1,314
Xenanthura brevitelson	11	557	219	1,971
Bivalvia	10	482	329	1,752
Hourstonius laguna	9	316	219	657
Cyclaspis cf. varians	8	301	219	876
Monticellina dorsobranchialis	8	1,779	1,314	5,913
Aricidea philbinae	7	3,504	1,533	17,301
Capitella capitata	7	375	219	876
Ampelisca holmesi	6	4,271	1,643	18,177
Cladotanytarsus sp.	6	803	876	1,314
Edotea triloba	6	329	219	657
Eteone heteropoda	6	584	329	1,971
Glycinde solitaria	6	511	438	876
Lyonsia floridana	6	292	219	438
Neanthes succinea	6	329	329	438

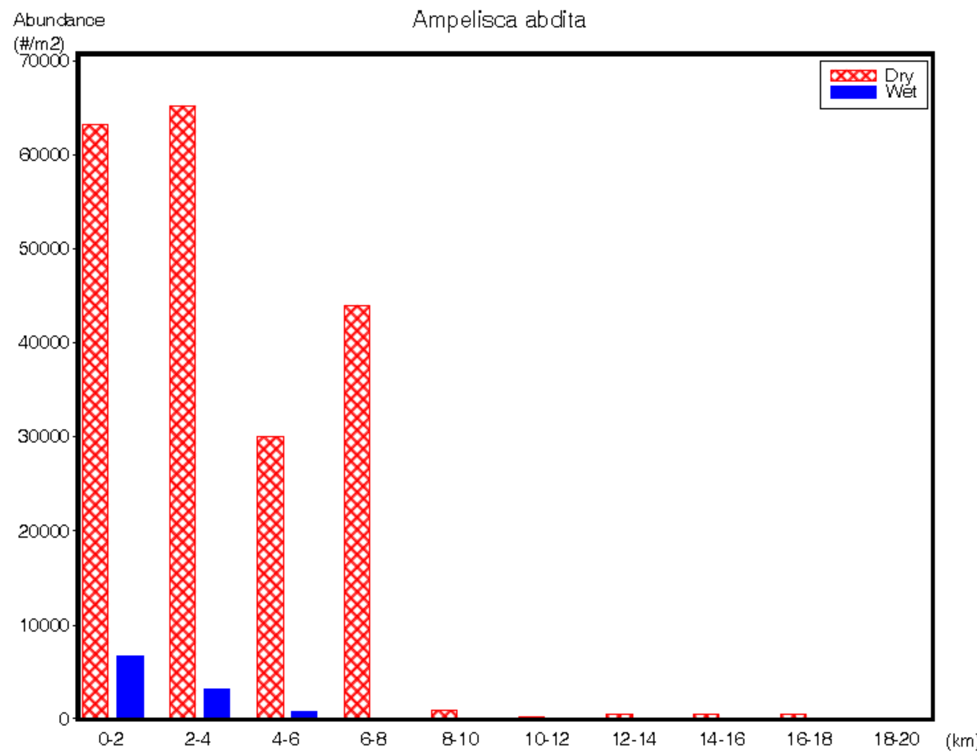
Paraprionospio pinnata	6	256	219	438
Ameroculodes miltoni	5	526	438	876
Fabricinuda triloba	5	350	219	657
Leitoscoloplos robustus	5	350	219	876
Leptochelia sp.	5	2,584	657	10,512
Mytilopsis leucophaeata	5	307	219	657
Phyllodoce arenae	5	482	438	876
Procladius sp.	5	350	438	438
Apocorophium lacustre	4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

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

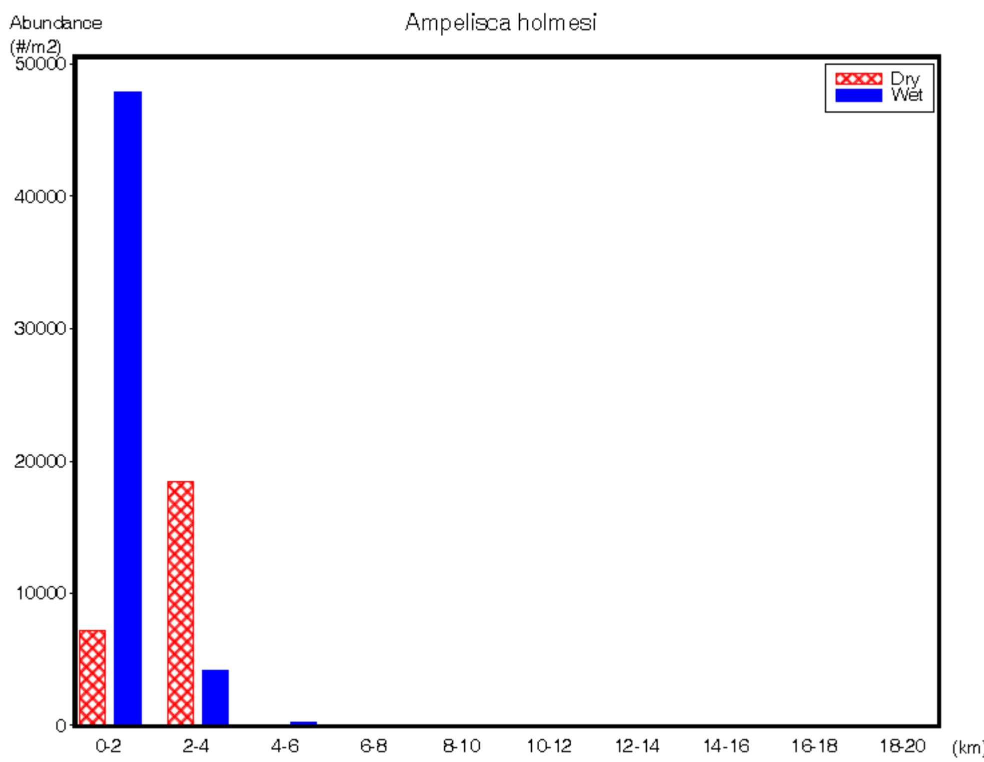
APPENDIX B: Longitudinal Distribution, by Season, of Taxa Occurring in ≥5% of Benthic Samples Collected in the Little Manatee River, 1996-2005



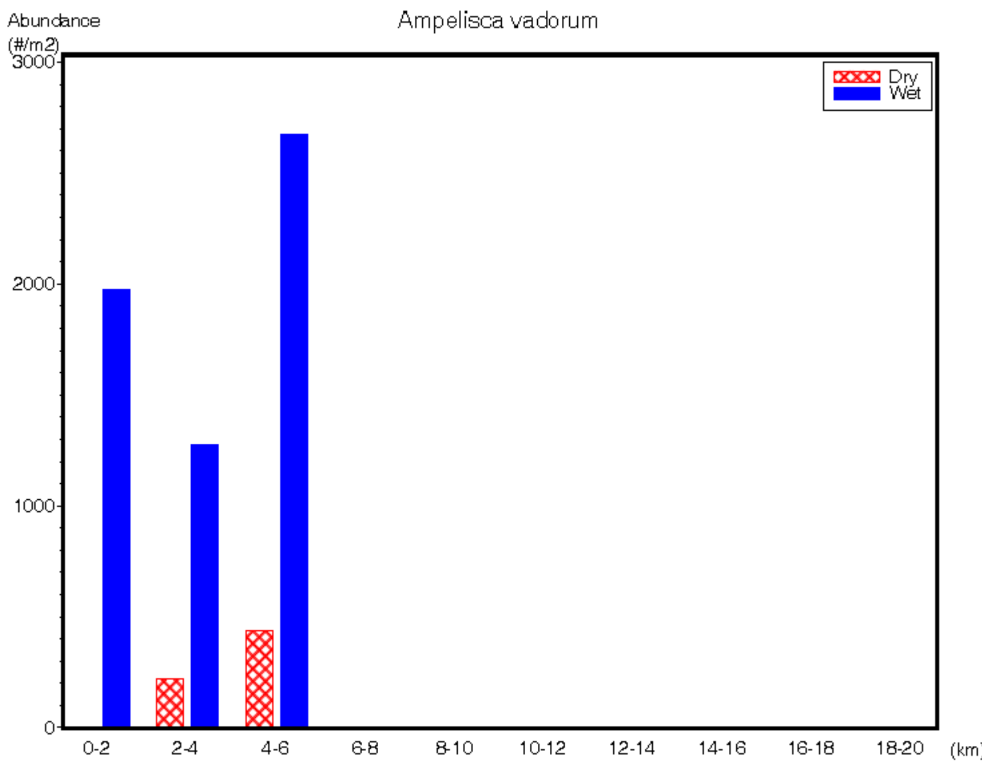




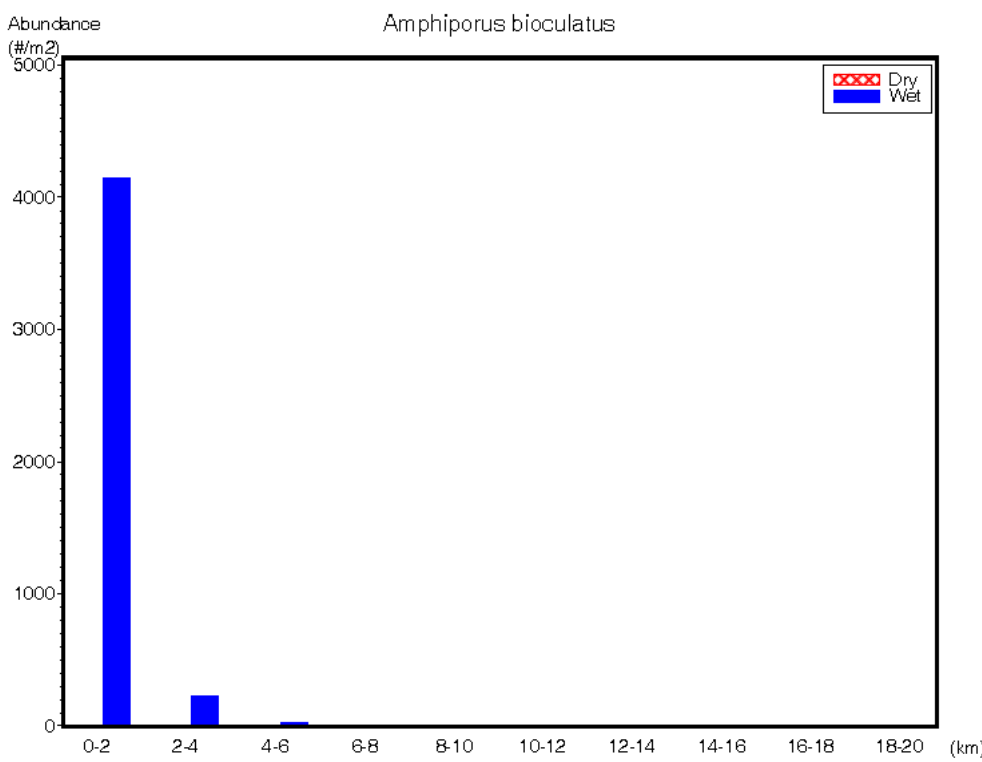
Ampelisca abdita
Abundance
(#/m2)
70000
60000
50000
40000
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)



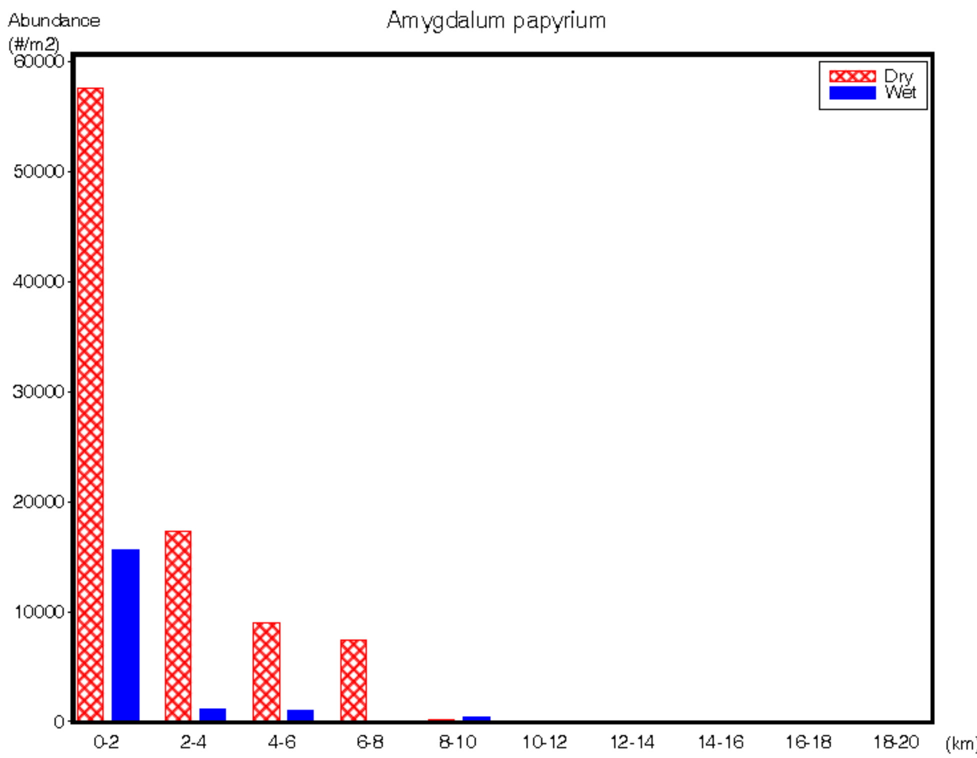
Ampelisca holmesi
Abundance
(#/m2)
50000
40000
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

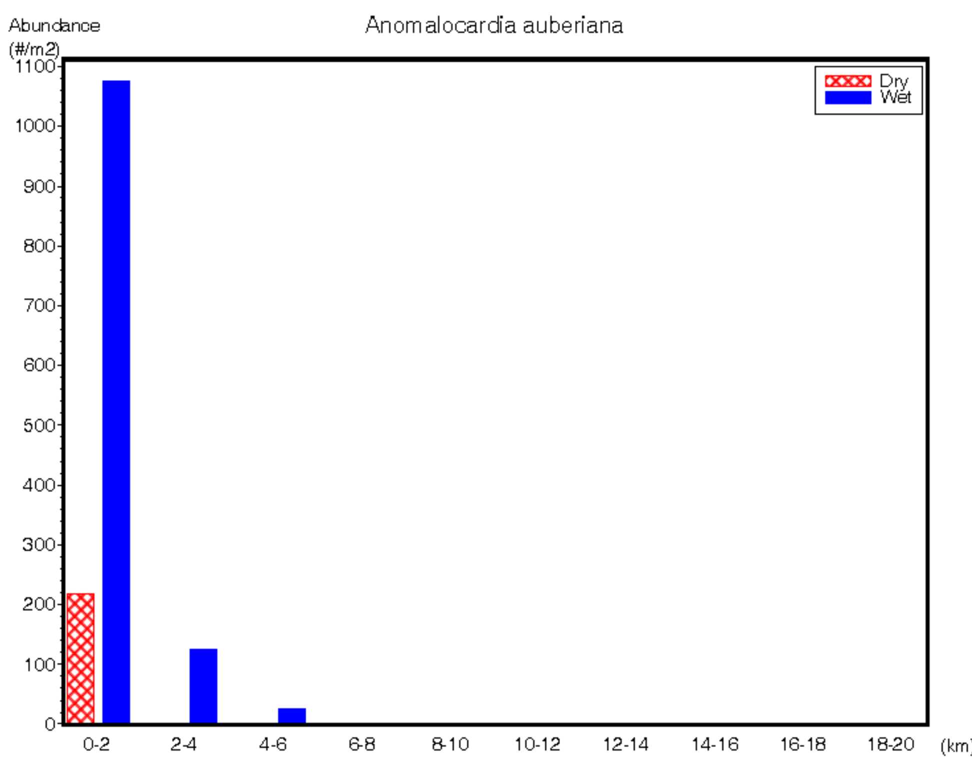


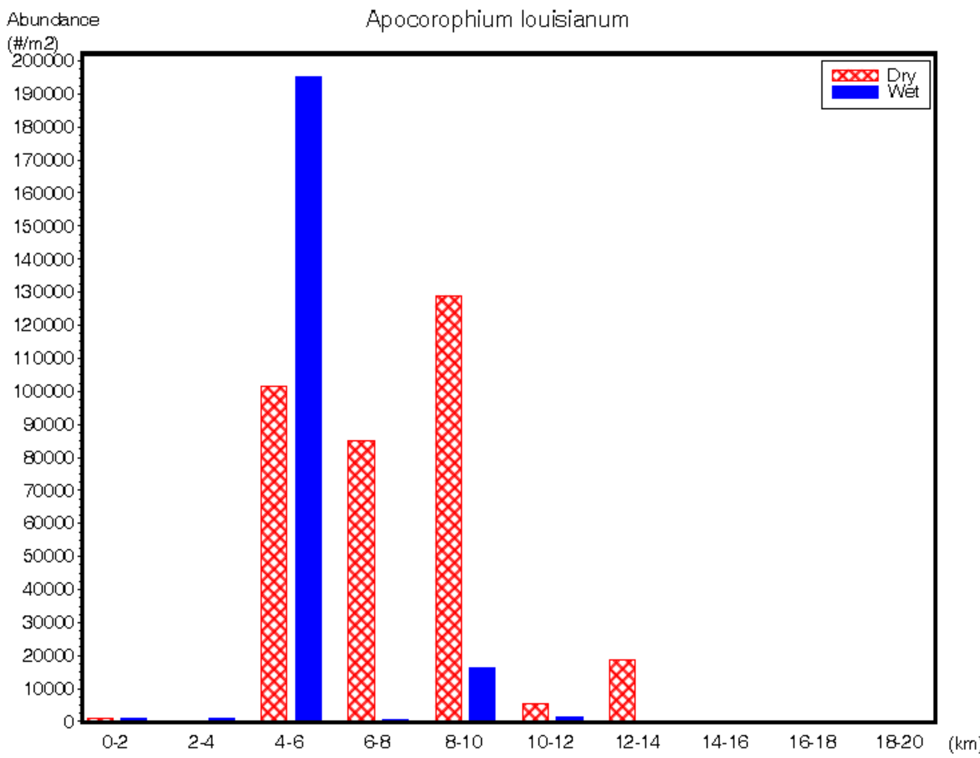
Abundance
(#/m2)
Ampelisca vadorum
Dry
Wet
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)



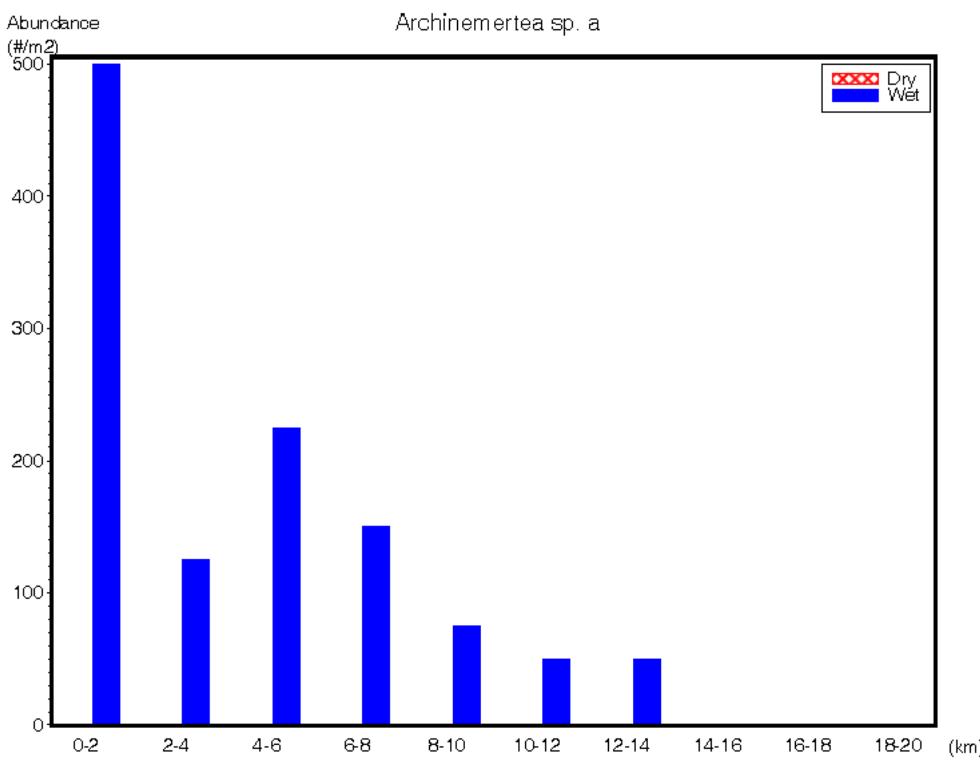
Abundance
(#/m2)
Amphiporus bioculatus
Dry
Wet
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Amygdalum papyrium
Abundance
(#/m2)
60000
50000
40000
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

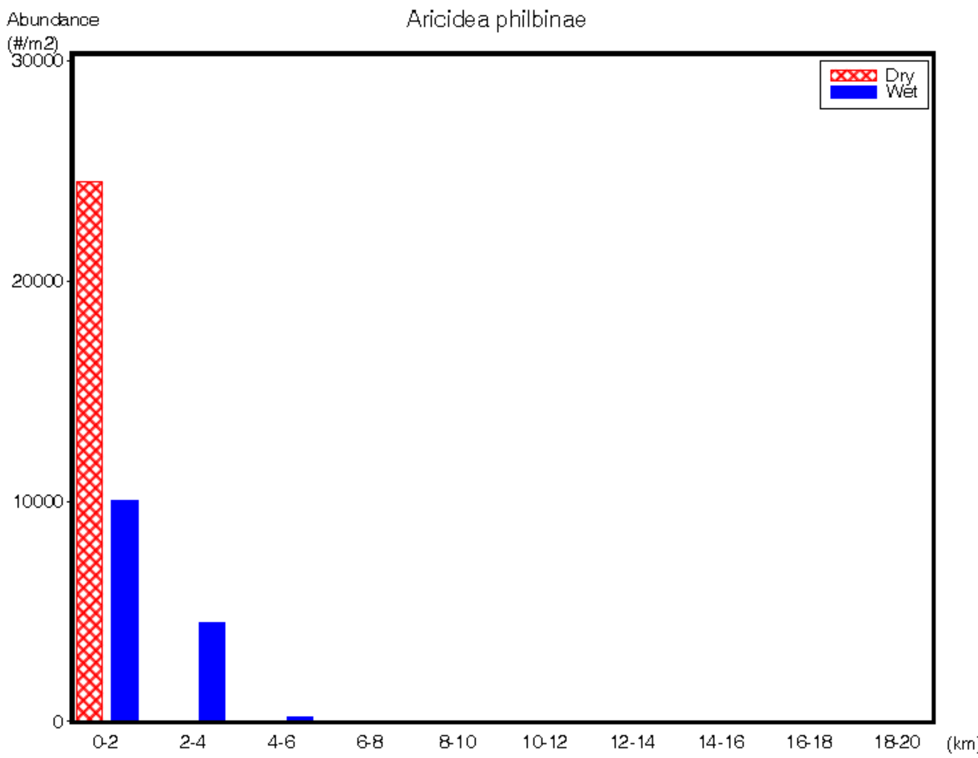

Anomalocardia auberiana
Abundance
(#/m2)
1100
1000
900
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)



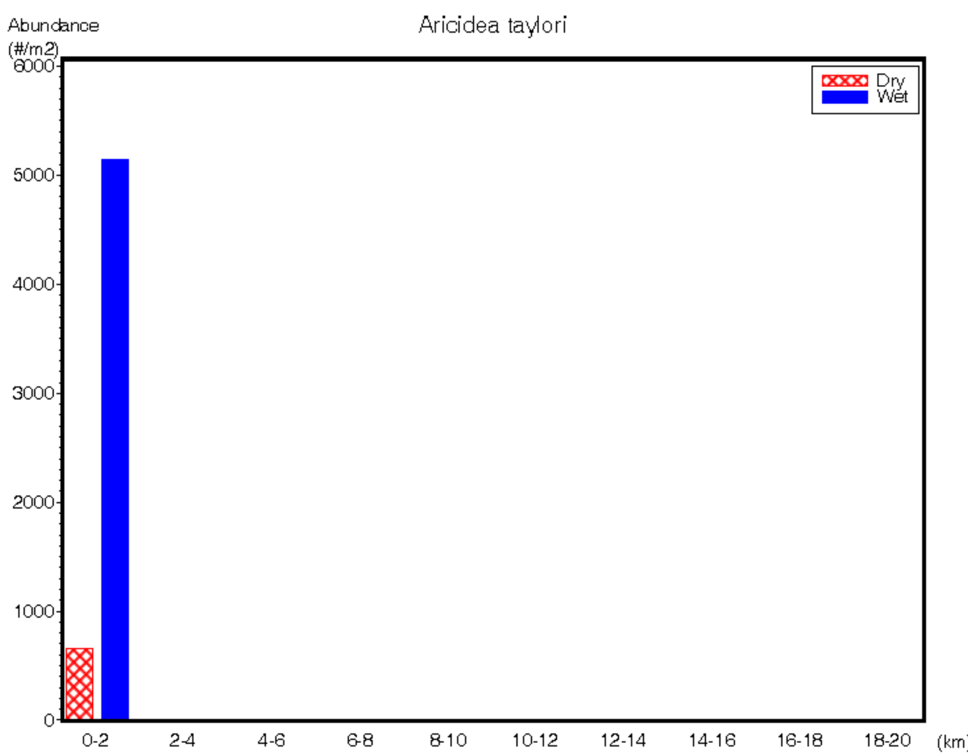
Abundance
(#/m2)
Apocorophium louisianum
Dry
Wet
200000
190000
180000
170000
160000
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)



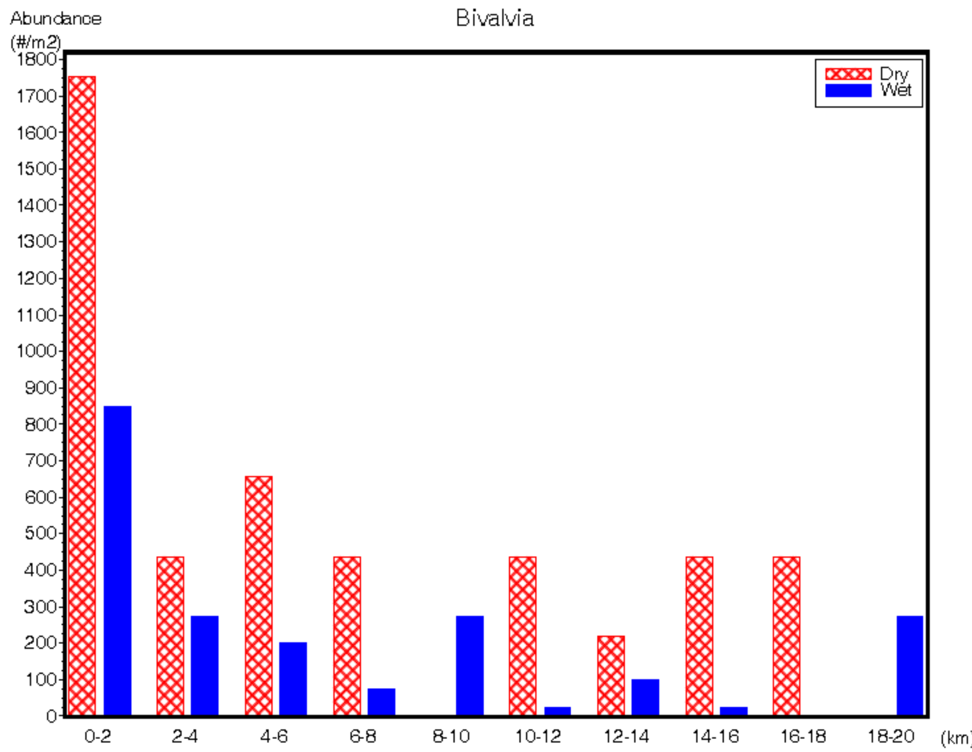
Abundance
(#/m2)
Archinemertea sp. a
Dry
Wet
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

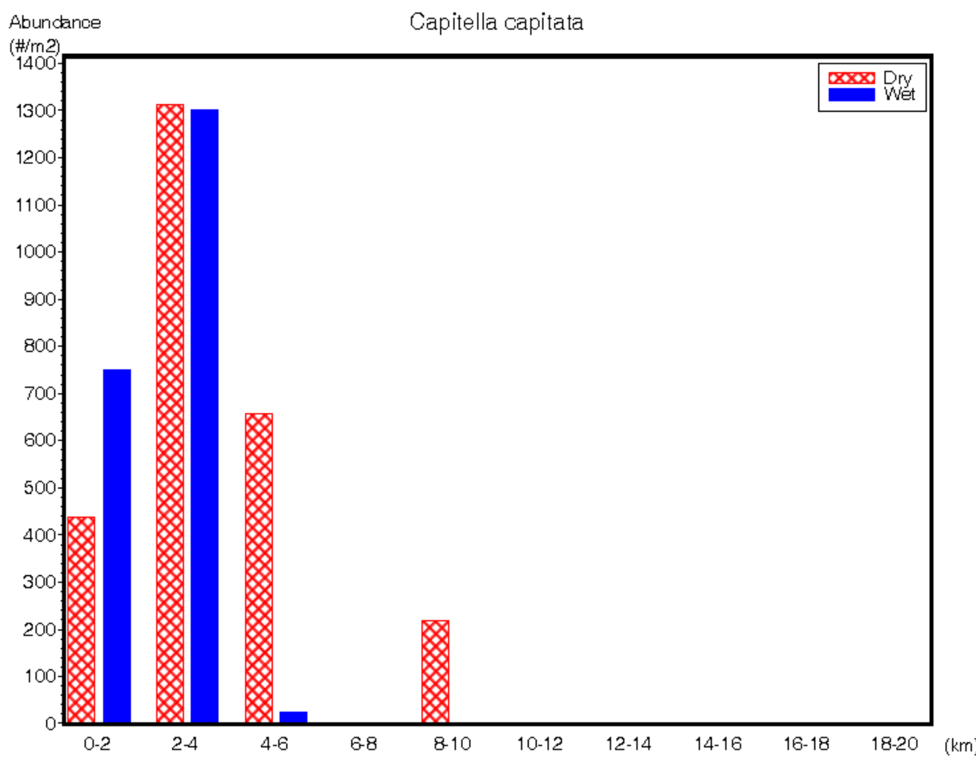


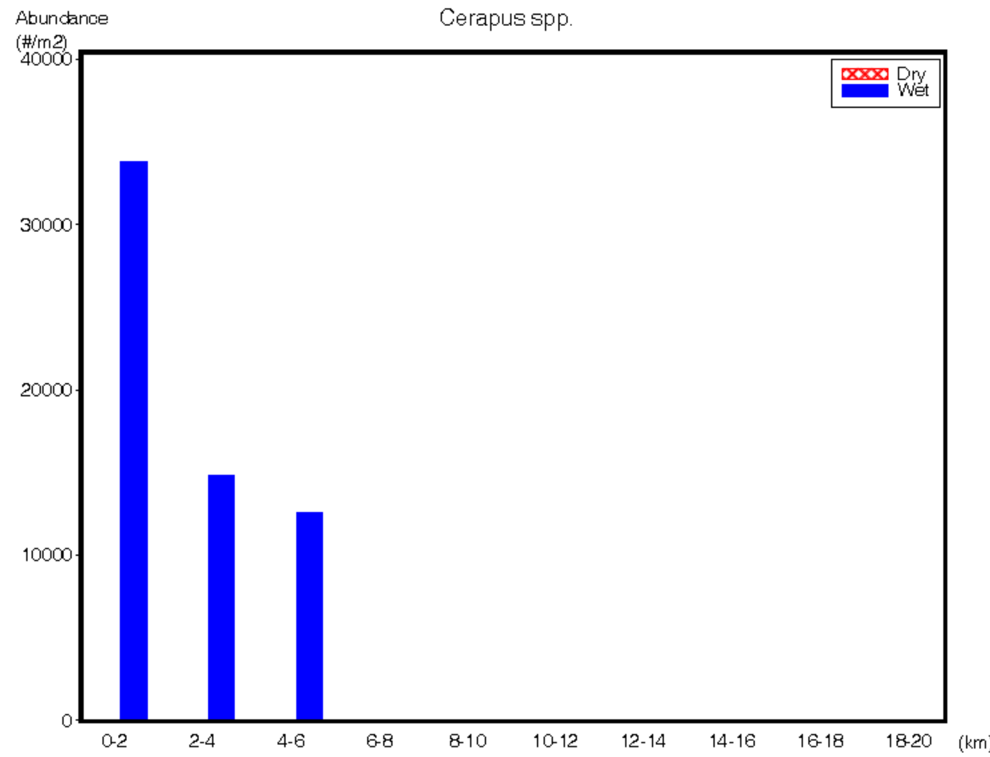
Abundance
(#/m2)
Aricidea philbinae
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

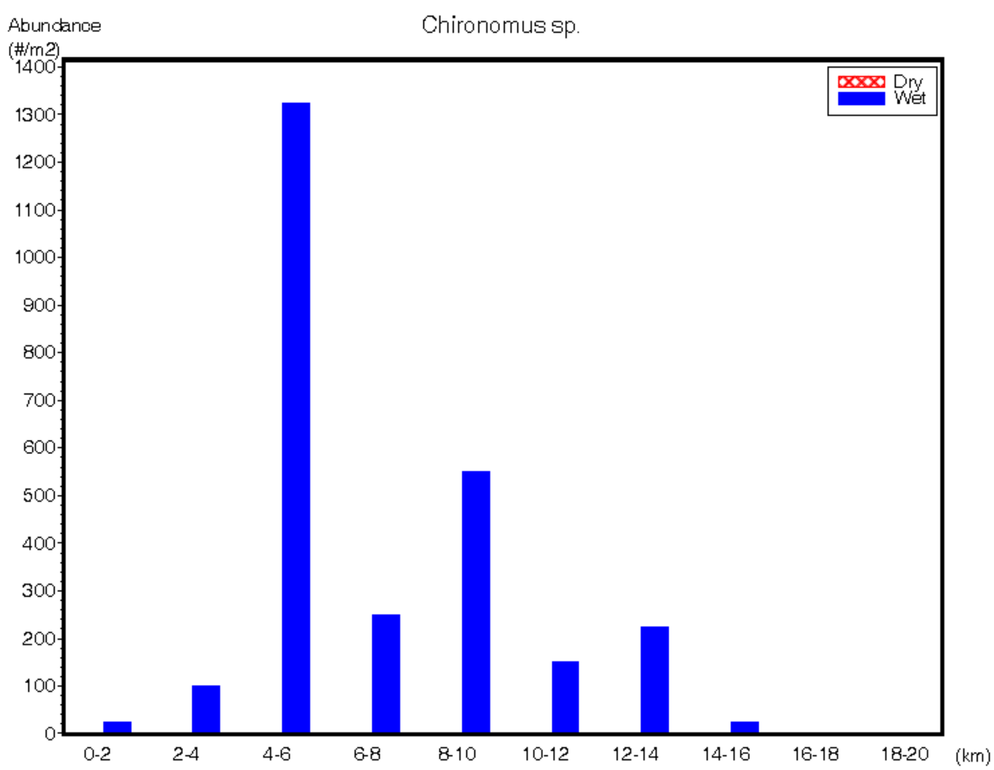


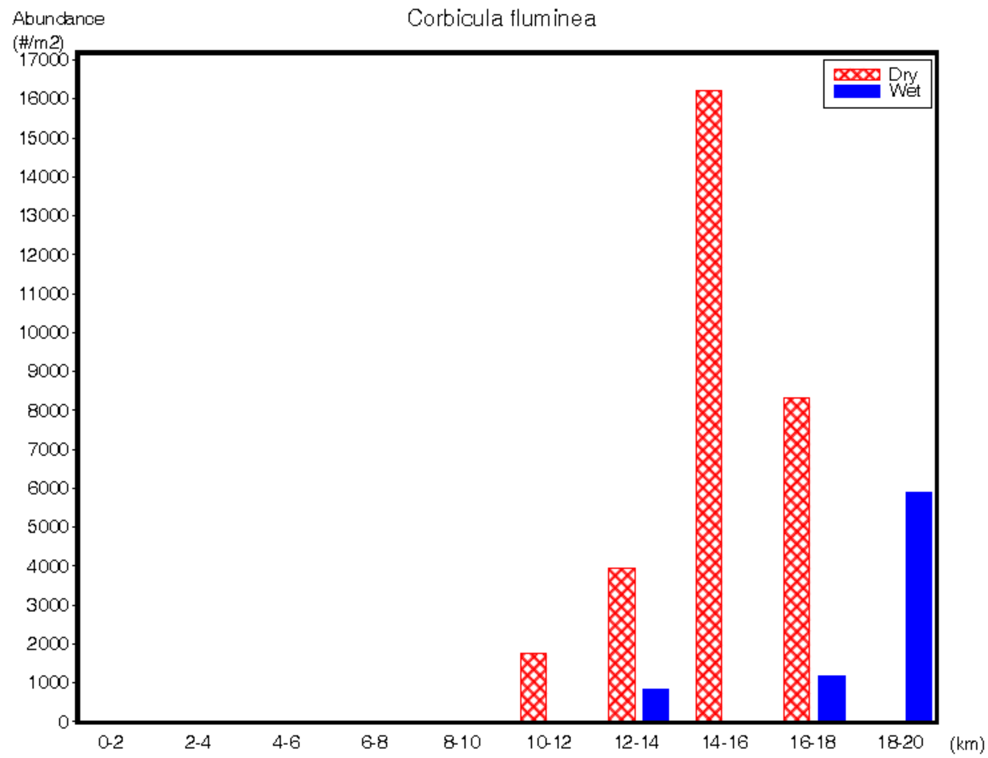
Abundance
(#/m2)
Aricidea taylori
6000
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

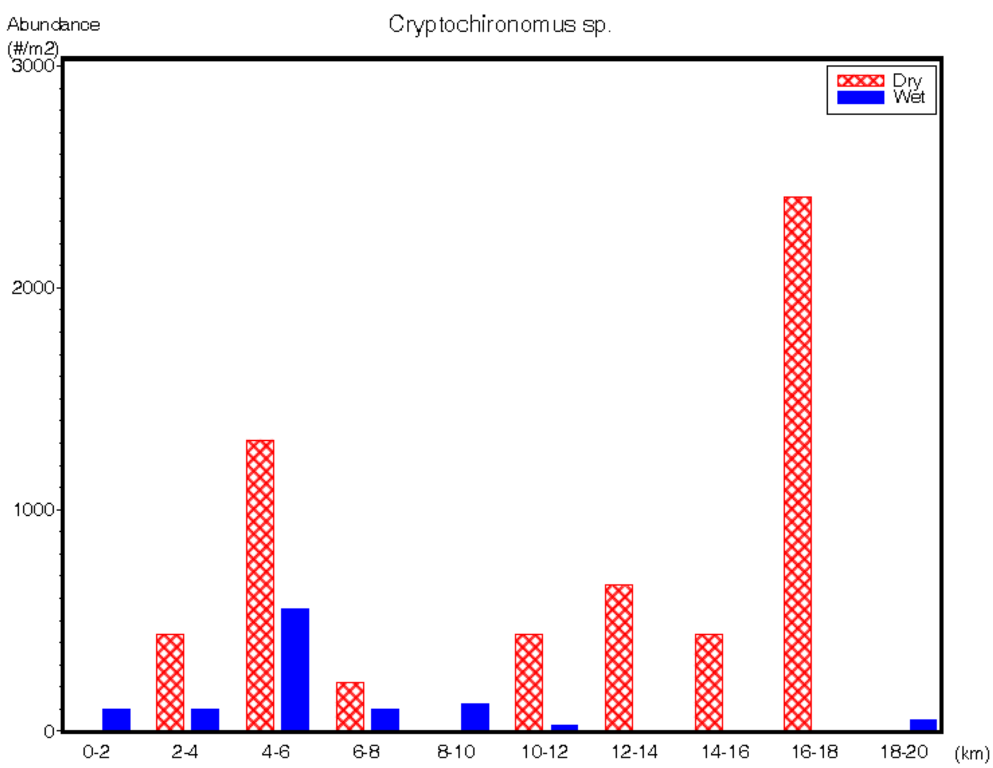

Abundance
(#/m2)
Bivalvia
Dry
Wet
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

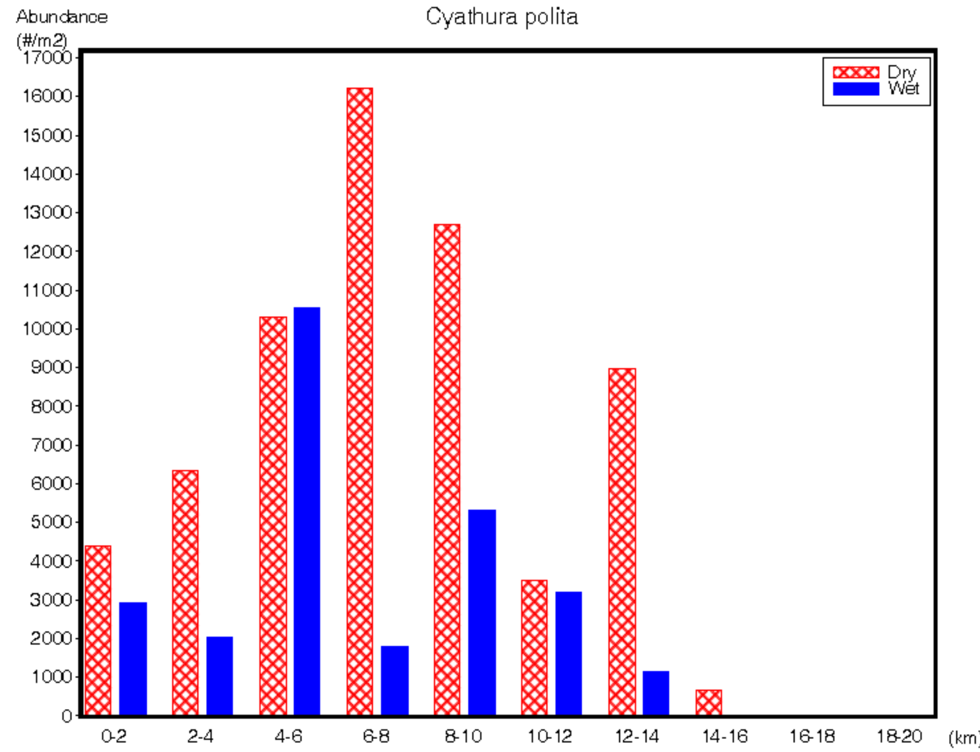

Abundance
(#/m2)
Capitella capitata
Dry
Wet
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

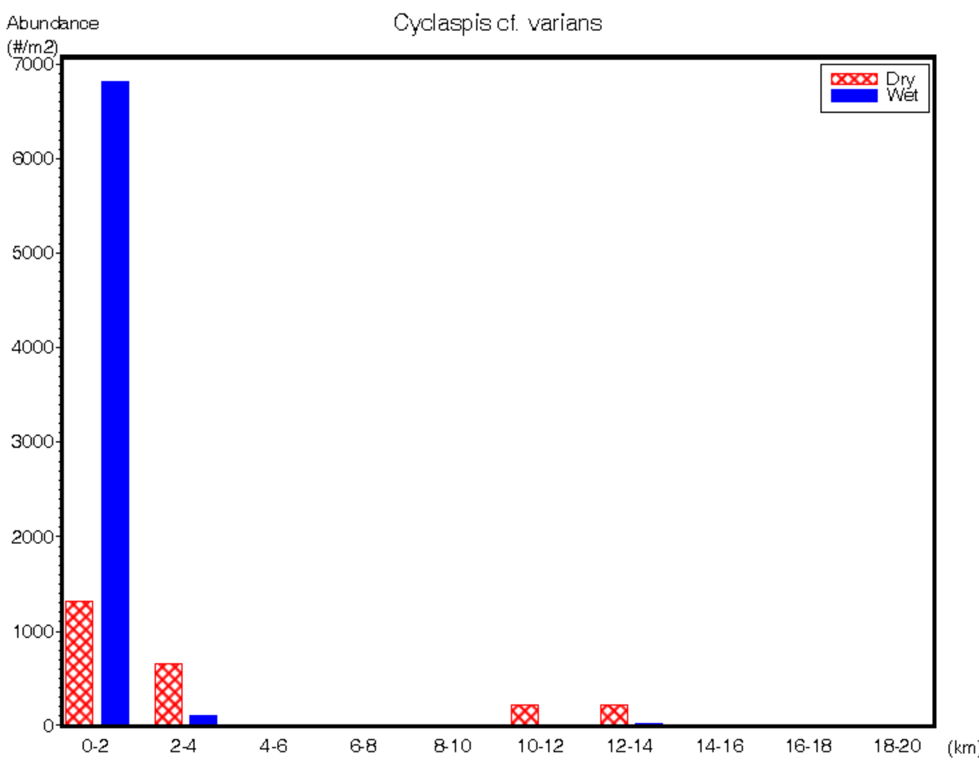

Abundance (#/m2)
Cerapus spp.
Dry
Wet
40000
30000
20000
10000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

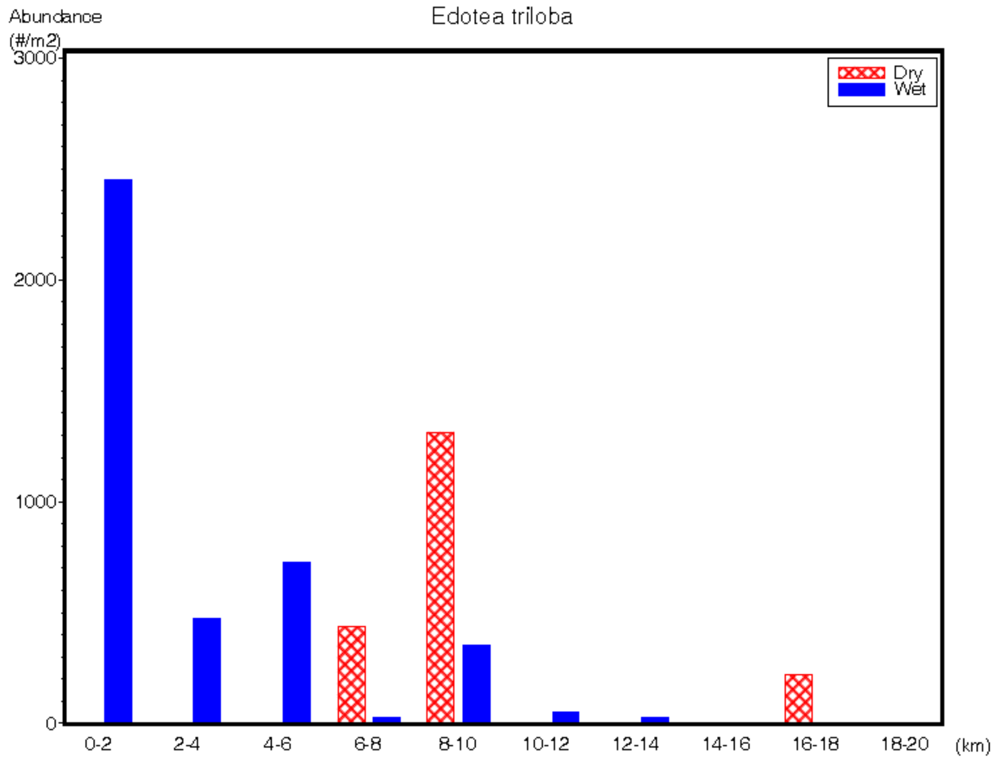

Abundance (#/m2)
Chironomus sp.
Dry
Wet
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

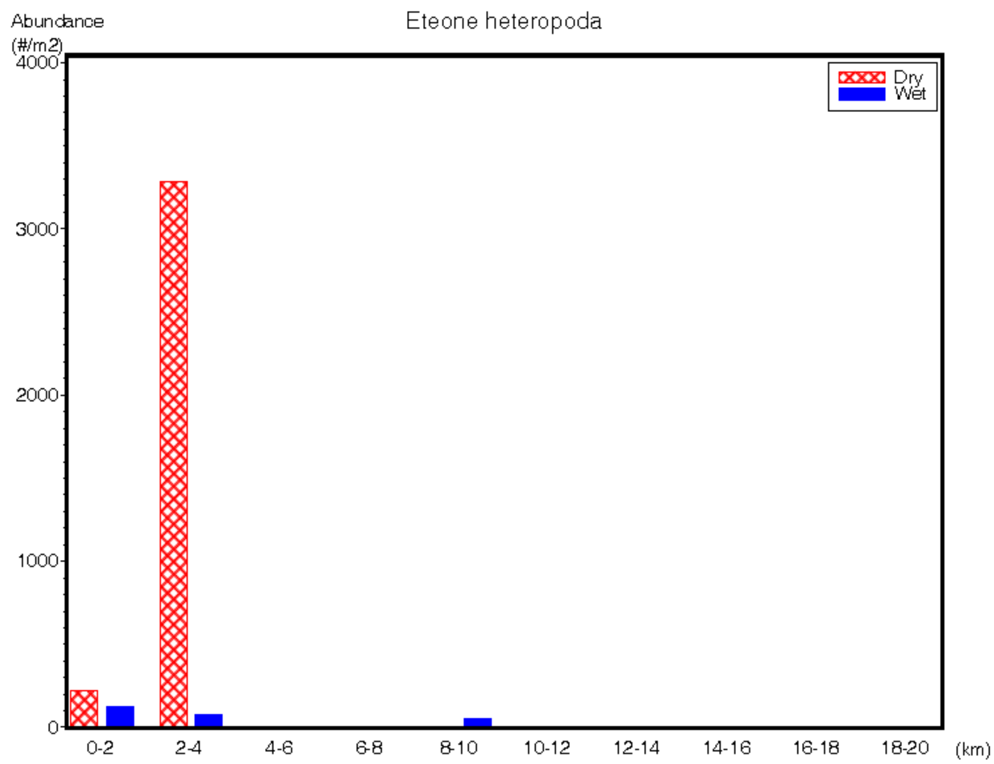

Abundance
(#/m2)
Corbicula fluminea
Dry
Wet
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

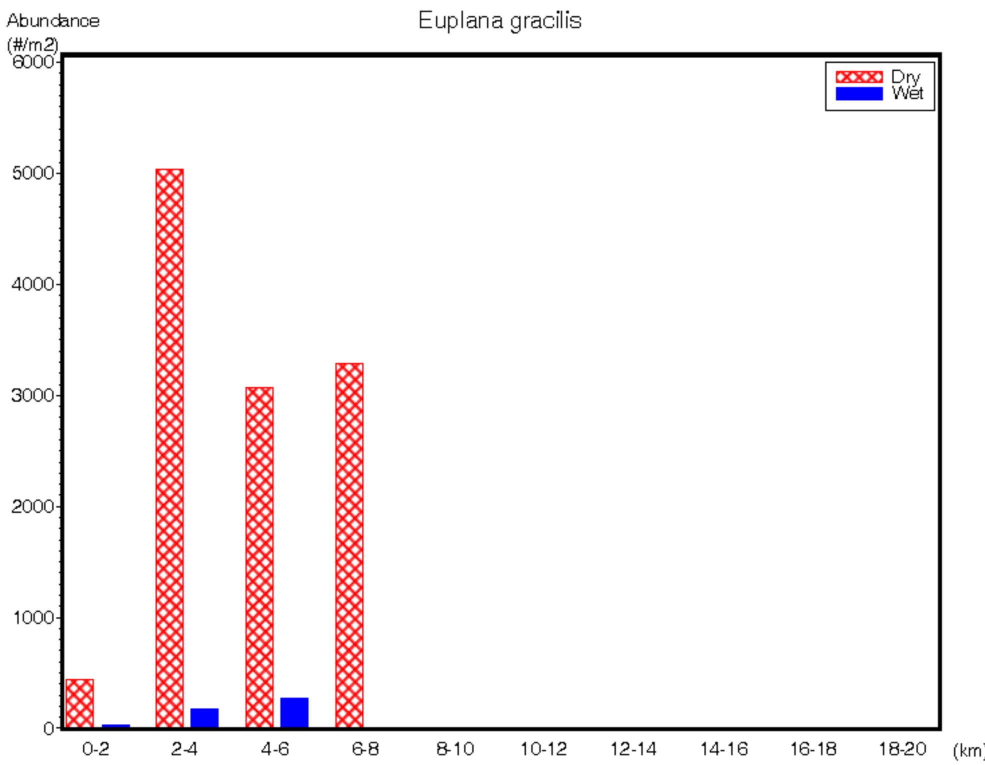

Abundance
(#/m2)
Cryptochironomus sp.
Dry
Wet
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

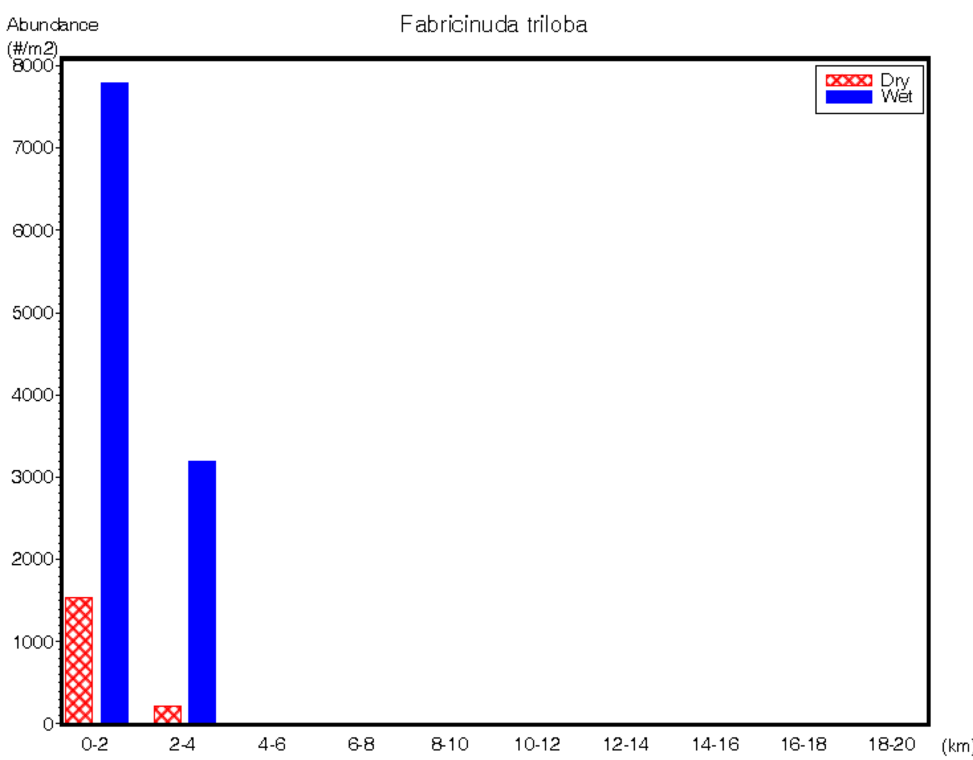

Cyathura polita
Abundance
(#/m2)
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

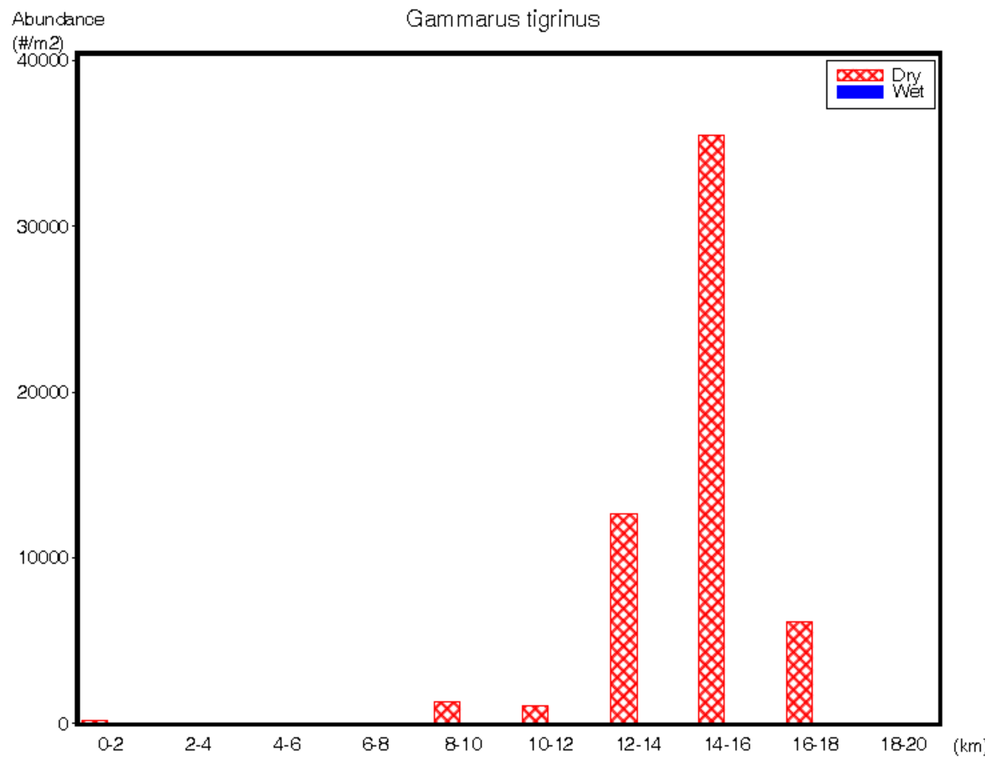

Cyclaspis cf. varians
Abundance
(#/m2)
7000
6000
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

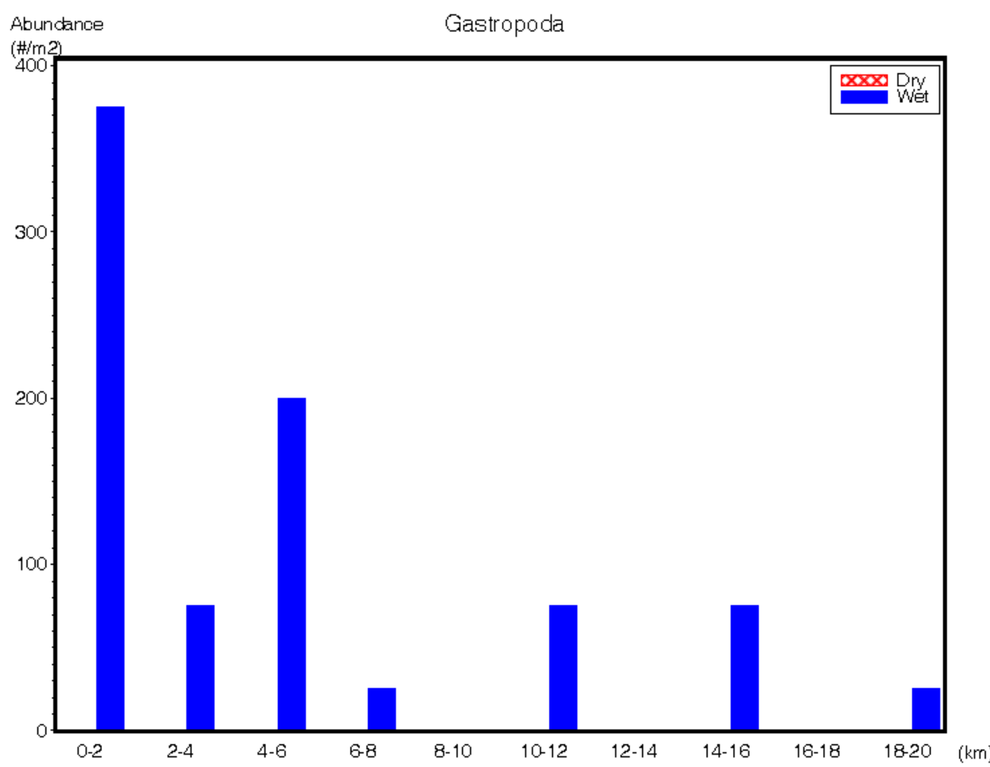

Abundance (#/m2)
Edotea triloba
Dry
Wet
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

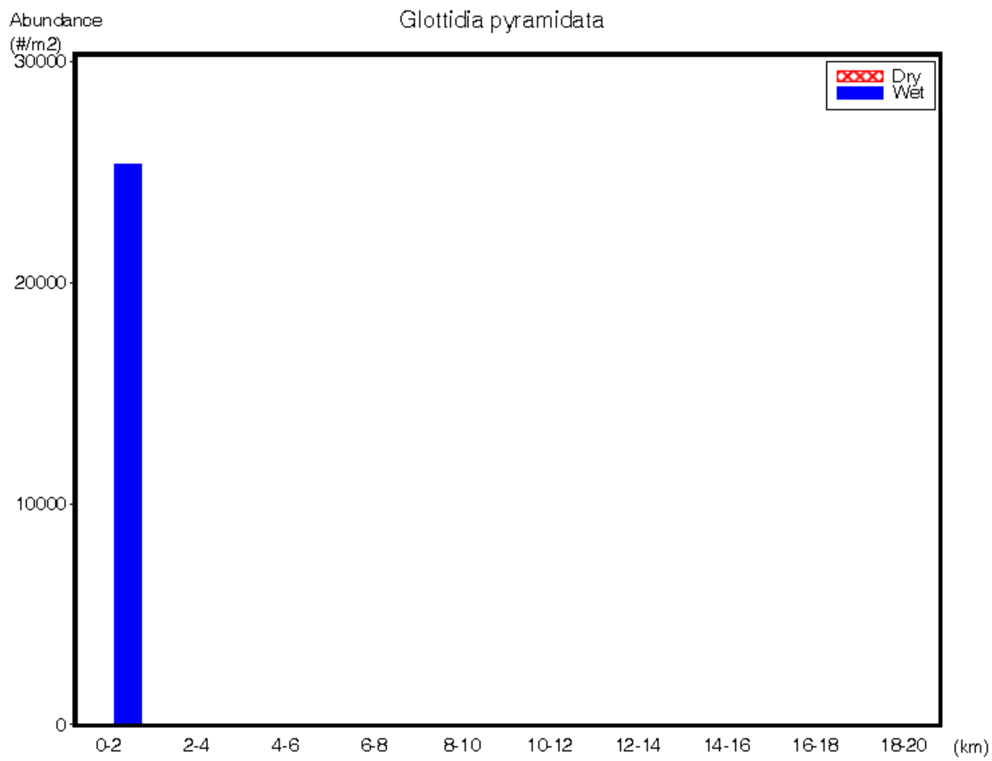

Abundance (#/m2)
Eteone heteropoda
Dry
Wet
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Euplana gracilis
6000
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

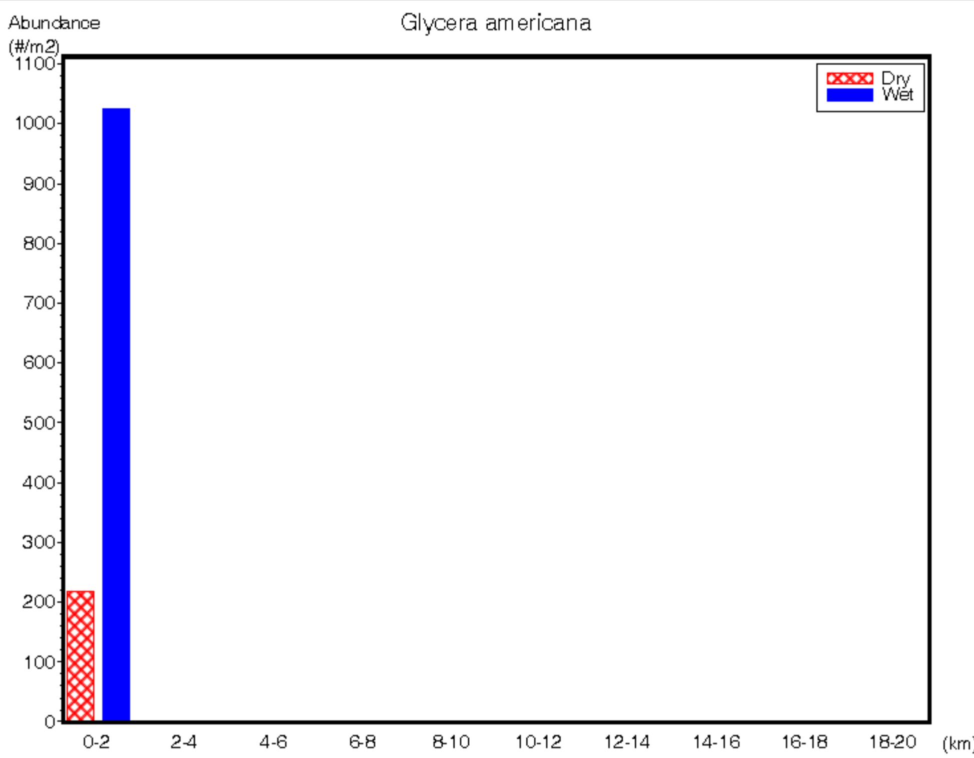

Abundance
(#/m2)
Fabricinuda triloba
8000
7000
6000
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Gammarus tigrinus
Abundance
(#/m2)
40000
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

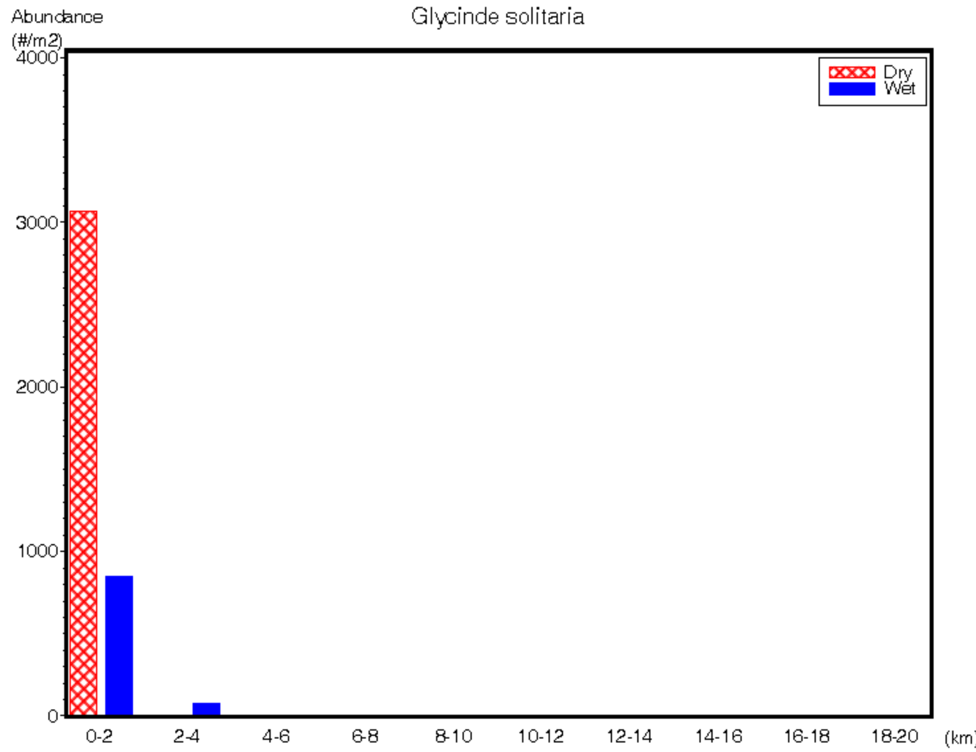

Gastropoda
Abundance
(#/m2)
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

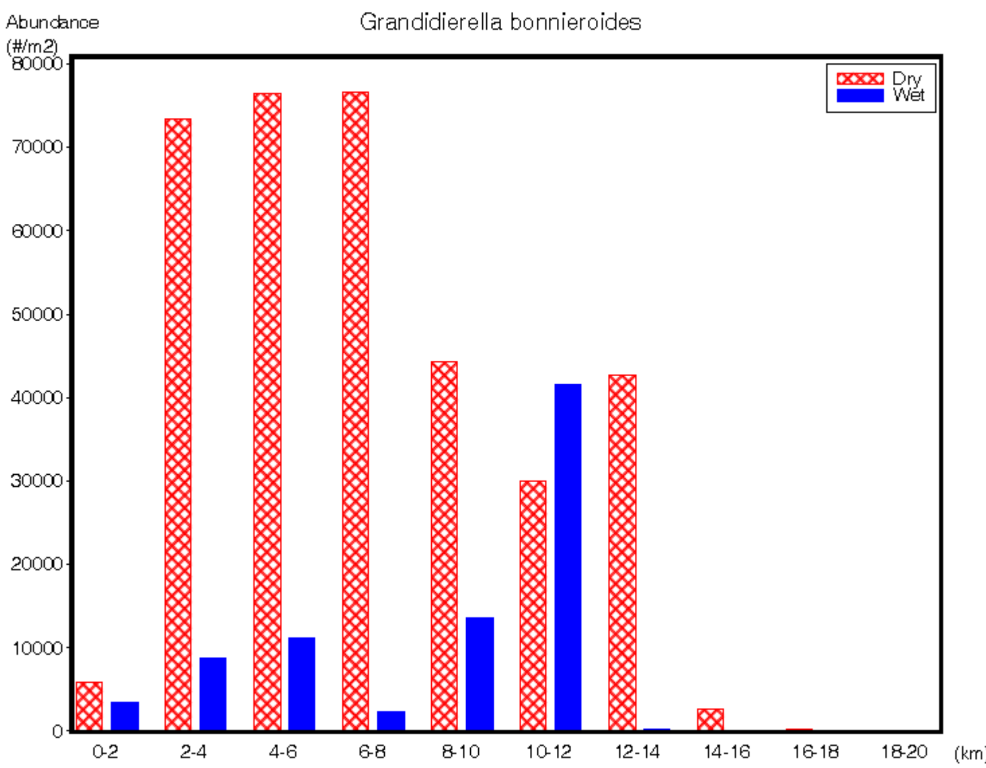


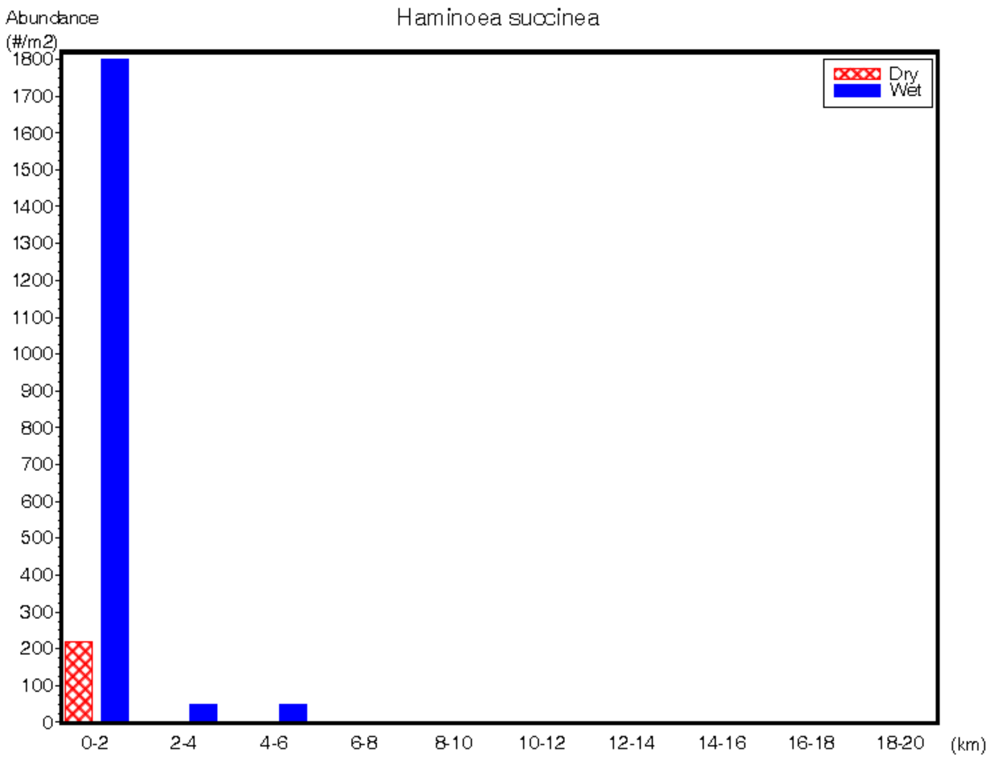
Glottidia pyramidata
Abundance
(#/m2)
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

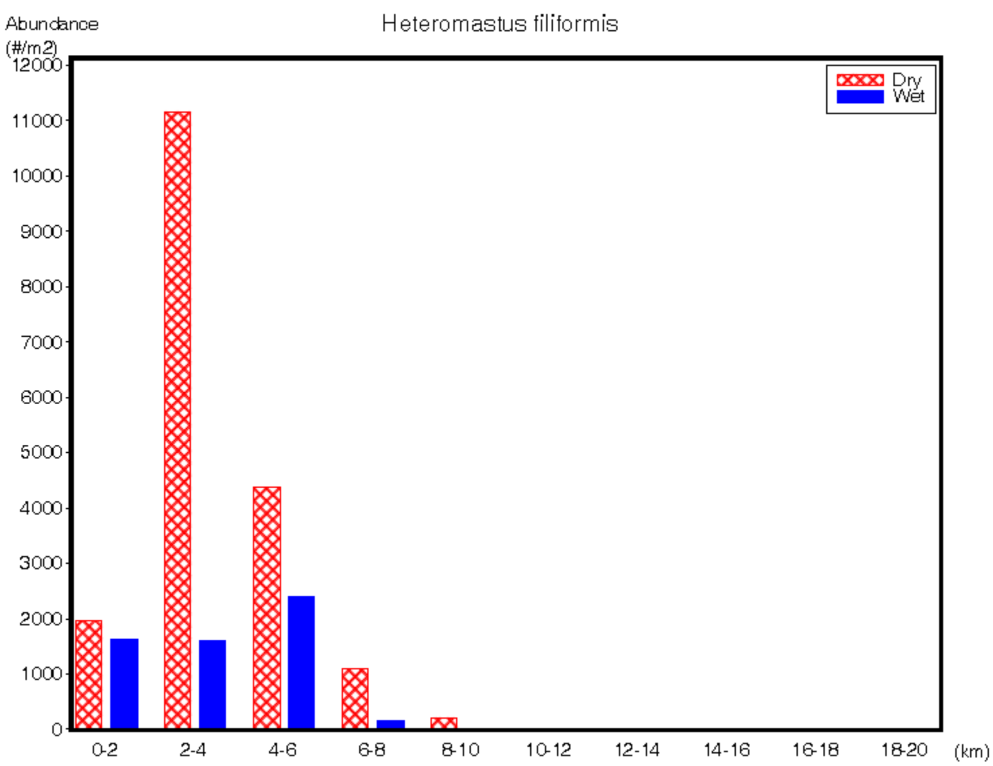


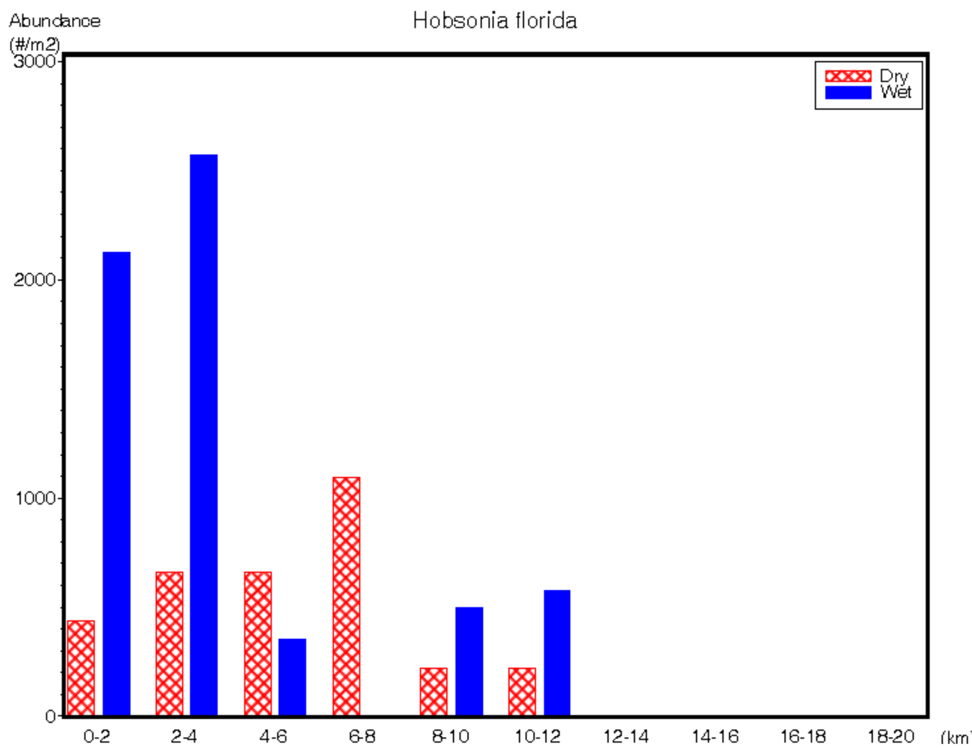
Glycera americana
Abundance
(#/m2)
1100
1000
900
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

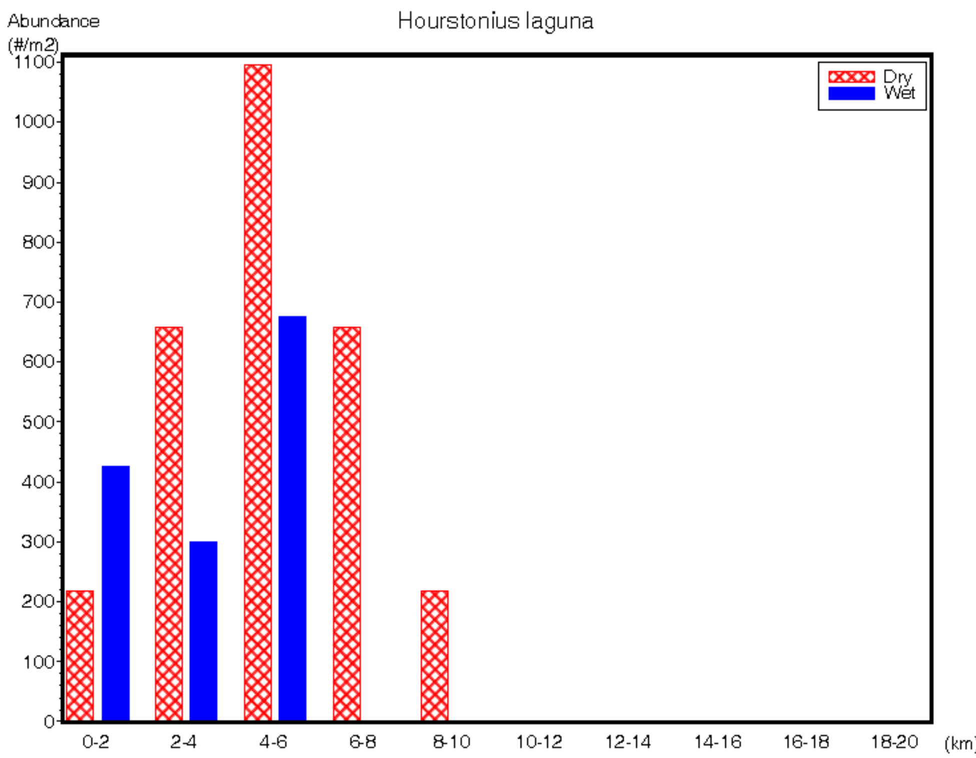

Glycinde solitaria
Abundance
(#/m2)
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

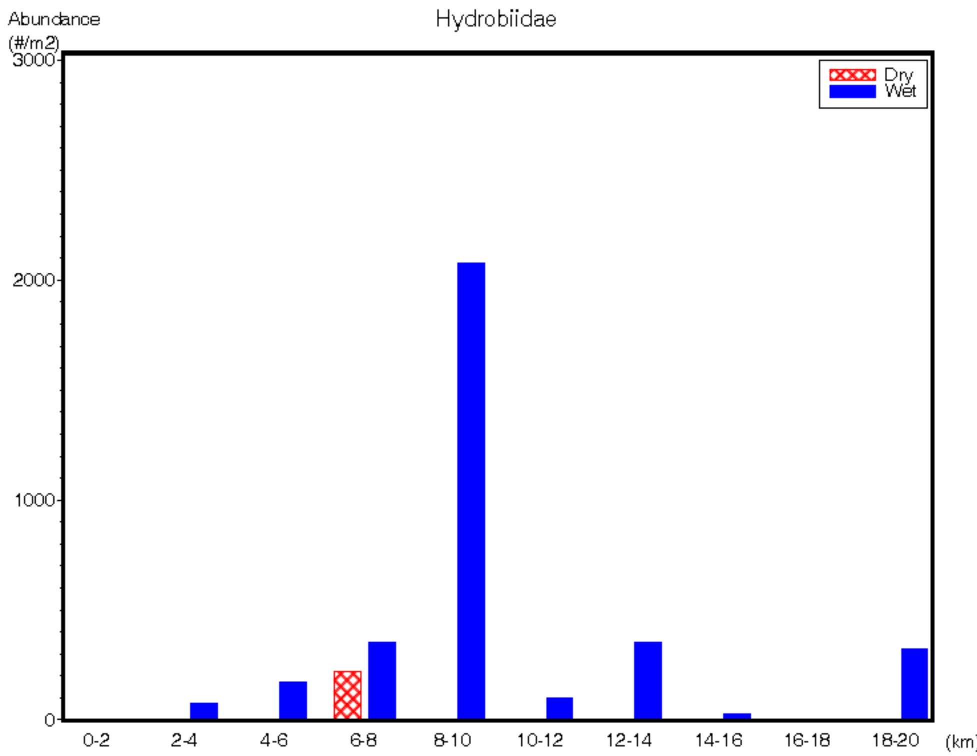

Grandidierella bonnieroides
Abundance
(#/m2)
80000
70000
60000
50000
40000
30000
20000
10000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

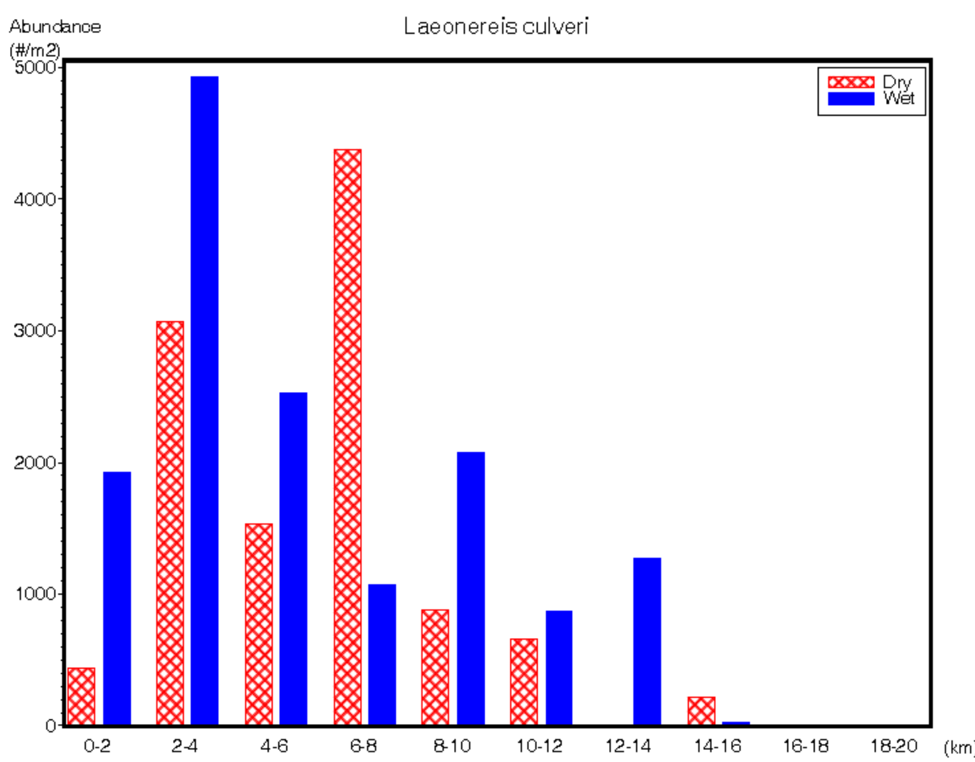

Abundance
(#/m2)
Haminoea succinea
Dry
Wet
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

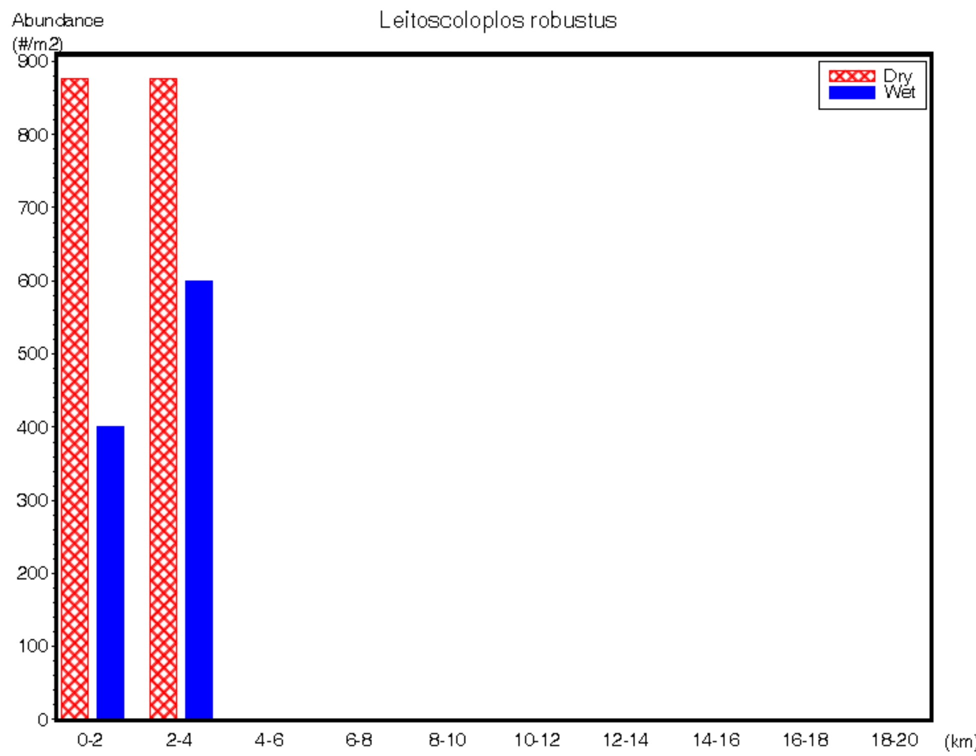

Abundance
(#/m2)
Heteromastus filiformis
Dry
Wet
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

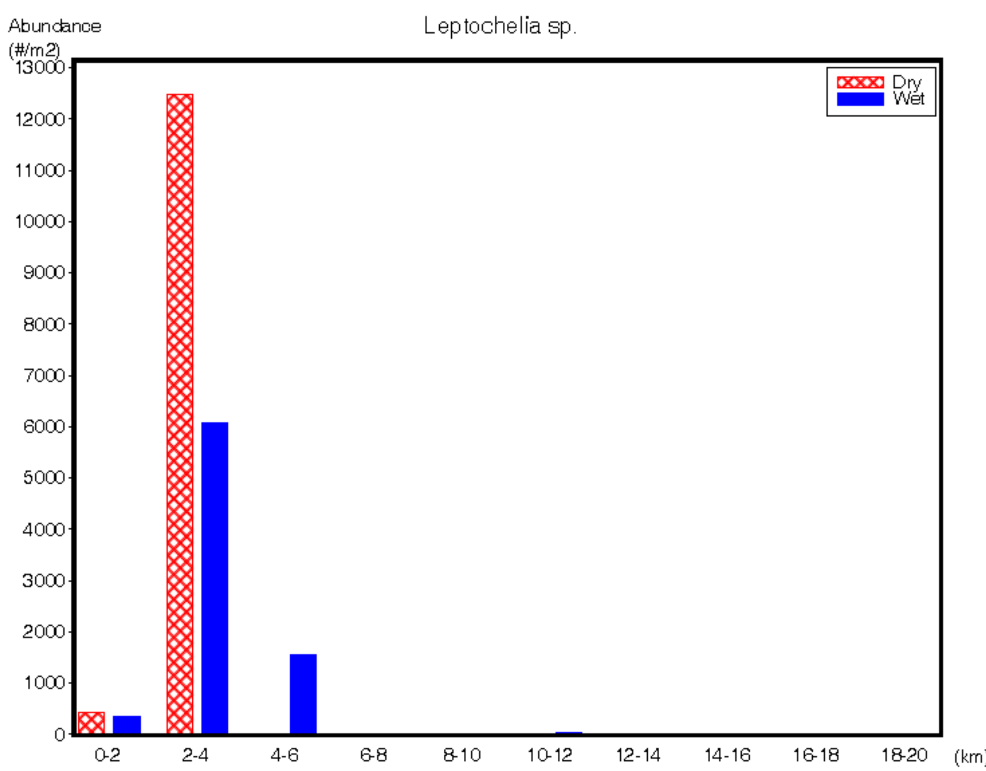

Abundance
(#/m2)
Hobsonia florida
Dry
Wet
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

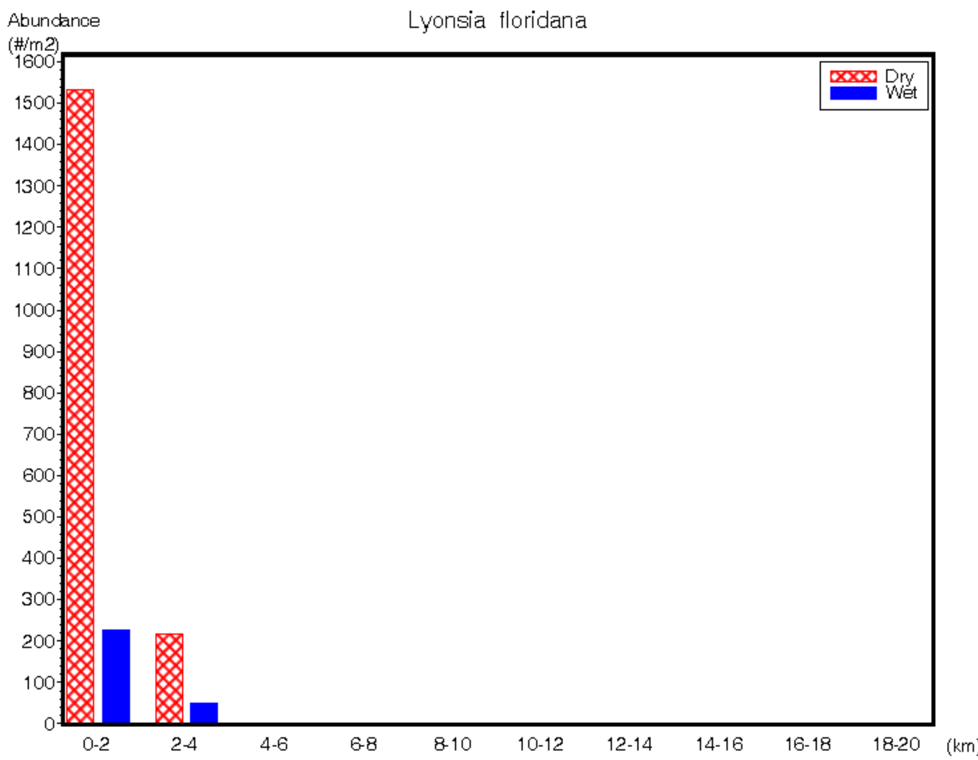

Abundance
(#/m2)
Hourstonius laguna
Dry
Wet
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

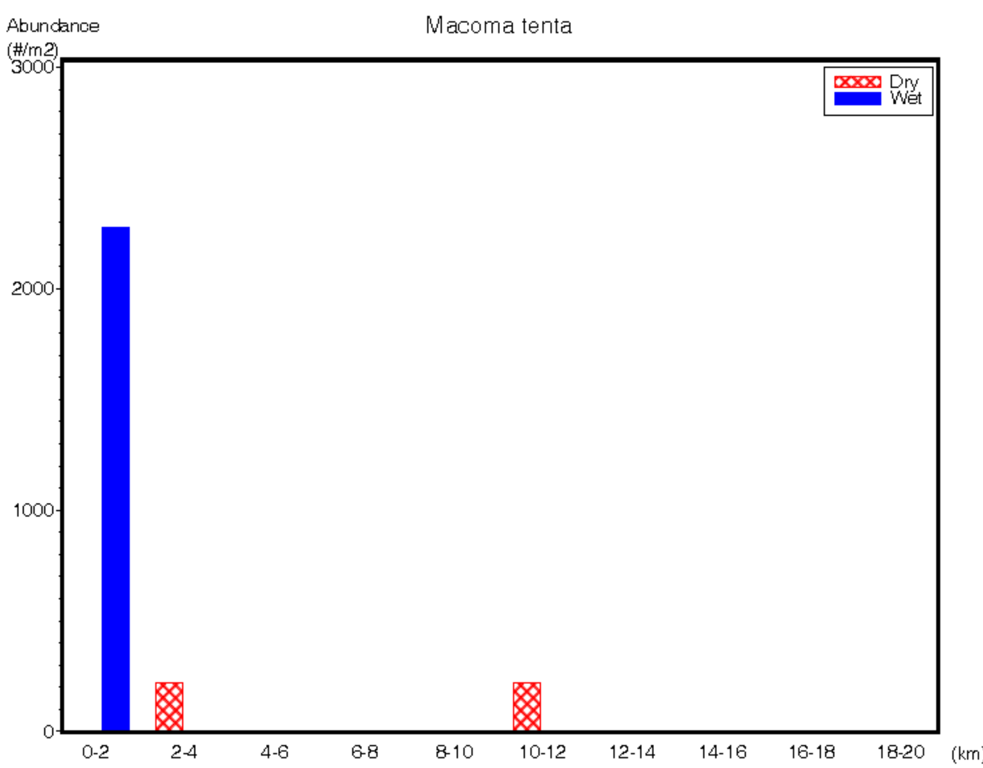

Hydrobiidae
Abundance
(#/m2)
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

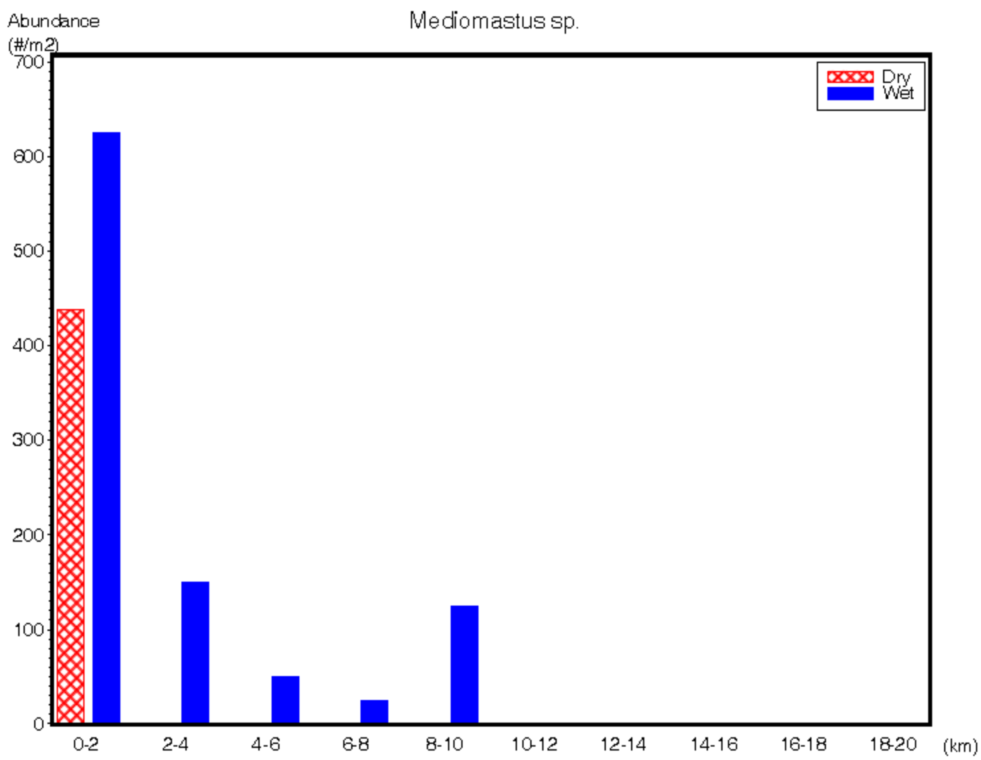

Laeonereis culveri
Abundance
(#/m2)
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

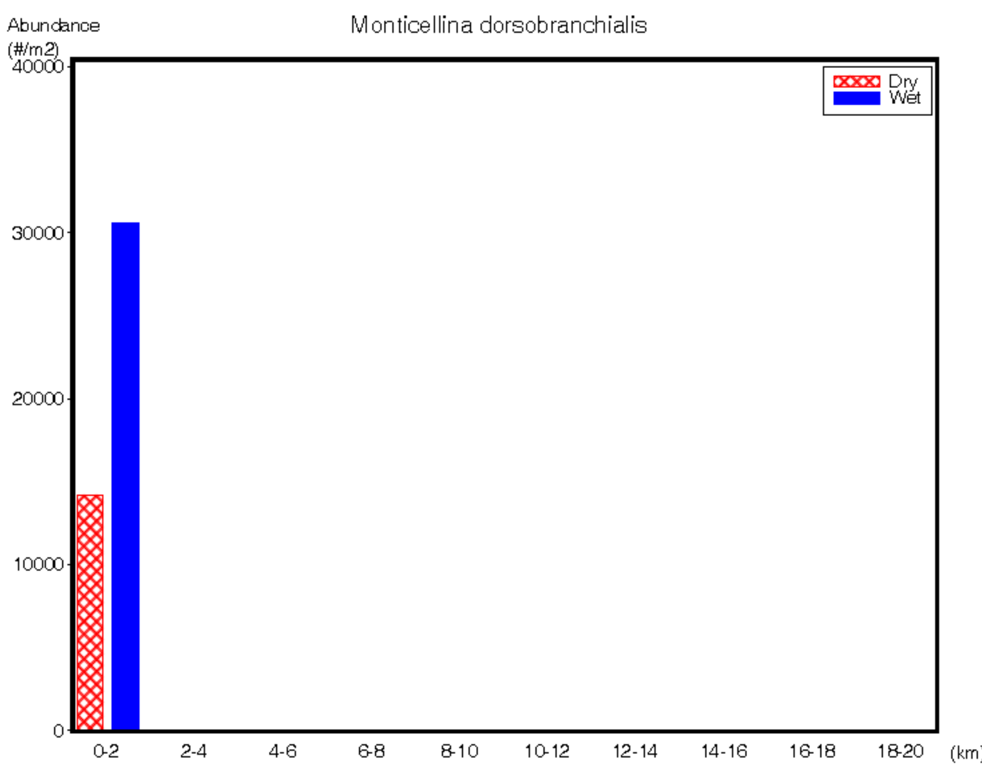

Abundance
(#/m2)
Leitoscoloplos robustus
Dry
Wet
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

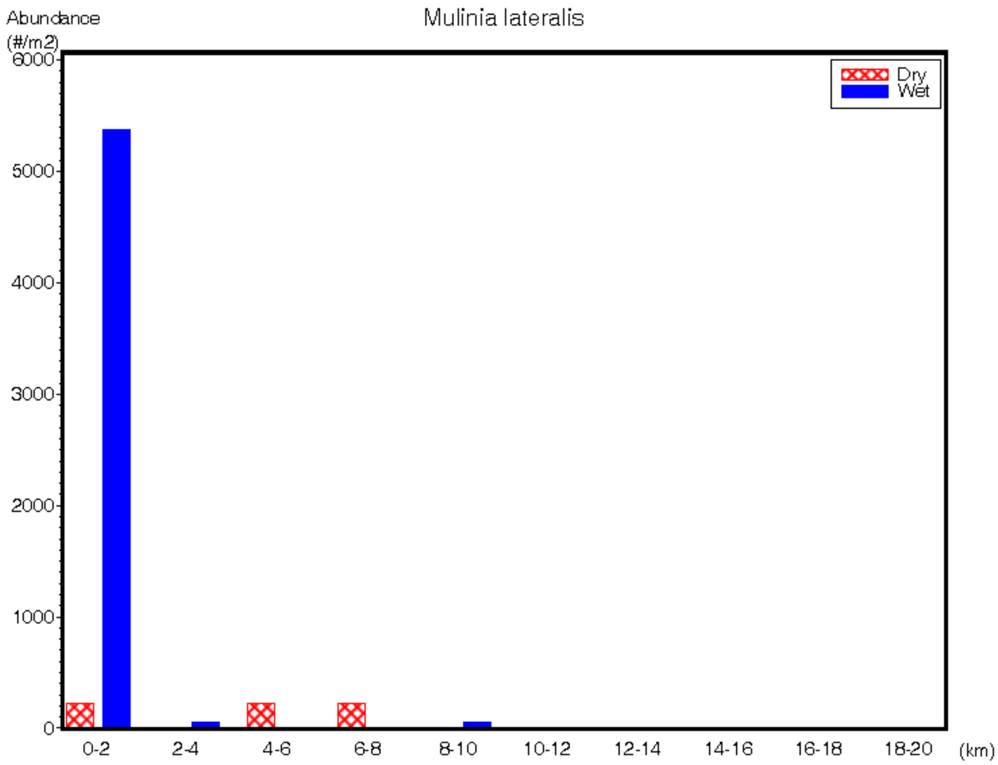

Abundance
(#/m2)
Leptochelia sp.
Dry
Wet
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

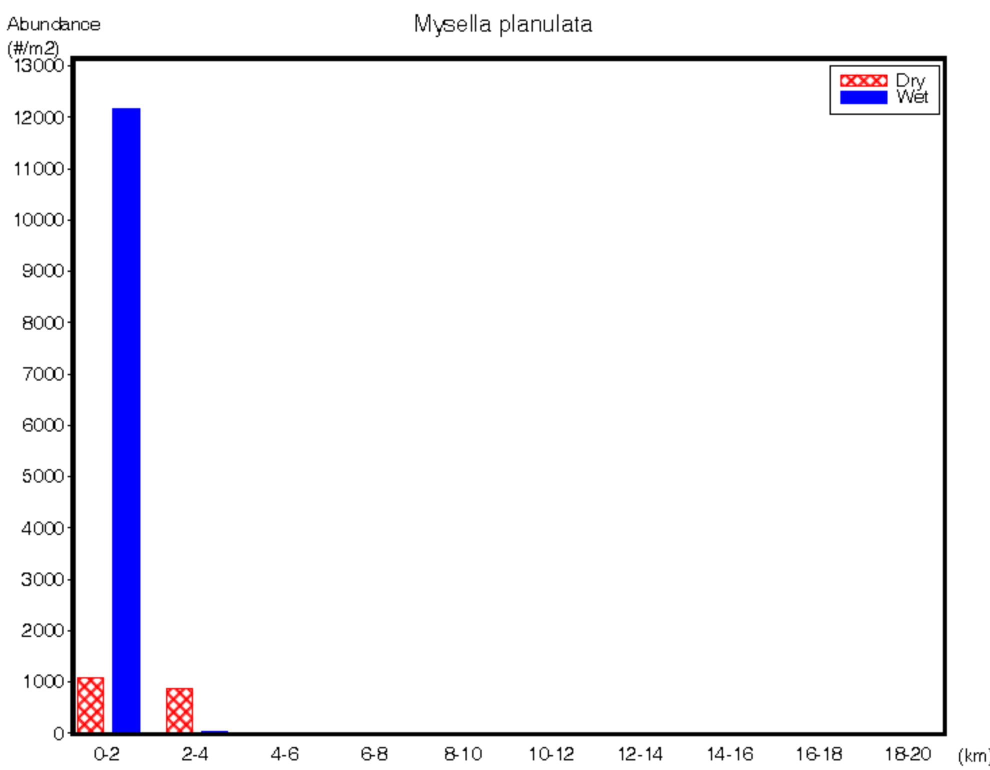

Abundance (#/m2)
Lyonsia floridana
Dry
Wet
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

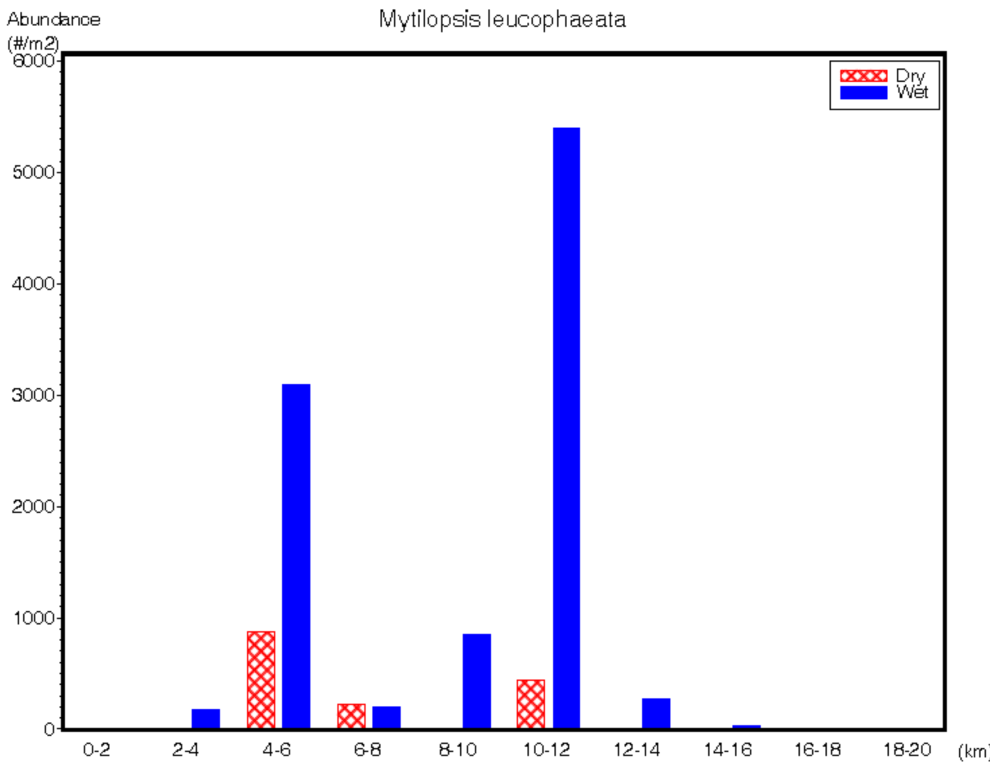

Abundance (#/m2)
Macoma tenta
Dry
Wet
0
1000
2000
3000
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Mediomastus sp.
Dry
Wet
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

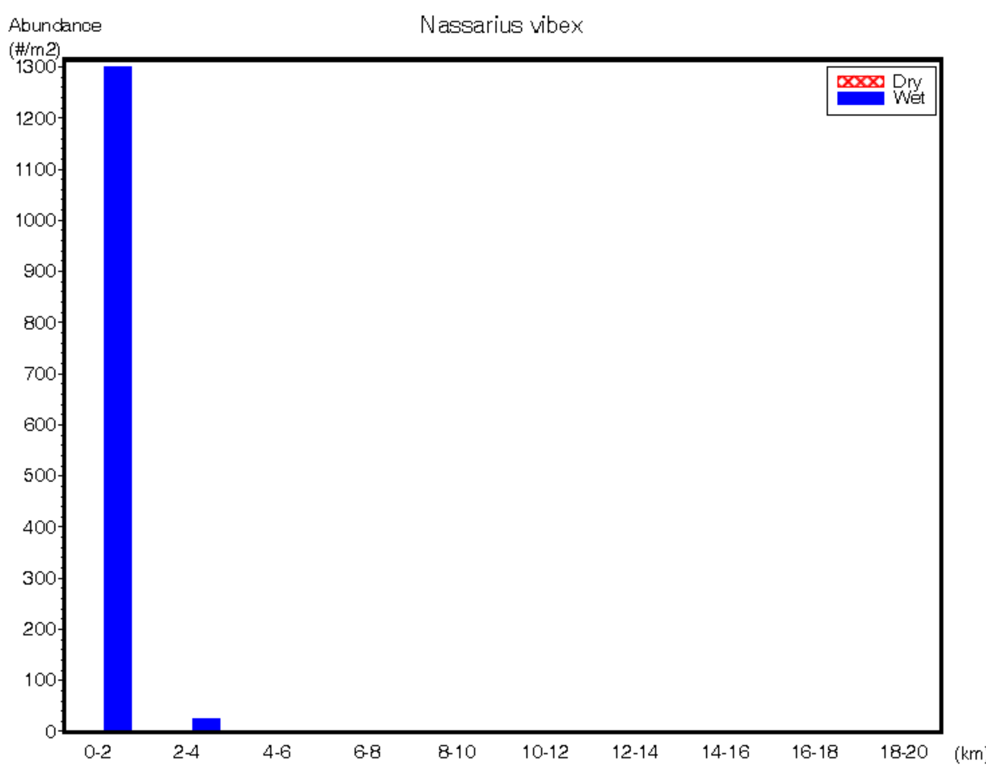

Abundance
(#/m2)
Monticellina dorsobranchialis
Dry
Wet
40000
30000
20000
10000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance (#/m2)
Mulinia lateralis
Dry
Wet
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

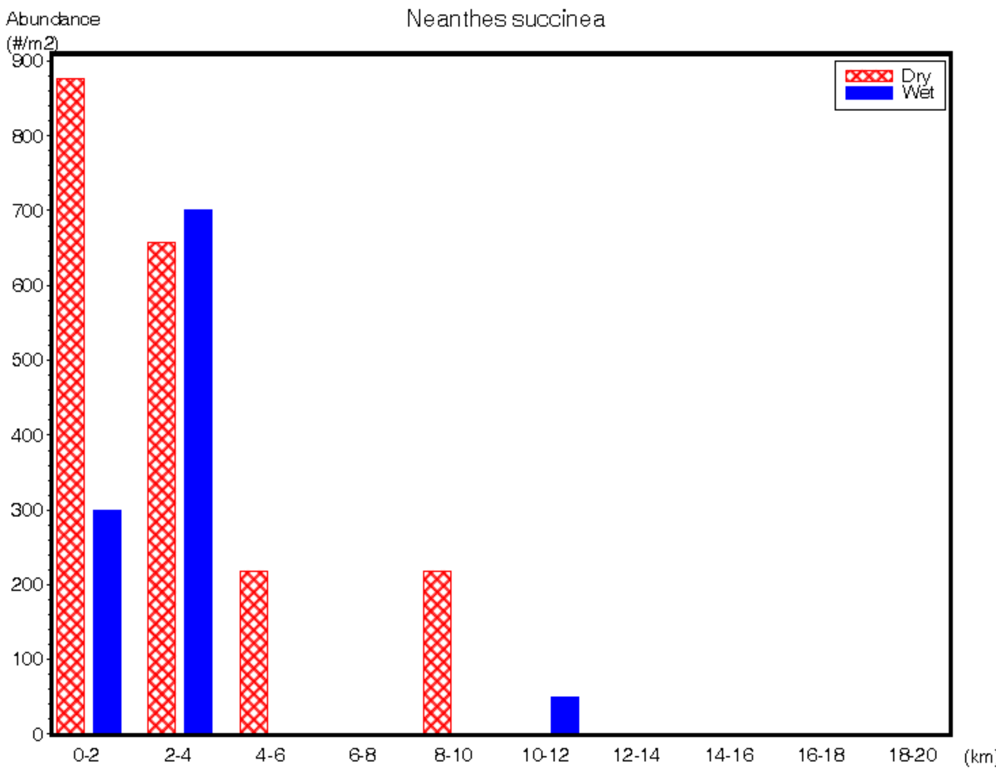

Abundance (#/m2)
Mysella planulata
Dry
Wet
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

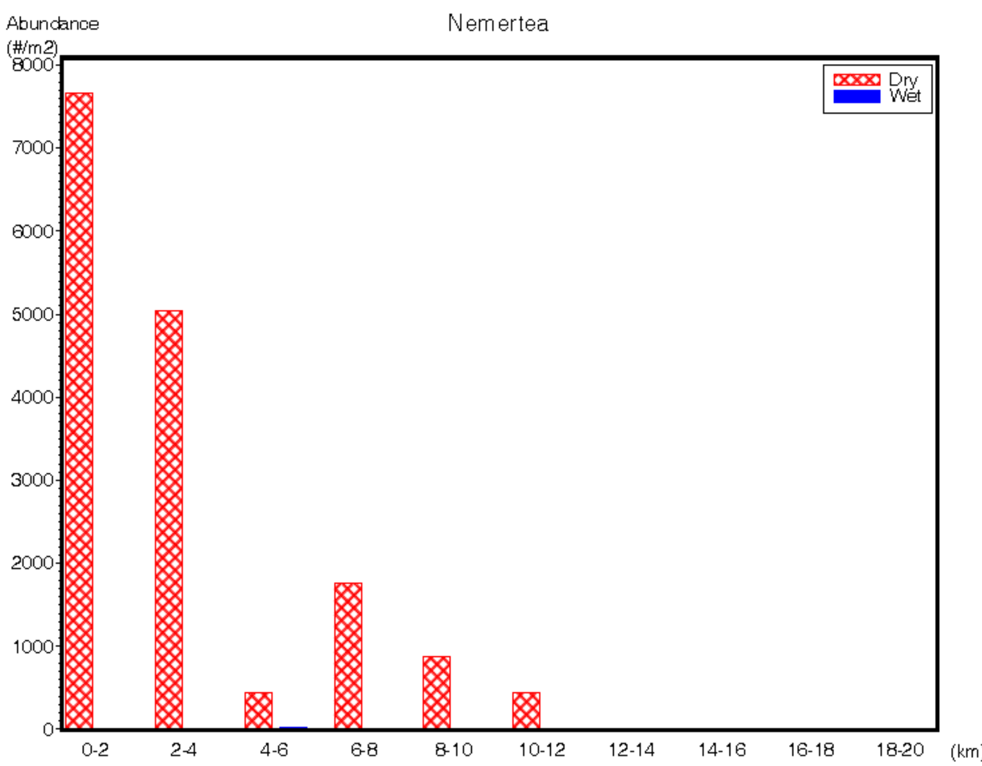


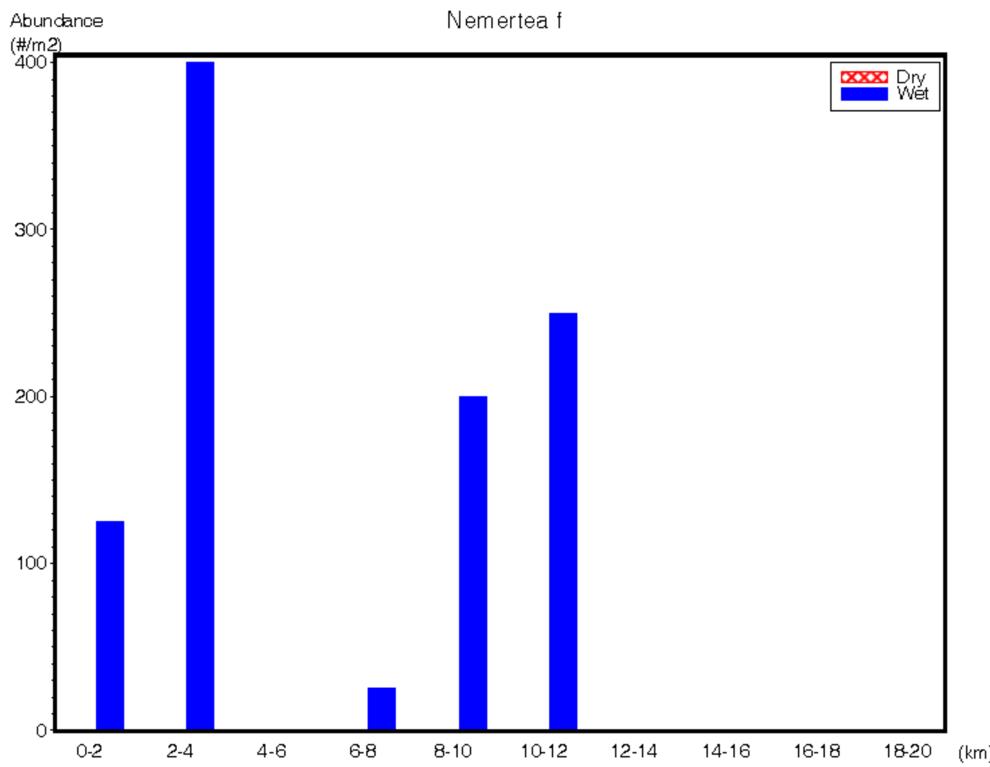
Mytilopsis leucophaeata
Abundance
(#/m2)
6000
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

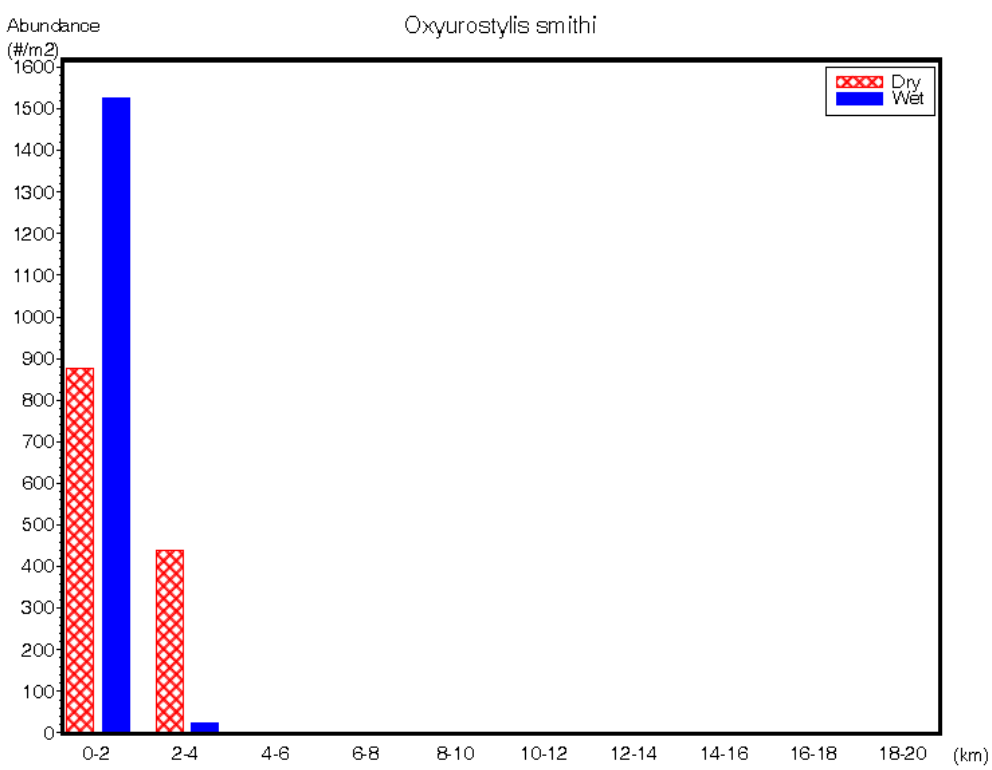


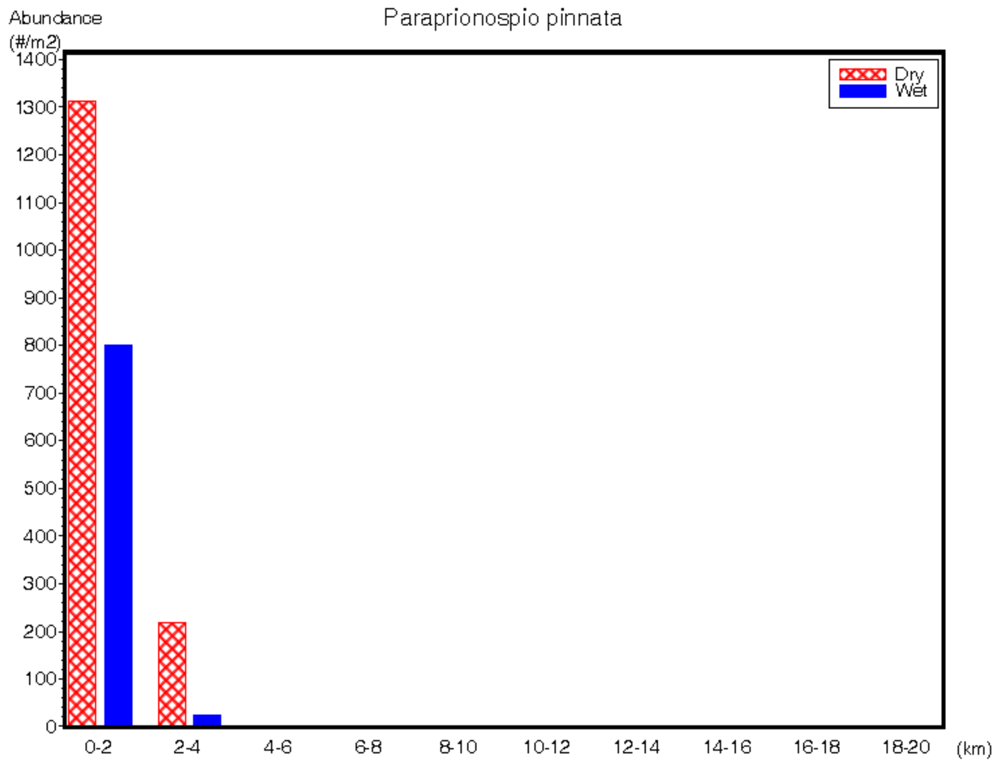
Nassarius vibex
Abundance
(#/m2)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Neanthes succinea
Dry
Wet
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

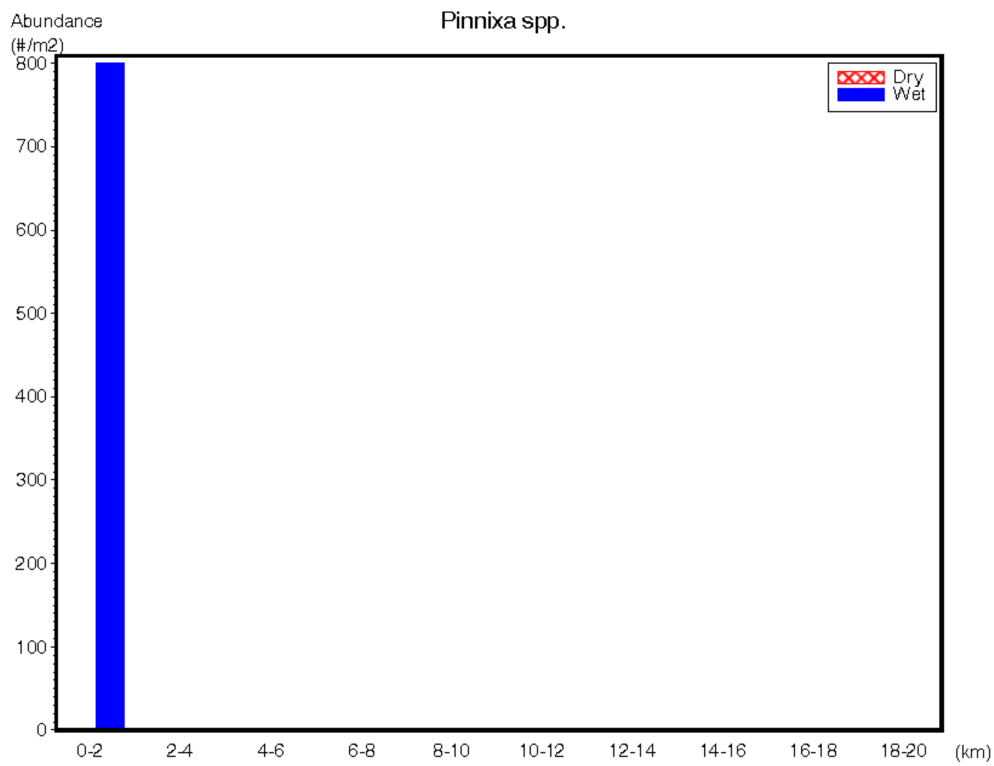

Abundance
(#/m2)
Nemertea
Dry
Wet
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Nemertea f
Dry
Wet
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

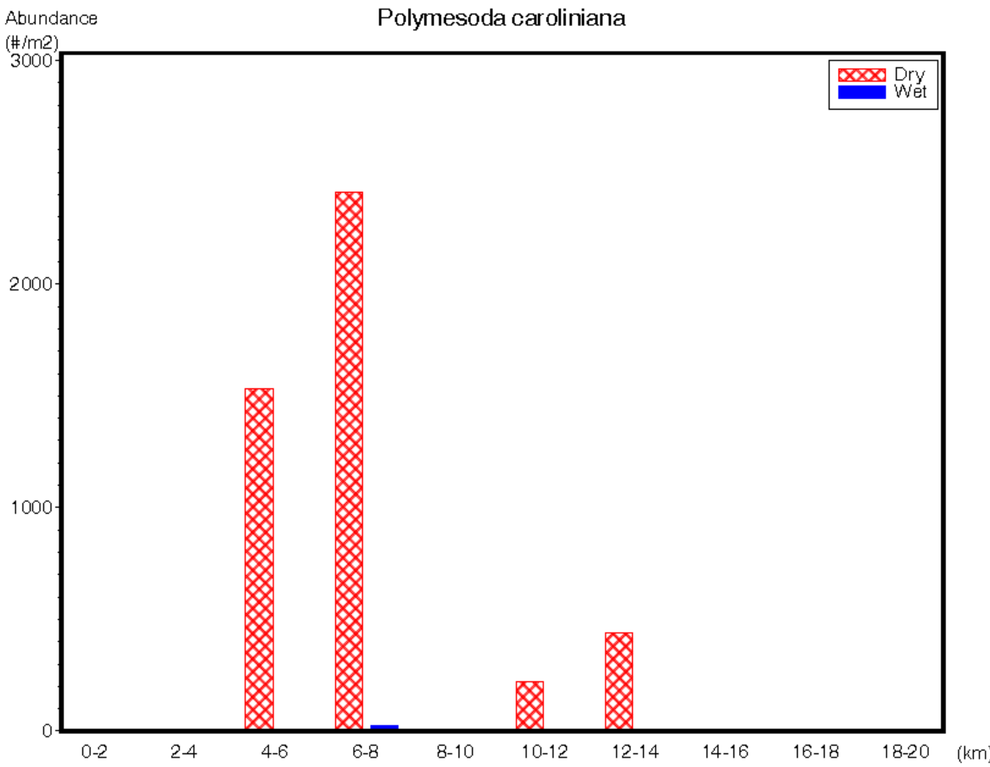

Abundance
(#/m2)
Oxyurostylis smithi
Dry
Wet
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

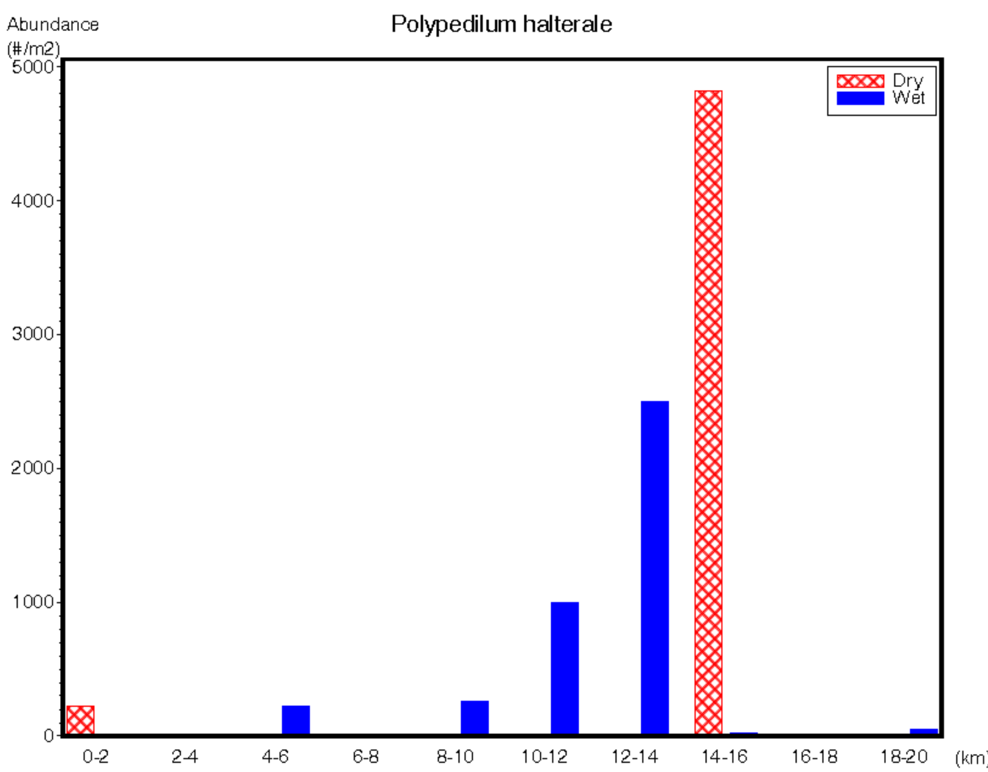


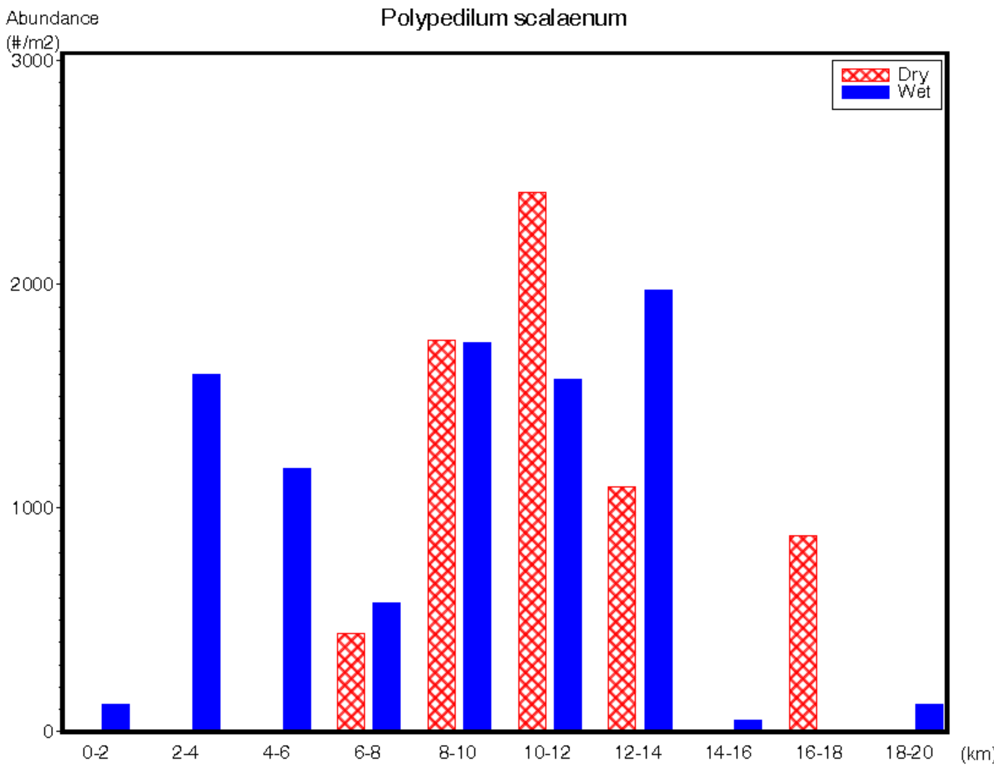
Paraprionospio pinnata
Abundance
(#/m2)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

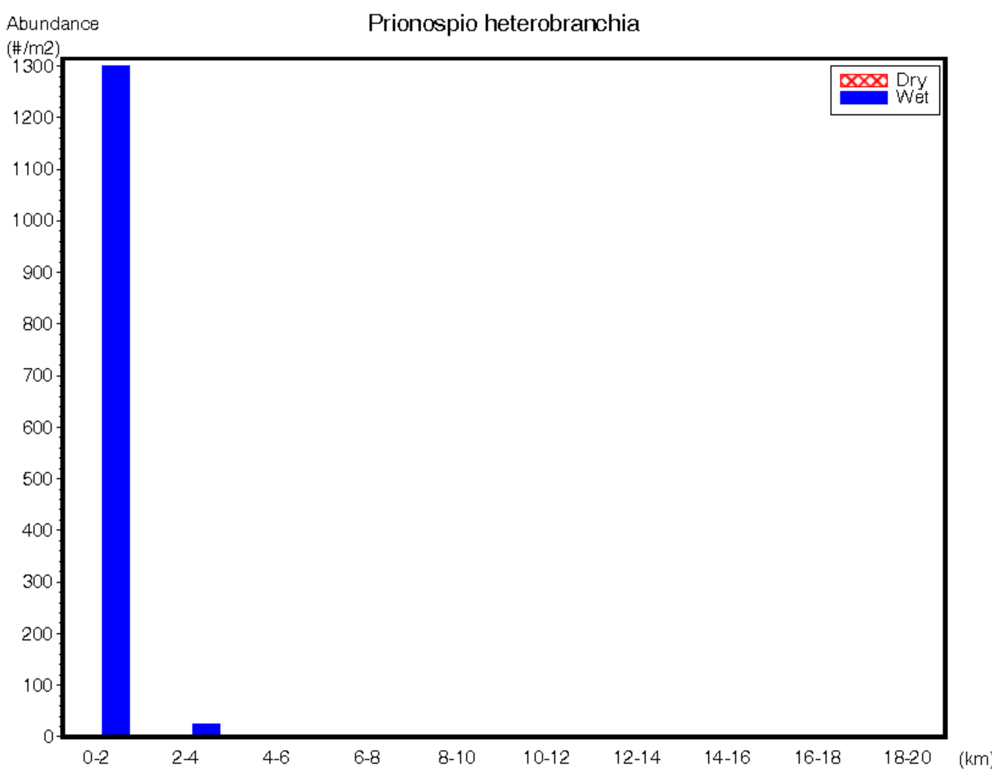


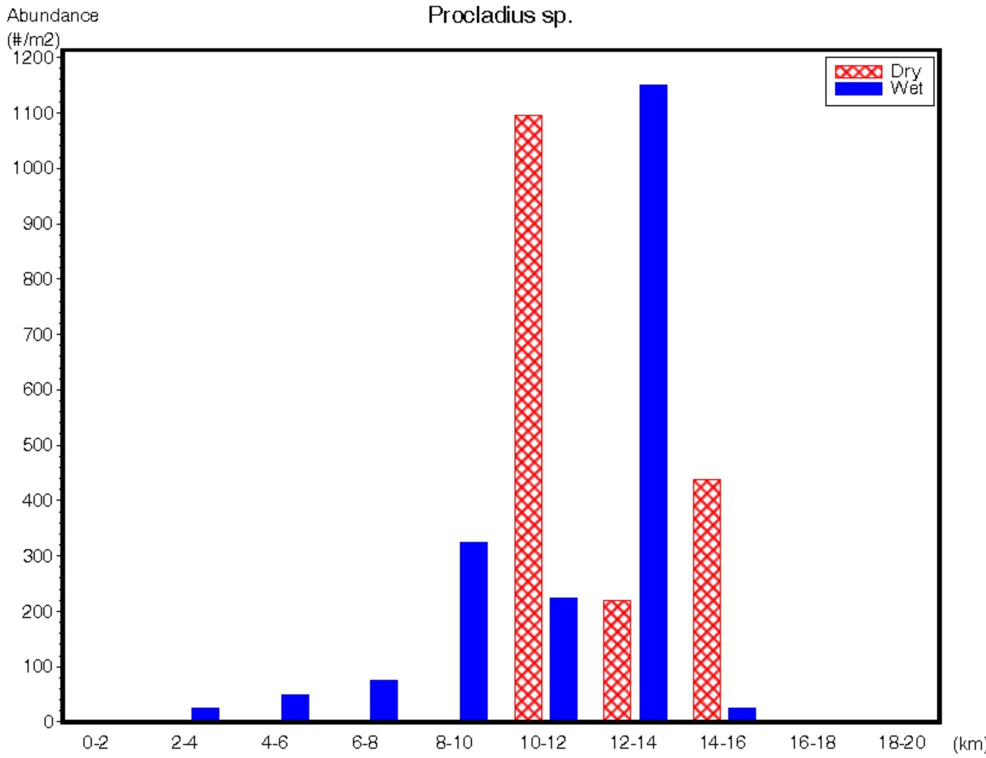
Pinnixa spp.
Abundance
(#/m2)
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Polymesoda caroliniana
Abundance
(#/m2)
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

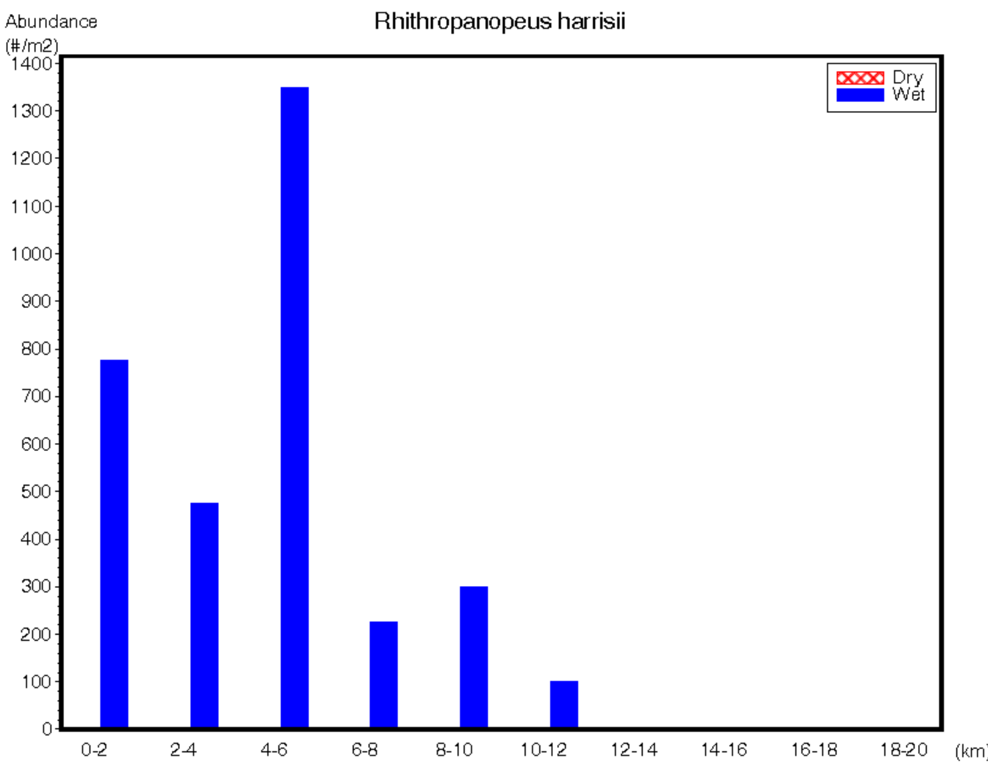

Polypedilum halterale
Abundance
(#/m2)
5000
4000
3000
2000
1000
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Polypedilum scalaenum
Dry
Wet
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

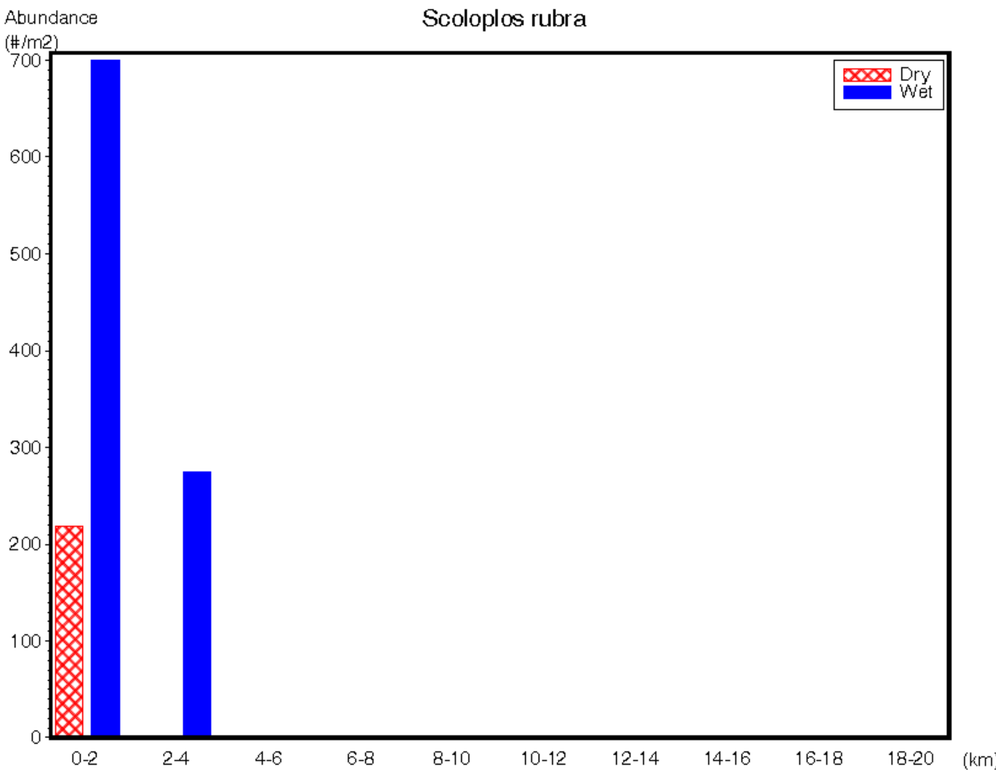

Abundance
(#/m2)
Prionospio heterobranchia
Dry
Wet
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

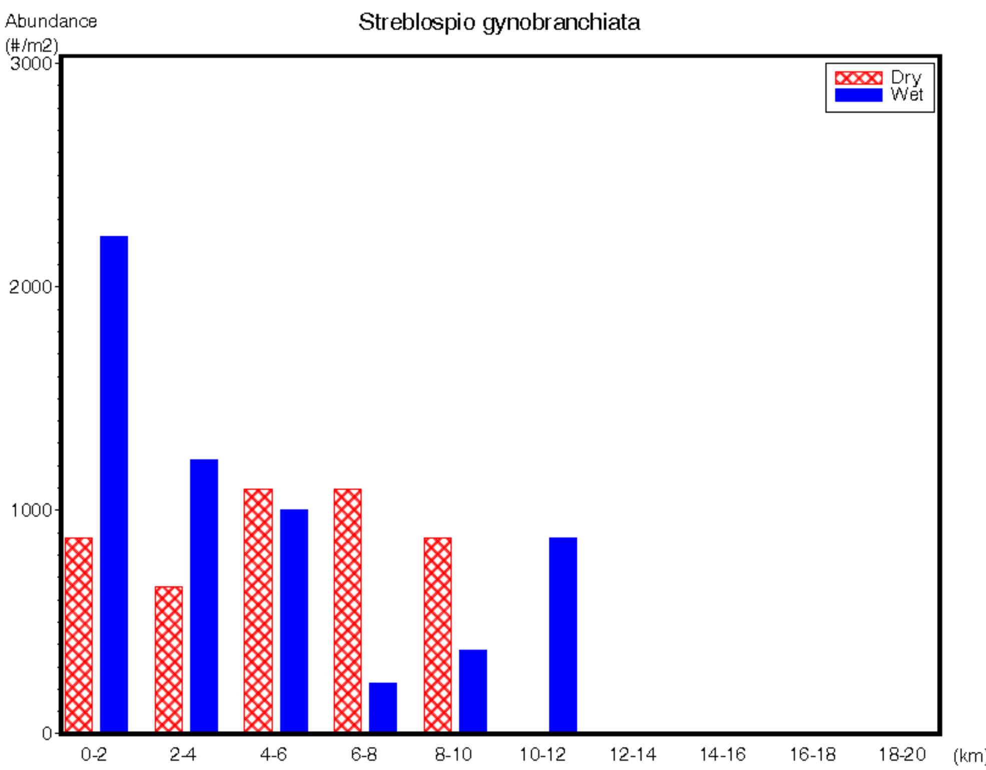


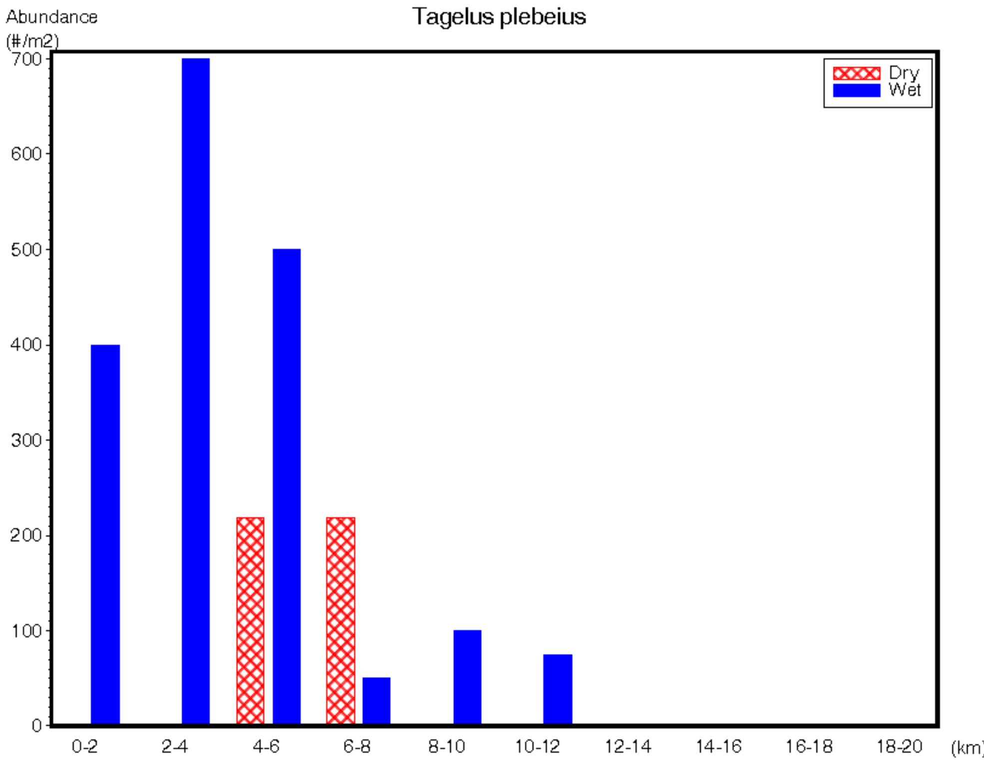
Procladius sp.
Abundance
(#/m2)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

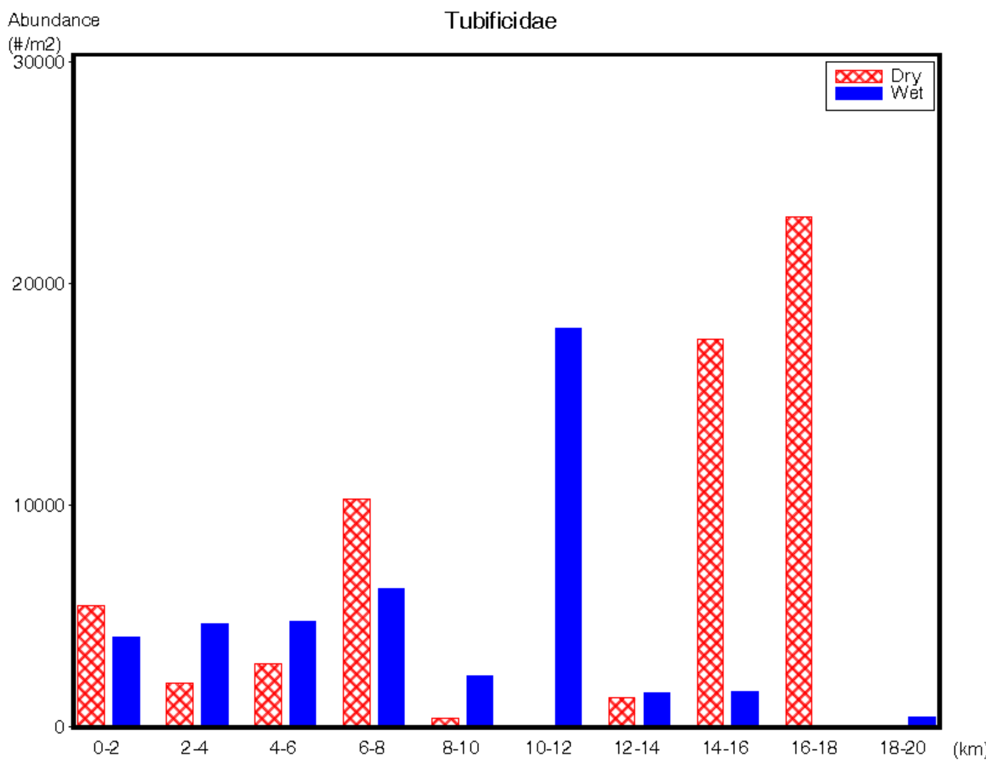


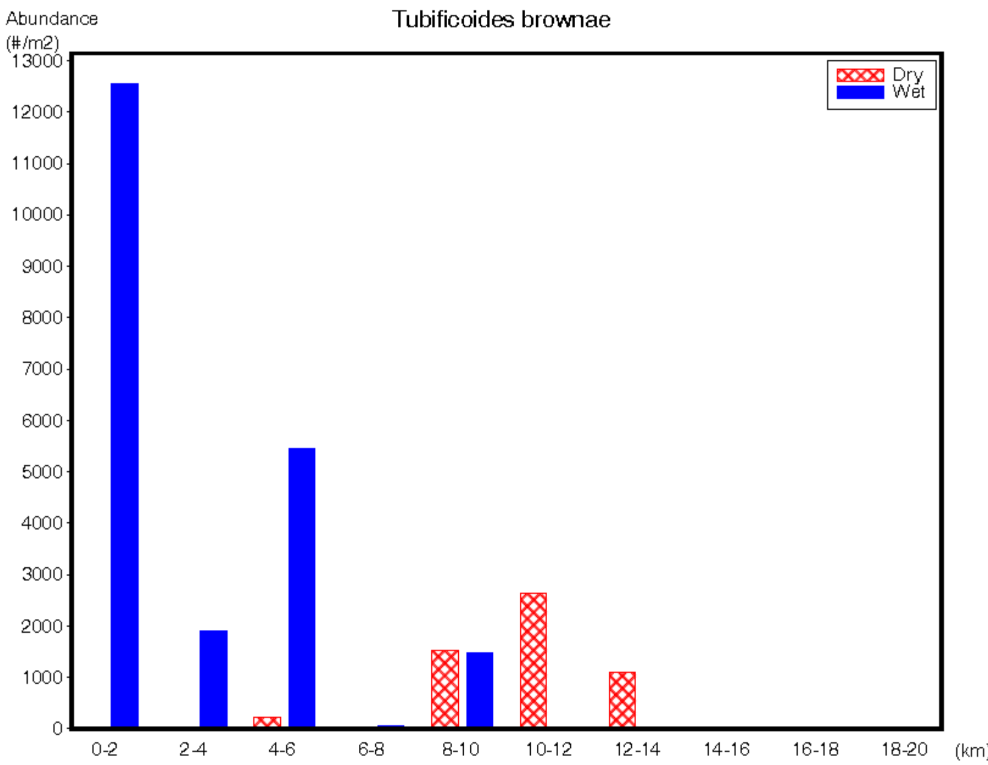
Rhithropanopeus harrisii
Abundance
(#/m2)
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Dry
Wet
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

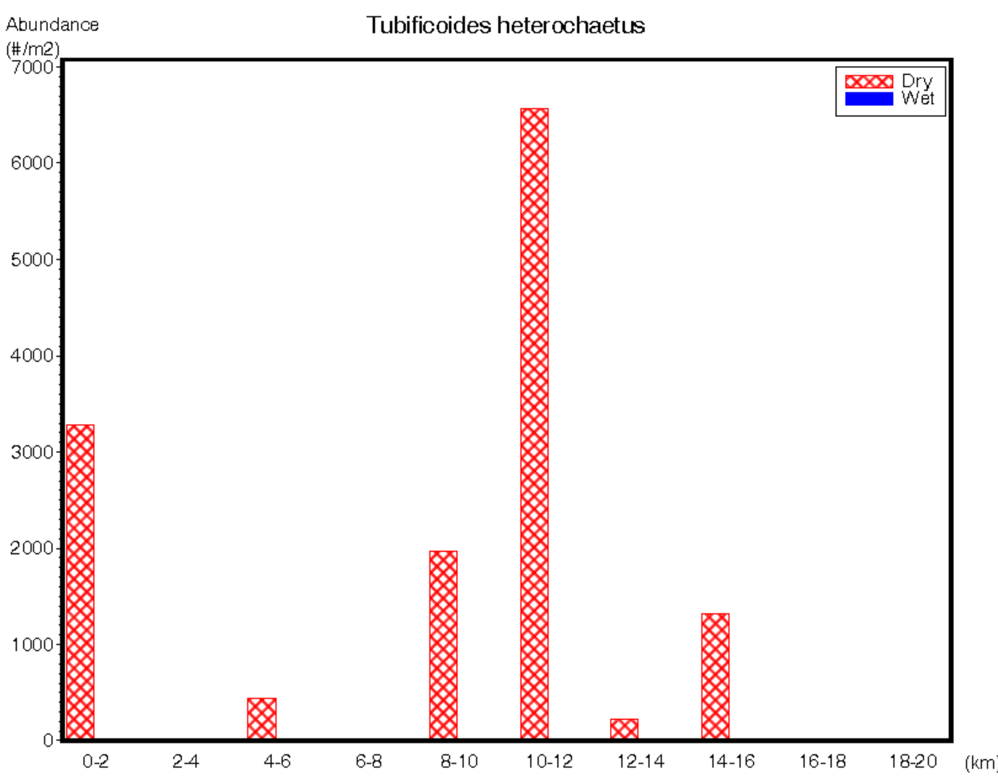

Abundance
(#/m2)
Scoloplos rubra
Dry
Wet
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

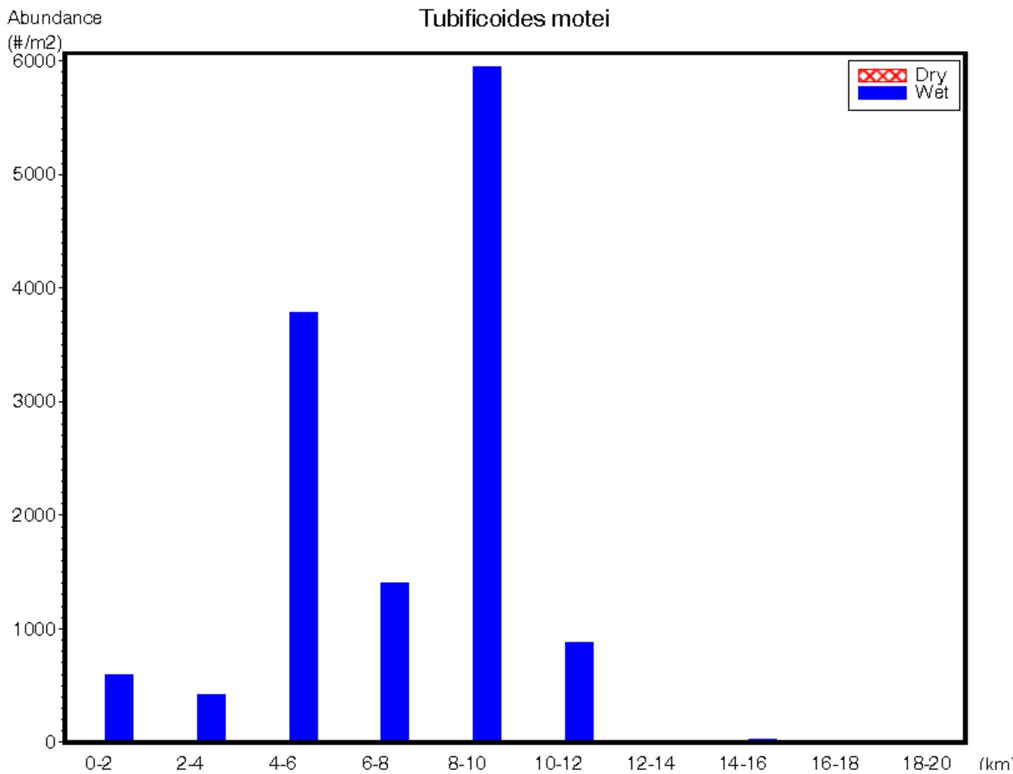

Abundance
(#/m2)
Streblospio gynobranchiata
Dry
Wet
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

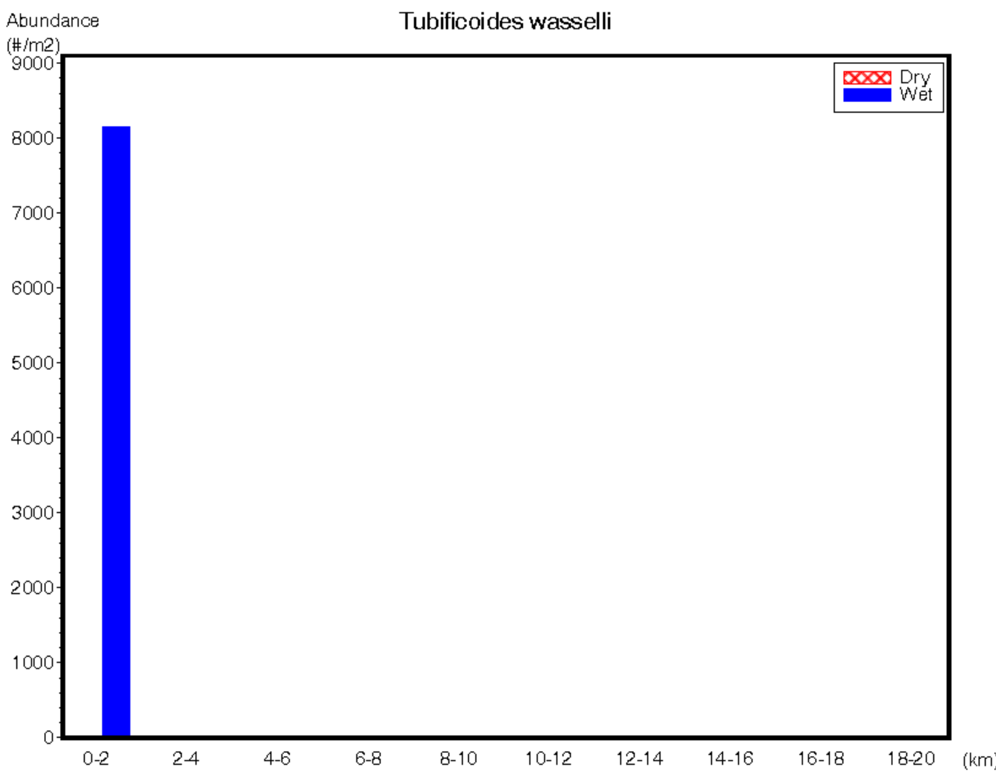

Abundance
(#/m2)
Tagelus plebeius
Dry
Wet
700
600
500
400
300
200
100
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

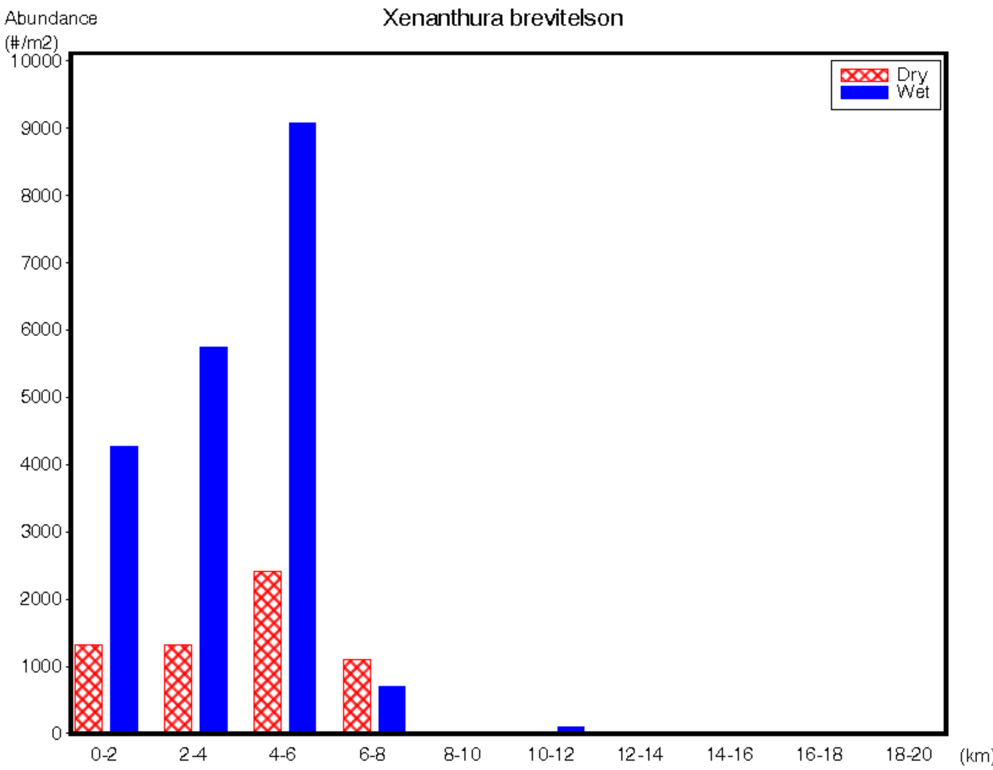

Abundance
(#/m2)
Tubificidae
Dry
Wet
30000
20000
10000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Tubificoides brownae
Dry
Wet
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Tubificoides heterochaetus
Dry
Wet
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Tubificoides motei
Dry
Wet
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Tubificoides wasselli
Dry
Wet
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)


Abundance
(#/m2)
Xenanthura brevitelson
Dry
Wet
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0-2
2-4
4-6
6-8
8-10
10-12
12-14
14-16
16-18
18-20
(km)

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

$ß_0$, $ß_1$, and $ß_2$ 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:

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

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