Tampa Bay National Estuary Program
Technical Publication #12-95a

ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM-ESTUARIES WEST INDIAN PROVINCE 1993 SAMPLING

VOLUME II

EXECUTIVE SUMMARY: A SYNOPTIC SURVEY OF THE BENTHIC MACROINVERTEBRATES AND DEMERSAL FISHES OF THE TAMPA BAY ESTUARINE SYSTEM

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JANUARY 1996

ACKNOWLEDGEMENTS

Financial support was provided by the Tampa Bay National Estuary Program (Mr. Richard Eckenrod, Program Director and Ms. Holly Greening, Project Scientist) and the Environmental Protection Commission of Hillsborough County (Mr. Roger Stewart, Director). Field operations could not have been conducted successfully without the full cooperation of the staff of the Wetlands Division of EPCHC; Tom Ash served as boat captain throughout, with assistance from Glen Lockwood. USEPA-Gulf Breeze staff provided training in EMAP field operations. Benthic samples were sorted by D. Alberdi, J. Alsum, T. Ash, P. Chipman, T. Christienson, C. Courtney, I. Davis, J. Faucher, D. Giler, A. Kiraly, and G. Lockwood. Identifications of benthic macroinvertebrates were subcontracted to Mote Marine Laboratory, Sarasota, FL (James Culter, Project Manager); Gulf Coast Research Laboratory, Ocean Springs, MS (Dr. Richard Heard, Project Manager) were subcontractors to Mote Marine Lab. Sediment chemistry samples were analyzed by Skidaway Institute of Oceanography, courtesy of USEPA-Gulf Breeze, FL. C. Jacobs and l. Scott were responsible for data entry. D. Karlen assisted with the data reductions and analyses. Ancillary data were provided by SWFWMD (rainfall), Lee Chapin of PORTS (meteorological data), and FDEP (oil spill map). Drafts of this report were reviewed by D. Camp (FDEP-Florida Marine Research Institute), T. Cardinale (EPCHC), R. Johannsen (City of Tampa), C. Kelley (EPCHC), R.E. Matheson (FDEP-Florida Marine Research Institute), and G. McRae (FDEP-Florida Marine Research Institute).

**THIS IS TECHNICAL PUBLICATION #95-12
OF THE
TAMPA BAY NATIONAL ESTUARY PROGRAM**

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INTRODUCTION

The Tampa Bay estuarine system is one of the largest in Florida, encompassing more than 398 mi^2. The Tampa Bay watershed, dependent upon four river systems (Hillsborough, Alafia, Manatee, and Palm) is approximately 2,300 mi^2 (Zarbock 1991). Traditionally, Tampa Bay has been divided into seven segments, six of which are the object of this study: Old Tampa bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, Terra Ceia Bay, and the Manatee River.

Tampa Bay as a whole is a major industrial port, and the Port of Tampa proper is the largest in Florida while Port Manatee ranks fourth (Tampa Bay National Estuary Program 1993; Tiffany & Wilkinson 1989). Shipping tonnage has risen from an estimated 1,000,000 tons in 1920 to approximately 50,000,000 tons annually since 1980 (Tampa Bay Regional Planning Council 1986). The total economic impact of the Port of Tampa is estimated at $500,000,000 per year (Tampa Bay Regional Planning Council 1986). Port Manatee contributes another approximately 5,000,000 tons annually.

The phosphate industry is the primary user of the port (more than 50% of the tonnage; Tampa Bay Regional Planning Council 1986), with exports of ammonium phosphate fertilizer, from the Hillsborough Bay segment, increasing markedly over the period 1964-1990 (Johansson 1991). Imports of petrochemical products rank second, comprising 13.5% of the annual tonnage (Tampa Bay Regional Planning Council 1986).

Six steam electricity generating stations utilize Tampa Bay waters as both a cooling water source and a dilutant for their thermal discharges (Phillips *et al.* 1989). These electric generating stations withdraw between approximately 300 cubic feet/second to more than 1,900 cubic feet/second and are permitted a "delta-T" (change from ambient intake water temperature to maximum discharge temperature) of up to 18°C (Clark & Brownell 1973). Electricity generating stations are operating in the Hillsborough Bay and Old Tampa Bay segments of the estuary.

This estuarine system is of considerable importance as a natural resource for both sport and commercial fishing interests. In 1986, local commercial fishermen harvested more than 30 million pounds of fish and shellfish, worth more than $24,000,000 (Kennedy, pers. comm. cited in Haddad 1989), primarily from the waters of the Gulf of Mexico, but including Tampa Bay. The major fishery in the bay proper has been mullet, but this will change beginning in 1995 as the State's "net-ban" amendment is enacted. Other commercially important species harvested from Tampa Bay waters include pink shrimp (as bait shrimp), menhaden, and spotted seatrout (Haddad 1989). Tampa Bay and its tributaries offer spawning and nursery areas for fishes of both commercial and sport value, as well as habitat for forage species (Springer & Woodburn 1960; Peebles *et al.* 1992).

More than two million people are estimated to live within the Tampa Bay watershed (Clark & Macauley 1989; Anonymous 1993). These residents exploit the bay and its waters for recreation and other amenities. Recreational fishing has been estimated to contribute approximately $197,000,000 to the local economy, with another $23,000,000 derived from other water-related businesses (Tampa Bay Regional Planning Council 1986). Local parks, such as Egmont Key (70,000 visitors), attract thousands of visitors, both local and tourists. The recreational boating industry (more than 90,000 registrations in the three county area during 1991-1992; Anonymous 1993) is also a significant part of this economy.

Thus Tampa Bay is a vital resource, not only to those who live and work in proximity to it, but to tourists who elect to vacation in the region, and to producers and consumers of the industrial products which traverse the waters of Tampa Bay. A consequence of Tampa Bay's importance as a commercial waterway and the attractiveness of the region for development in general, however, has been degradation of its water quality, its sediments, and loss of submerged aquatic vegetation (Estevez 1989).

In recent years, efforts to restore water quality have yielded positive results. Nutrient and chlorophyll concentrations have declined as advanced wastewater treatment methods have been implemented (Boler *et al.* 1991; Johansson 1991; Boler 1995). Improvements in water clarity (Boler 1995) and the reappearance of seagrasses in areas previously devoid of vegetation (Johansson, pers. comm., cited in Avery 1991; Lewis *et al.* 1991) have been documented.

On April 30, 1990 Tampa Bay was added to the National Estuary Program. ***The TBNEP's mission was to improve and protect the living resources of the Bay through the development of a Comprehensive Conservation and Management Plan.*** The USEPA convened a Management Conference consisting of (among other committees) a Technical Advisory Committee to carry out the mission of assessing the adequacy of existing information and programs and recommending where data were deficient and should be supplemented as well as where new programs should be developed.

The Technical Advisory Committee recognized that there was a gap in synoptic information on the benthic macroinvertebrate community of the bay as a whole. Within the context of protecting the integrity and health of Tampa Bay, benthic macroinvertebrates, a complex assemblage of small (larger than 0.5 mm) organisms living within and on the aquatic sediments of Tampa Bay, are of interest for at least two reasons.

First, from an economic standpoint, benthic macroinvertebrates typically constitute the primary prey items for many, if not most, of the fish species which inhabit Tampa Bay and its tributaries (Reid 1954; Springer & Woodburn 1960; Sykes & Finucane 1966; Killam *et al.* 1992; Nelson 1992; Motta *et al.* 1995). Benthic macroinvertebrates are also preyed upon by shorebird species (Piersma *et al.* 1993). The composition of the benthic macroinvertebrate community, then, can have a profound effect on commercial and recreational fishing, as well as on migratory waterfowl.

Second, benthic macroinvertebrates have been recognized as sensitive indicators of the environmental health of a waterbody. In fact, several states (Florida, Maine, Ohio, Vermont, Washington) have incorporated measures of the benthic macroinvertebrate community into their water and sediment quality regulations and the USEPA (1990) is encouraging the use of biological measures in water quality protection. Because many of these organisms are not very mobile and are usually resident in a single location, and others lack planktonic ("free-floating") developmental stages and must recruit new members from local populations, benthic macroinvertebrates are susceptible to local environmental changes and impacts. This includes the effects of trace metals, pesticides, and hydrocarbons which ultimately settle out of the water column to become bound to sediment particles. Benthic macroinvertebrates are also effective "integrators" of environmental contaminants. That is, benthic macroinvertebrates respond to all contaminants in the environment-- not necessarily only those measured in a conventional water or sediment quality monitoring program.

Figure 1 shows some examples of the types of animals which are termed "benthic macroinvertebrates".

The Technical Committee also recognized that ***a synoptic benthic monitoring program should be developed as part of the Comprehensive Conservation & Management Plan as a means of making statements about the health of the various segments of the bay as part of a background monitoring program***. In order to economize these two objectives, this synoptic design has employed the USEPA's Environmental Monitoring and Assessment Program [EMAP] protocols.

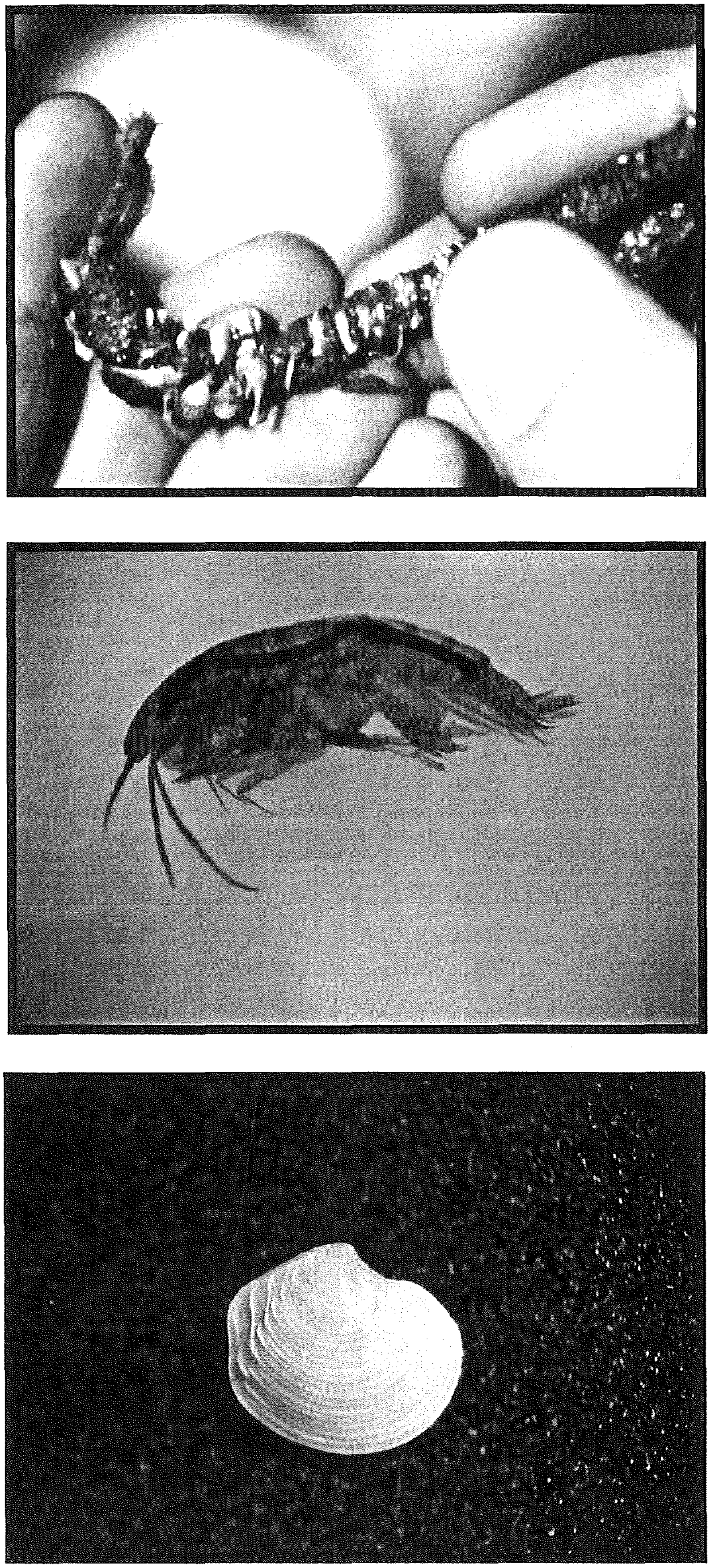

Figure 1. Representative types of benthic macroinvertebrates. Top: Polychaete worm (*Diopatra cuprea*), with its head area protruding from its tube; Middle: Amphipod crustacean (*Ampelisca* sp.); Bottom: Bivalve mollusk (*Parvilucina multilineata*).

The primary goal of the Tampa Bay National Estuary Program benthic analysis initiative is to provide an assessment of the overall ecosystem condition or status of the Tampa Bay estuarine system. To accomplish this goal for the Tampa Bay ecosystem, a number of "indicators" of ecosystem condition have been proposed. Indicators that were analyzed during 1993 for this program include:

1. benthic species composition;
2. habitat indicators (salinity, temperature, pH, water depth);
3. sediment characteristics (percent silt + clay and apparent redox potential discontinuity layer);
4. sediment contaminant concentrations (trace metals only in 1993);
5. dissolved oxygen minima;
6. gross pathology of fish;
7. aesthetic indicators (flotsam, jetsam, water clarity);
8. composition of the demersal finfish community.

A focal point of this Tampa Bay National Estuary Program project is the effort to develop a Benthic Index which can discriminate between "healthy" and "degraded" locations within Tampa Bay. Development or adoption of a Benthic Index for Tampa Bay would provide a more easily understood measure of the bay's health and status than the statistical tools more commonly used to interpret biological data. While ensuring a high quality product is critical from the scientific perspective, it is imperative that the results of this program be effectively communicated to the elected and appointed officials of the region, who are ultimately responsible for making decisions which will affect Tampa Bay. Similarly, the lay public should also have access to a measurement tool which is easily understood. A scientifically valid program, executed with stringent quality assurance and quality control protocols will ultimately be of little use if the results cannot be adequately communicated to the individuals managing and using the resource that is Tampa Bay.

These data are to be available for use by area resource managers to assess the outcomes of management decisions. For example, the Tampa Bay National Estuary Program's Science Advisory Group has drafted an "action plan" to address the issue of toxic sediments and how to manage them in Tampa Bay (MacDonald 1995). ***The ecosystem objective by which the success of the strategy is to be measured is to "maintain environmental conditions in Tampa Bay sediments such that the benthic community, including epibenthic and infaunal species, is protected and, where necessary, restored"*** (MacDonald 1995).

The protocols which were adopted to implement this program are specifically designed to provide a statistically valid program for identifying trends in estuarine health. This initial investigation period provides only a "snapshot" of conditions in Tampa Bay during the late summer of 1993 (September-October), when stresses from low dissolved oxygen, high temperatures, and stormwater runoff are presumed to be greatest. The real value of the program will be realized when multiple years of data are available so that trends may be evaluated and confidence intervals may be computed for the various indicators of the status of the Tampa Bay estuarine system.

The information obtained from this program, then, are to be used:

a. to aid in determining regional goals for natural resource protection in Tampa Bay;
b. to estimate areal extents of and temporal changes within the segments of the Tampa Bay estuary not meeting "living resource requirements" (Coastal Environmental, Inc. 1994);
c. as a management tool to assess efforts at reducing the amounts of toxic substances entering Tampa Bay (MacDonald 1995);
d. as a tool to measure the effectiveness of actions taken by local governments and regulatory agencies under the auspices of the CCMP (Versar 1992);
e. to provide scientifically valid data and assessments which can be used to modify the Comprehensive Conservation and Management Plan as needed (Versar 1992).

SECTION 2

METHODS

The study design employed was a stratified (by bay segment), random ("consciously without bias") probability based (the likelihood of sampling any known point can be estimated) sampling design (Larsen *et al.* 1994; Coastal Environmental, Inc. 1994). One of three hexagonal grids were randomly superimposed over the Tampa Bay estuarine system. For the main stem of Tampa Bay, comprising the Old Tampa Bay [OTB], Middle Tampa Bay [MTB], and Lower Tampa Bay [LTB] segments, the grid size was 3,200 acres, or 13 km^2 ("7x7").The "7x7"refers to a grid density twice enhanced by a factor of seven from the base EMAP hexagon (9,900 acres or 40 km^2). Denser grids were used for the Hillsborough Bay [HB] ("7x7x3"=1,100 acres or 4.4 km^2) and Terra Ceia Bay [TCB]/Manatee River [MR] segments ("7x7x7"=470 acres or 1.9 km^2). Within each hexagon, the sampling location was randomly determined, with a known probability of inclusion.

The value of such an approach is that it is possible to determine the extent to which the sample population represents the "true" population (*i.e.*, Tampa Bay and its segments); it is also possible to estimate how much of the bay, and how much of each segment, is "degraded" or "healthy" and confidence limits (*i.e.*, $\pm$10%, $\pm$20%, *etc.*) can be placed on these estimates.

Benthic macroinvertebrates, demersal ("bottom dwelling") fishes, water column profiles of hydrographic measurements (temperature, dissolved oxygen, salinity, pH), 24-hour measurements of hydrographic data from near-bottom waters, and sediments were collected using the standard EMAP techniques adopted by USEPA for the northern Gulf of Mexico (Holland 1990). Detailed descriptions are found in Courtney *et al.* (1993).

All sampling occurred during September-October 1993. The methodology for the sample selection process is described in Courtney *et al.* (1993). Station locations are depicted in Figures 2, 3, and 4. More than 100 stations, in six bay segments, were scheduled for sampling: 23 in Hillsborough Bay, 21 in Old (upper) Tampa Bay, 22 in Middle Tampa Bay, 19 in Lower Tampa Bay, 11 in the Manatee River, and 7 in the Terra Ceia Bay Aquatic Preserve (Manatee County). All samples, exclusive of those from Manatee County, were collected by the Environmental Protection Commission of Hillsborough County; Manatee County samples in the Manatee River and Terra Ceia Bay segments were collected by the Manatee County Environmental Action Commission. Some stations were either not accessible (*e.g.*,too shallow, located on land), or sample collections were aborted due to physical obstructions.

At each station the latitude/longitude, time, date, and weather conditions at the station were recorded. The water column profile was then measured with either a Hydrolab Surveyor 3 (temperature, dissolved oxygen, pH, and salinity/conductivity) or equivalent and a LICOR LI-1000 radiometer (measures "photosynthetically active radiation" [PAR], light in the range of wavelengths used by aquatic plants (such as seagrasses) in photosynthesis); water column transparency was measured with a Secchi disk.

If the bottom dissolved oxygen concentration was greater than 1.0 milligrams per liter [mg/L], a Hydrolab Recorder was deployed to measure temperature, dissolved oxygen, salinity/conductivity, and pH every 15 minutes over a 12 to 24 hour cycle. If bottom dissolved oxygen was less than 1.0 mg/L, the Recorder was not deployed, as the absence of oxygen was likely to damage the instrument. In practice, only in the Terra Ceia Bay and Manatee River segments were data collected over a diel cycle; in other segments sampling was restricted because only a single Recorder was available.

Sediment samples were collected with a 0.04 m^2 stainless steel, Young-modified Van-Veen grab sampler (Figure 5). For biological samples, the contents of the grab was sieved (through 0.5 mm mesh) and the organisms preserved in a 10% solution of borax-buffered formalin, with Rose Bengal added to stain the organisms. Additional samples (upper 2 cm only) were composited for chemical and silt+clay analyses.

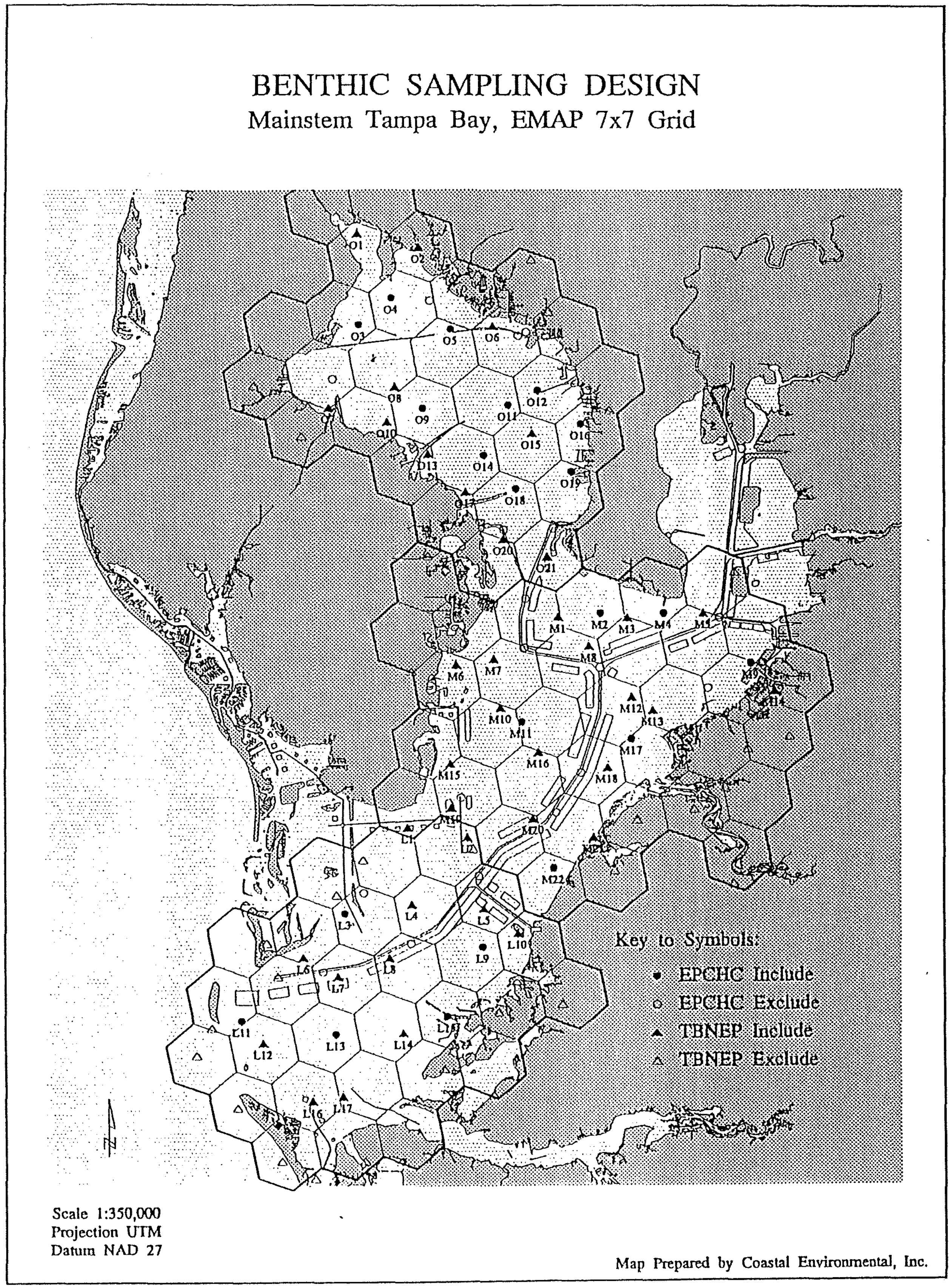

Figure 2. Location of sampling stations in the main body (Old Tampa Bay, Middle Tampa Bay, and Lower Tampa Bay segments) of Tampa Bay, September 1993.

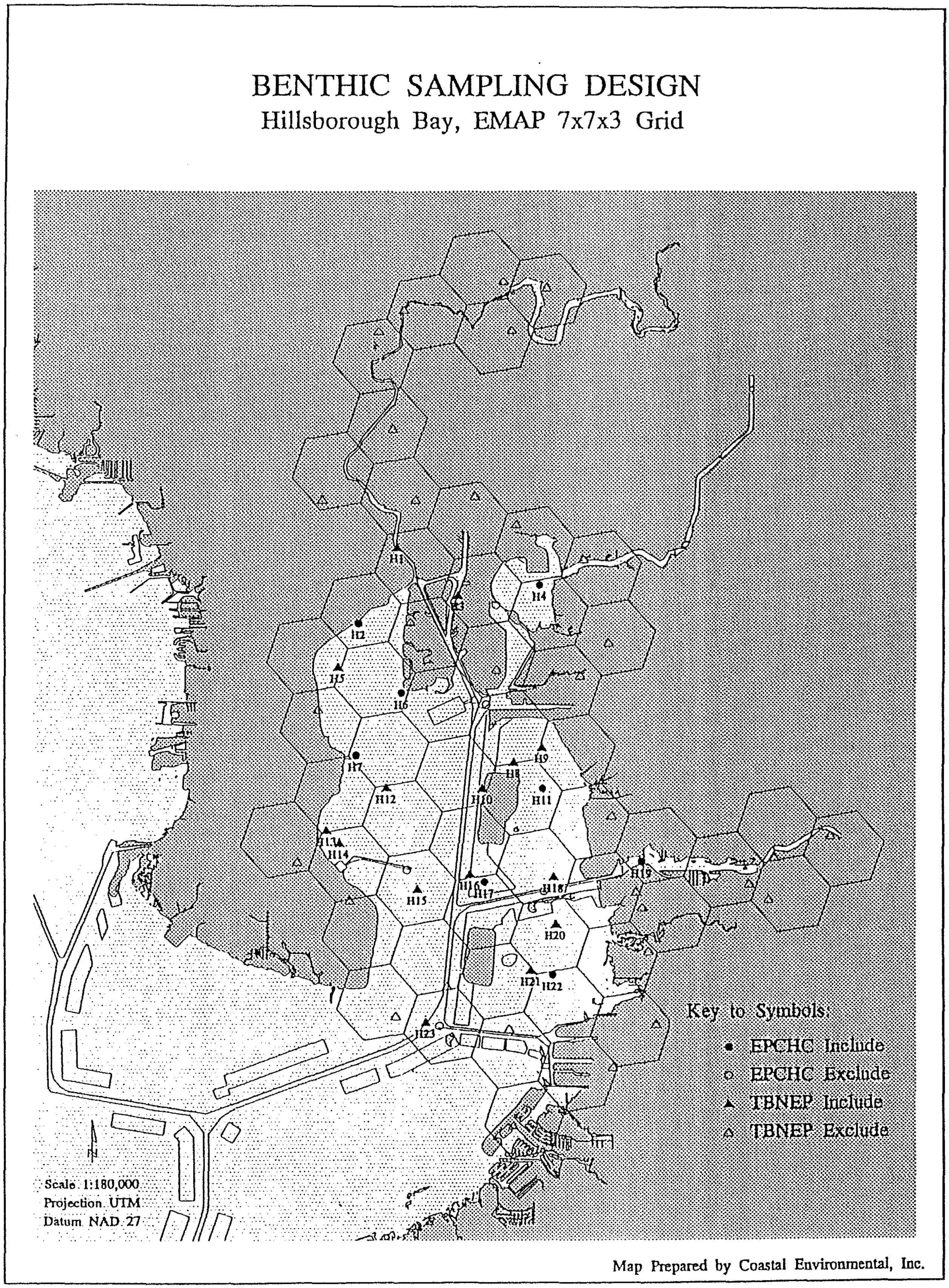

Figure 3. Location of sampling stations in the Hillsborough Bay segment of Tampa Bay, September 1993.

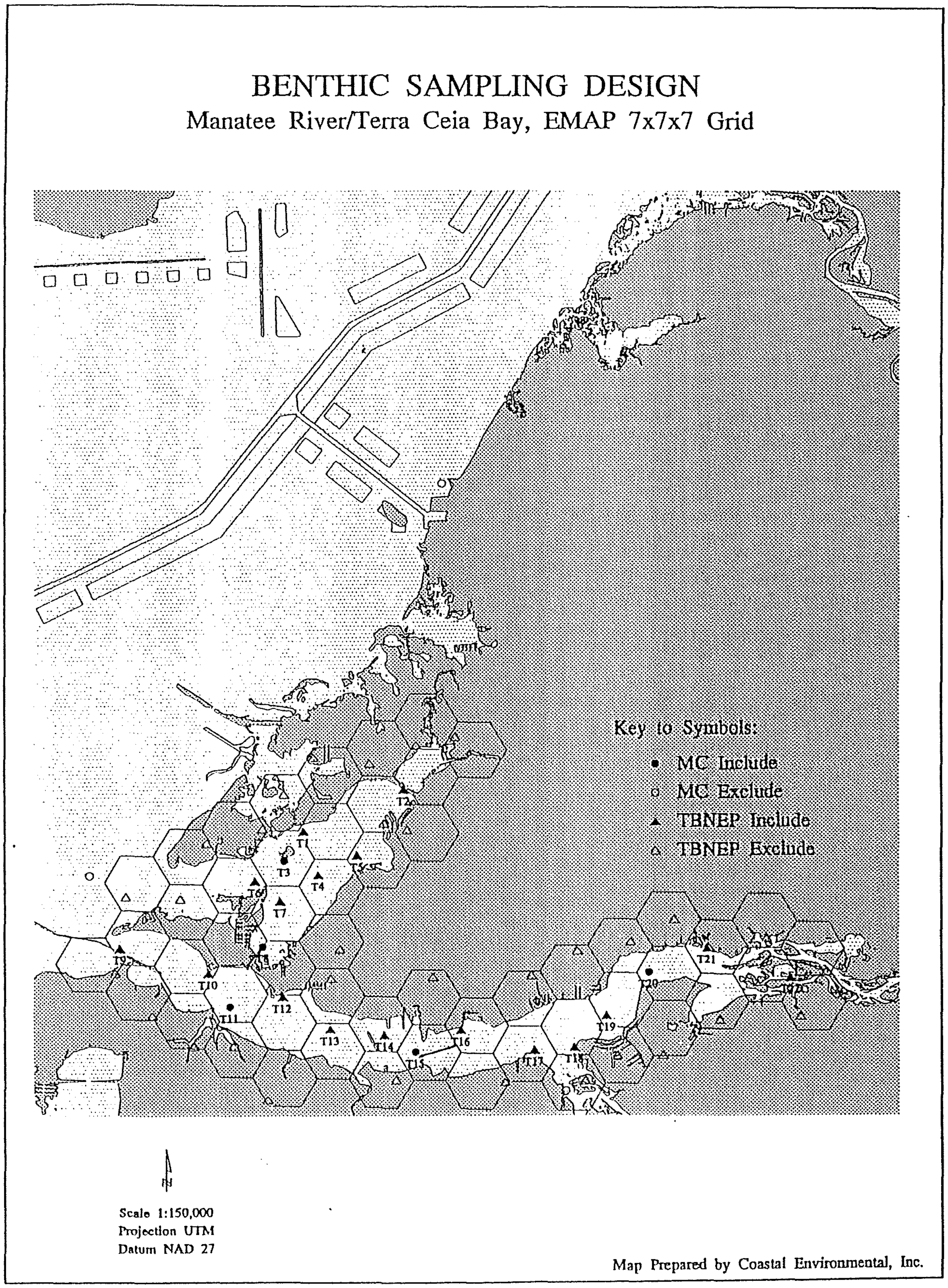

Figure 4. Location of sampling stations in the Manatee River and Terra Ceia Bay (Manatee County) segments of Tampa Bay, October 1993.

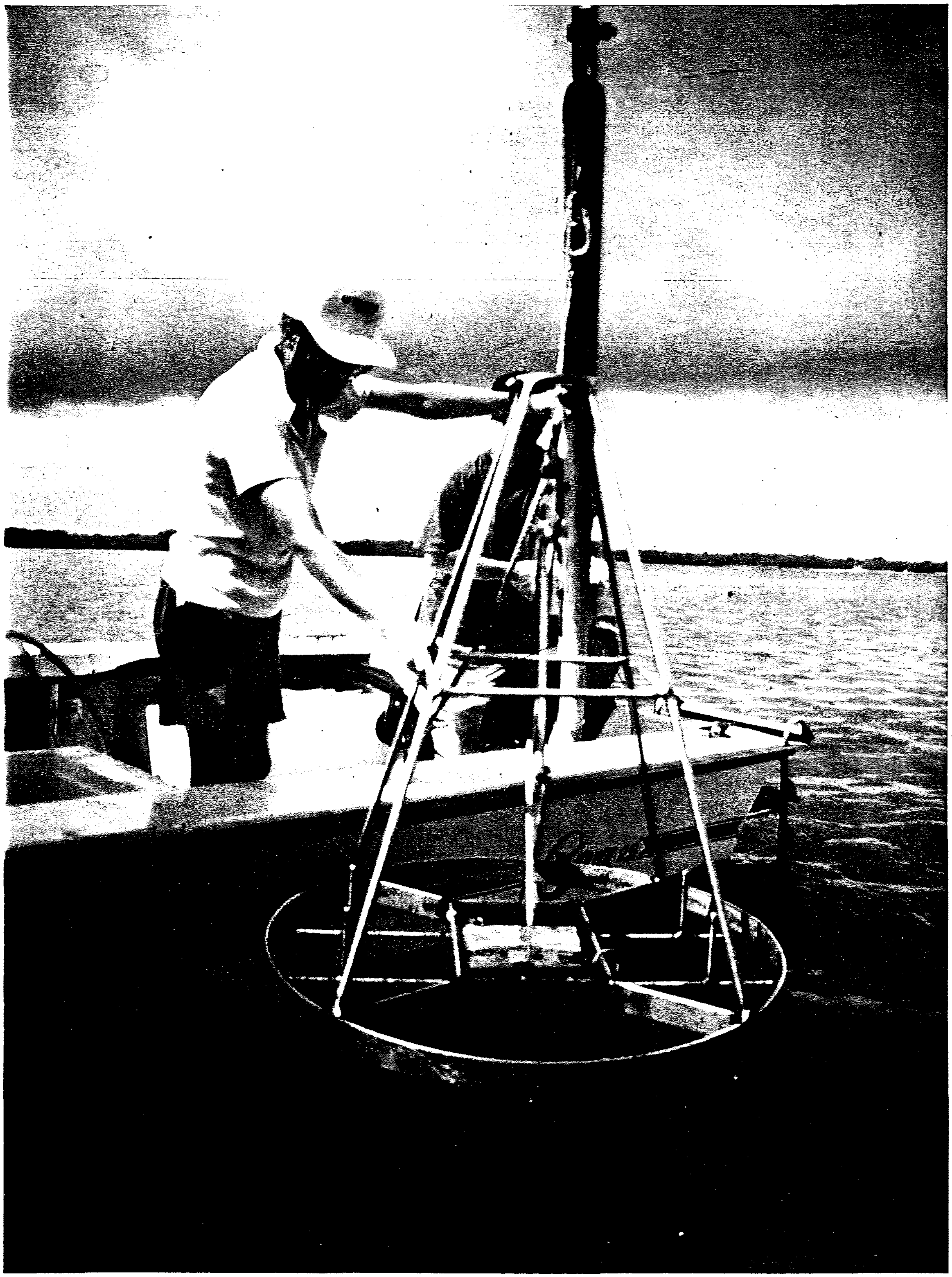

Figure 5. Young-modified Van Veen sampler for benthic macroinvertebrates and submerged sediments.

A single 10 minute fish trawl was taken at each station using a high rise trawl with a 16-ft footrope and a chain sweep. All fish were identified, counted, and at least 30 randomly selected fish were measured. All individuals of the designated target fish species (*cf.* Courtney *et al.* 1993) were examined for evidence of gross pathology. While fish were still alive or freshly dead, their skin, fins, eyes and gill chambers were inspected for evidence of disease and body abnormalities according to the protocols outlined in the Louisianian Province Field Operations Manual (Macauley 1993).

SECTION 3

RESULTS & DISCUSSION

3.1 STATION CHARACTERISTICS

Sampling stations ranged in depth from 1.6 to 32 feet (0.5 to 9.8 meters); most stations (43) had bottom depths of 6.5 to 13 feet (2 to 4 meters). Submerged aquatic vegetation (seagrasses and macroalgae), was observed at almost one fourth of the stations in the Old Tampa Bay segment (manatee grass and shoal grass) and at single stations in the Middle Tampa Bay and Terra Ceia Bay segments.

3.2 HYDROGRAPHIC CHARACTERISTICS

The data collected during this September-October 1993 survey (Table 1) showed that the ***bay segments differed in terms of water mass (temperature-salinity) characteristics***. The average water temperatures of the Middle, Hillsborough and Lower Tampa Bay segments were equal and greater than those of the other bay segments; the average water temperature of the Manatee River segment was significantly cooler than that of any other segment. Freshwater inflow to the estuary affected average segment salinities. Salinity was lowest in the Old Tampa Bay, Manatee River, and Hillsborough Bay segments and highest in the Lower Tampa Bay and Terra Ceia Bay segments. Overall, most salinities were in the polyhaline range (15-28 parts/thousand [ppt]). Some of the Hillsborough Bay segment stations were considered to be oligohaline to mesohaline (2-19 ppt); at least some stations in each bay segment, and many of the stations in the Lower Tampa Bay segment were euhaline (above 23 ppt).

Salinity stratification of the water column is considered to be a short-lived phenomenon in Tampa Bay, readily broken down by tides and winds (Orlando *et al.* 1993). However, during the "wet season" (generally June through October), stratification may be evident near freshwater inputs (Orlando *et al.* 1993). These characterizations of the estuary were confirmed. Bottom salinities were significantly higher than surface salinities, but rarely did the surface to bottom difference exceed 3 ppt.

Hypoxia, defined as a dissolved oxygen concentration less than 2.0 mg/L (Diaz *et al.* 1992), can alter biological communities by encouraging migrations out of impacted areas, by causing benthic macroinvertebrates to modify their behavior (*e.g.*, reduce the depth that they burrow into the sand) which may make them more susceptible to being preyed upon by fish, or if the condition persists, may contribute directly to their death (Santos & Simon 1980; Gaston 1985).

Dissolved oxygen (Figure 6) concentrations below the 5 mg/L Florida State standard for Class II (shellfish harvesting) and III waters (suitable for recreation and propagation of fish and shellfish) were most common in bottom waters of the Hillsborough Bay segment. Hypoxia (dissolved oxygen less than 2 mg/L) was only evident in the Hillsborough Bay segment and was estimated to cover 21% (more than 5,000 acres; 22 km^2) of this segment. 73% of the Manatee River segment (ca. 10,000 acres; 40 km^2) and 63% of the Hillsborough Bay segment (more than 16,000 acres; 66 km^2) were estimated to be out of compliance with the State standard for Class III waters. Conversely, more than 75% of the Old, Middle, and Lower Tampa Bay segments had near-bottom dissolved oxygen concentrations greater than the 5 mg/L State standard.

Anoxia (dissolved oxygen less than 0.2 mg/L; Diaz* et al. *1992) was never detected. However, Rabalais (1991 and 1992) provided data which suggested that benthic macroinvertebrates are adversely affected by dissolved oxygen concentrations less than 0.5 mg/L; such conditions were detected at two stations in the Hillsborough Bay segment.

Table 1. Summary of the average (minimum-maximum) temperature (°C), salinity (ppt), dissolved oxygen (mg/L), pH (arithmetic mean), and Secchi disk depth (m) in Tampa Bay, September-October 1993: by bay segment. Average of surface and bottom measurements except Secchi disk.

Bay Segment	Temperature	Salinity	Dissolved oxygen	pH	Secchi Disk depth
OTB	28.8 (26.4-30.2)	24.5 (19.6-26.3)	6.54 (2.45-11.05)	7.88 (7.57-8.18)	1.4 (0.8-3.5)
HB	29.8 (27.9-31.4)	23.0 (9.9-27.5)	5.22 (0.27-12.80)	7.81 (7.28-8.31)	1.4 (0.8-2.3)
MTB	29.9 (28.8-32.0)	26.9 (22.6-29.4)	6.25 (4.24-9.58)	7.89 (7.66-8.07)	1.7 (1.2-2.5)
LTB	29.7 (28.4-31.7)	31.3 (21.1-34.3)	5.61 (2.55-7.94)	7.86 (7.65-8.00)	2.1 (1.5-3.0)
TCB	27.9 (26.9-29.0)	28.7 (24.5-29.8)	5.72 (3.6-8.10)	no data	2.5 (1.7-3.0)
MR	27.0 (25.8-29.0)	24.3 (11.0-32.0)	5.21 (3.20-7.10)	7.63 (6.54-8.19)	1.9 (1.0-3.2)

BAY SEGMENTS

OTB: Old Tampa Bay HB: Hillsborough Bay MTB: Middle Tampa Bay
LTB: Lower Tampa Bay TCB: Terra Ceia Bay MR: Manatee River

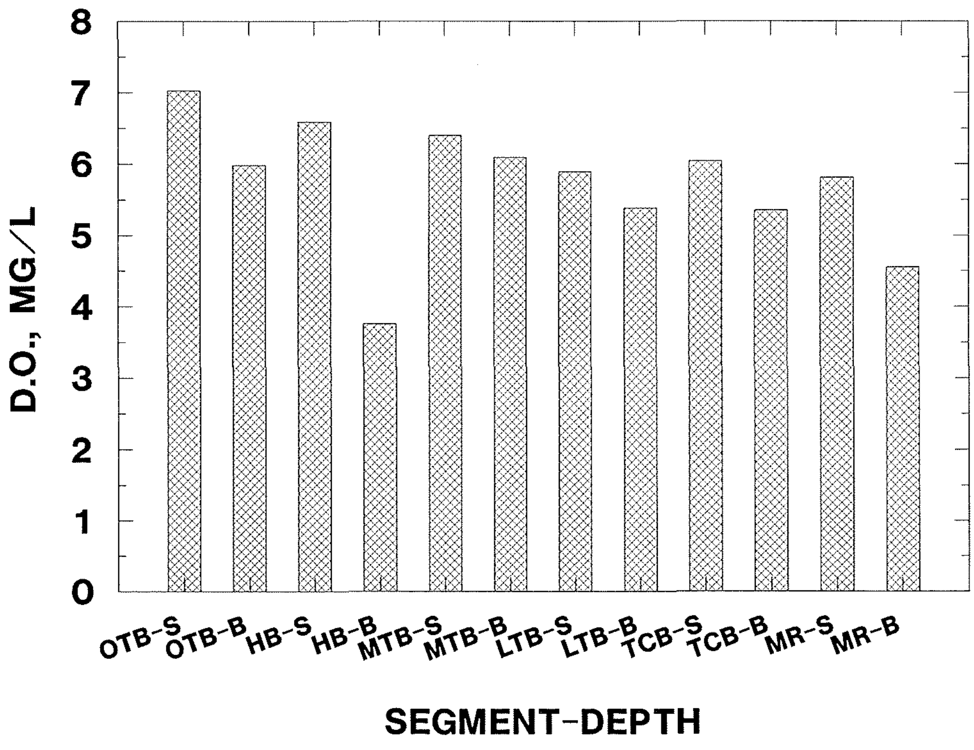

Figure 6. Average concentration of dissolved oxygen (mg/L) in the Tampa Bay estuarine system, by bay segment and relative depth (surface [S] *vs.* bottom [B]) September-October 1993.

Dissolved oxygen stratification (Figure 7) was observed where there were suggestions of algal "blooms". The data showed that surface dissolved oxygen concentrations were extremely high (greater than 8 mg/L) at several locations in the Old Tampa Bay segment. Concommitant with these elevated dissolved oxygen concentrations were high pH values (up to 8.3). Such co-occurrences tend to be indicative of phytoplankton (microscopic algae) "blooms". Rabalais (1992) suggests that chronicling the extents of extremely high concentrations may also provide valuable information for characterizing eutrophication (the process of nutrient entrichment, which generally encourages "blooms" of phytoplankton). Recently Karydis (1994) has suggested that analysis of extreme conditions (in this case low and high dissolved oxygen concentrations) may be more sensitive at characterizing the extents of eutrophication than assessments based upon "average" concentrations.

Transparency of the water column (as Secchi disk depth), was related to salinity: transparency decreased as salinity decreased. It is likely that other factors, not salinity *per se*, is responsible for this relationship (*cf.* McPherson & Miller 1987). The extents to which light can penetrate the water column is critical to the growth of seagrasses and low transparency (due to phytoplankton growth) is another indicator of nutrient enrichment. Low salinity sites are directly influenced by freshwater (=stormwater) inputs (*e.g.*, Hillsborough and Palm Rivers). These inputs in turn, carry with them nutrients, which can stimulate phytoplankton production, and suspended particulate matter-- both of which act together to reduce light penetration of the water column (McPherson & Miller 1987).

The hydrographic factors measured during this survey of the benthic macroinvertebrates and demersal fishes of the Tampa Bay estuarine system indicate that the bay segments differed during the survey period. The primary difference was in the salinity regime, where distance from sources of freshwater input was a factor. Lower water temperatures in the Old Tampa Bay and Manatee County segments further distinguished these segments from the Middle, Lower, and Hillsborough Bay segments.

There was indirect evidence from dissolved oxygen (and pH) data for the occurrence of localized algal blooms and direct evidence of dissolved oxygen stratification at several locations in the Old Tampa Bay and Hillsborough Bay segments. ***Hypoxia of near-bottom waters, which may be detrimental to animals including benthic macroinvertebrates and fish, was measured at approximately 20% of the sampling stations in the Hillsborough Bay segment.*** Light penetration was also reduced in the Hillsborough Bay segment compared to the Lower Tampa Bay segment.

3.3 DEMERSAL FINFISH

Thirty-six species of fish (Table 2), from 88 trawls, were identified during the September-October 1993 survey period (Table 2). The most abundant fish included mojarras (46.7%), pinfish (11.6%), and gafftopsail catfish (7.2%); 15 species were represented by only a single specimen. Three individual species (pinfish, pigfish, and inshore lizardfish) and the mojarras (comprising at least two species) were collected in all six bay segments. The fish collected during this survey were those commonly identified as "typical" residents of Tampa Bay and the numerical dominants were similar to those reported in other studies employing trawls (Lindell *et al.* 1973; Comp 1985; Lewis & Estevez 1988; Killam *et al.* 1992; Nelson 1992). The number of species collected was not especially high compared to the estimated 125 species reported to inhabit Tampa Bay, its tributaries, and coastal waters near to Tampa Bay (Comp 1985). However, this effort represents that of only a single daytime survey period, during the season of the year considered to be most stressful to the fish, employing only a single sampling gear.

Overall catch per unit effort (CPUE= catch per ten minute trawl) was highest in the Hillsborough Bay segment and lowest in the Lower Tampa Bay segment (Table 3). The possibility that the greater water clarity in the Lower Tampa Bay segment may have contributed to the greater number of "empty" trawls in this segment (ten of the twelve), by increasing the likelihood of gear avoidance, was found (by statistical analysis) not to be a factor.

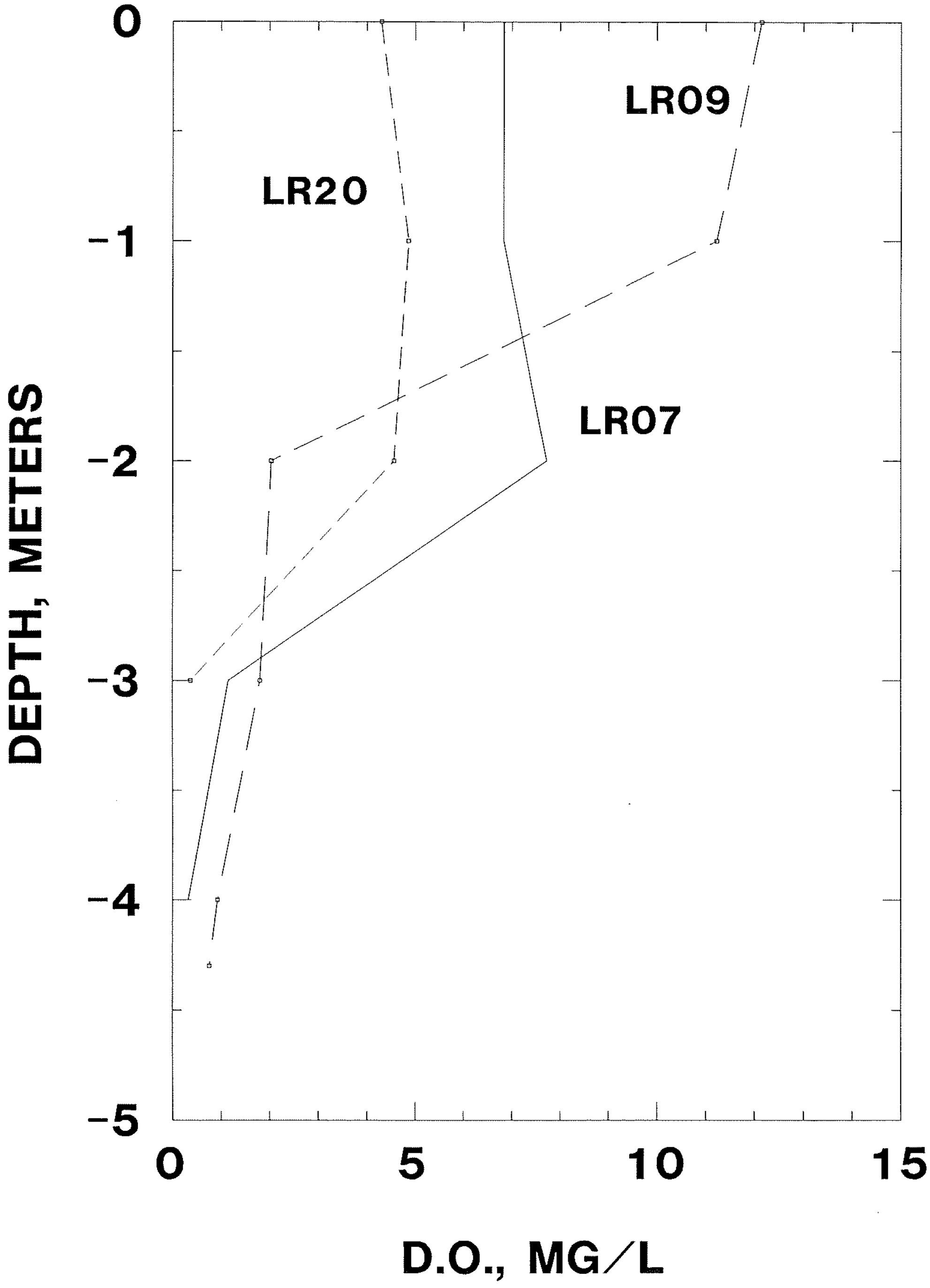

Figure 7. Vertical profiles of dissolved oxygen (mg/L) at Stations LR07, 09, and 20 in the Hillsborough Bay segment, September 1993. Surface= 0 meters depth. See Figure 3 for station locations.

Table 2. Inventory of fish species collected from Tampa Bay, September-October 1993.

Scientific Name	Common Name[a]
CHONDRICHTHYES (Cartilaginous fishes)	
Dasyatidae (Stingrays)	
Gymnura micrura **(Bloch & Schneider)**	**Smooth butterfly ray**
Myliobatidae (Eagle rays)	
Rhinoptera bonasus **(Mitchill)**	**Cownose ray**
Sphyrnidae (Hammerhead sharks)	
Sphyrna tiburo **(Linnaeus)**	**Bonnethead**
OSTEICHTHYES (Bony fishes)	
Ariidae (Sea catfishes)	
Arius felis **(Linnaeus)**	**Hardhead catfish**
Bagre marinus **(Mitchill)**	**Gafftopsail catfish**
Balistidae (Leatherjackets)	
Aluterus scriptus **(Osbeck)**	**Scrawled filefish**
Bothidae (Lefteye flounders)	
Ancyclopsetta quadrocellata **Gill**	**Ocellated flounder**
Paralichthys lethostigma **Jordan & Gilbert**	**Southern flounder**
Carangidae (Jacks)	
Chloroscombrus chrysurus **(Linnaeus)**	**Atlantic bumper**
Oligoplites saurus **(Bloch & Schneider)**	**Leatherjack**
Selene vomer **(Linnaeus)**	**Lookdown**
Clupeidae (Herrings)	
Harengula jaguana **Poey** (=*H. pensacolae* **Good & Bean)**	**Scaled sardine**
Opisthonema oglinum **(Lesueur)**	**Atlantic thread herring**
Echeneidae (Remoras)	
Echeneis naucrates **Linnaeus**	**Sharksucker**
Engraulidae (Anchovies)	
Anchoa hepsetus **(Linnaeus)**	**Striped anchovy**
Ephippidae (Spadefishes)	
Chaetodipterus faber **(Broussonet)**	**Atlantic spadefish**
Gerreidae (Mojarras)	
Eucinostomus argenteus complex	Mojarras

Table 2. (Continued)

Scientific Name	Common Name[a]
Haemulidae (Grunts)	
Haemulon plumieri **(Lacepede)**	**White grunt**
Orthopristis chrysoptera **(Linnaeus)**	**Pigfish**
Lepisoteidae (Gars)	
Lepisosteus **sp.**	**Gar**
Ostraciidae (Boxfishes)	
Lactophrys quadricornis **(Linnaeus)**	**Scrawled cowfish**
Rachycentridae (Cobias)	
Rachycentron canadum **(Linnaeus)**	**Cobia**
Sciaenidae (Drums)	
Bairdiella chrysoura **(Lacepede)**	**Silver perch**
Cynoscion arenarius **Ginsburg**	**Sand seatrout**
C. nebulosus **(Cuvier)**	**Spotted seatrout**
Leiostomus xanthurus **Lacepede**	**Spot**
Menticirrhus littoralis **(Holbrook)**	**Gulf kingfish**
Sciaenops ocellatus **Linnaeus**	**Red drum**
Serranidae (Sea basses)	
Centropristis striata **(Linnaeus)**	**Black sea bass**
Sparidae (Porgies)	
Lagodon rhomboides **(Linnaeus)**	**Pinfish**
Syngnathidae (Pipefishes)	
Syngnathus scovelli **(Evermann & Kendall)**	**Gulf pipefish**
Synodontidae (Lizardfishes)	
Synodus foetens **(Linnaeus)**	**Inshore lizardfish**
Tetraodontidae (Puffers)	
Chilomycterus schoepfi **(Walbaum)**	**Striped burrfish**
Sphoeroides nephelus **(Goode & Bean)**	**Southern puffer**
Triglidae (Searobins)	
Prionotus salmorubior **Jordan**	**Blackwing searobin**
P. scitulus **Jordan & Gilbert**	**Leopard searobin**

The numbers of species ("species richness") in Hillsborough Bay, which is the segment of Tampa Bay considered to be most perturbed (Sykes & Finucane 1966) due to freshwater inputs (Hutchinson 1983; Lewis & Estevez 1988) and the presence of contaminated, toxic sediments (Long *et al.* 1991 and 1994), was relatively high (22 species). This compares favorably to reports from previous studies in this segment. For example, Price & Schleuter (1985) identified 30 species in the Hillsborough-McKay Bay system while sampling over an annual cycle deploying a sampling gear (seine) which was more effective at collecting inshore and water column species than the bottom trawl used in this survey.

Both species richness and diversity ("Shannon-Wiener" index; diversity is a measure of both the numbers of species and how the numbers of individuals are distributed among the species) ***generally declined as salinity decreased. There were no differences in segment averages for either species richness or diversity*** (Figure 8).

There were notable differences in the fish composition of the various bay segments. The Old Tampa Bay, Hillsborough Bay, and Terra Ceia Bay segments each had at least three species which were unique to that bay segment. Species which were unique to Old Tampa Bay included spot, scrawled filefish, black seabass, and gulf pipefish. Species which, although never abundant, were rarely if ever collected outside of Hillsborough Bay during this survey, included cobia, cownose ray, southern puffer, Gulf kingfish, and lookdown. Fish species only caught in Terra Ceia Bay included ocellated flounder, blackwing searobin, and scrawled filefish.

Although conclusions from this single survey are necessarily limited, ***it appears that hypoxic conditions may affect the composition of the fish assemblages since the average catch of most species was lower where dissolved oxygen levels were low.*** Avoidance of low oxygen conditions by fishes is well documented (Kramer 1987) and may be accomplished by moving either horizontally (inshore, offshore, upstream, downstream) or vertical (closer to the surface).

Such behavior by fish may also affect the composition of the benthic macroinvertebrate community. Pihl *et al.* (1992) observed that two species of fish shifted the feeding preferences to take advantage of the effects of hypoxia on burrowing benthic macroinvertebrates. Benthic species which normally burrow, moved closer to the sediment-water boundary; some individuals even moved to the point at which their bodies extended into the water column, making them more susceptible to predation by those fish able to tolerate the low oxygen levels. Fish which moved upwards into the water column to avoid the low oxygen concentrations could then make forays into the hypoxic layer to feed (Pihl 1994).

The average catch for each of the catfish species (gafftopsail and hardhead catfish), was considerably higher at stations with low oxygen concentrations (Table 3) than at stations with normal oxygen concentrations. It may be that these catfish can tolerate lower oxygen conditions thereby allowing these species to compete more effectively for food. Fish which are "opportunistic" feeders may shift their prey to take advantage of increased availability of burrowing species (Pihl *et al.* 1992; Pihl 1994).

Other than a low incidence of external parasites, no fish were collected which exhibited any gross pathology such as lesions, tumors, and skeletal abnormalities.

This element of the program was dropped after 1994. Much of the information it provides is redundant in light of the Florida Marine Research Institute's Fishery Independent Monitoring Program. Where the programs differ, however, is the integration of finfish data with diel dissolved oxygen minima and sediment chemistry in this program.

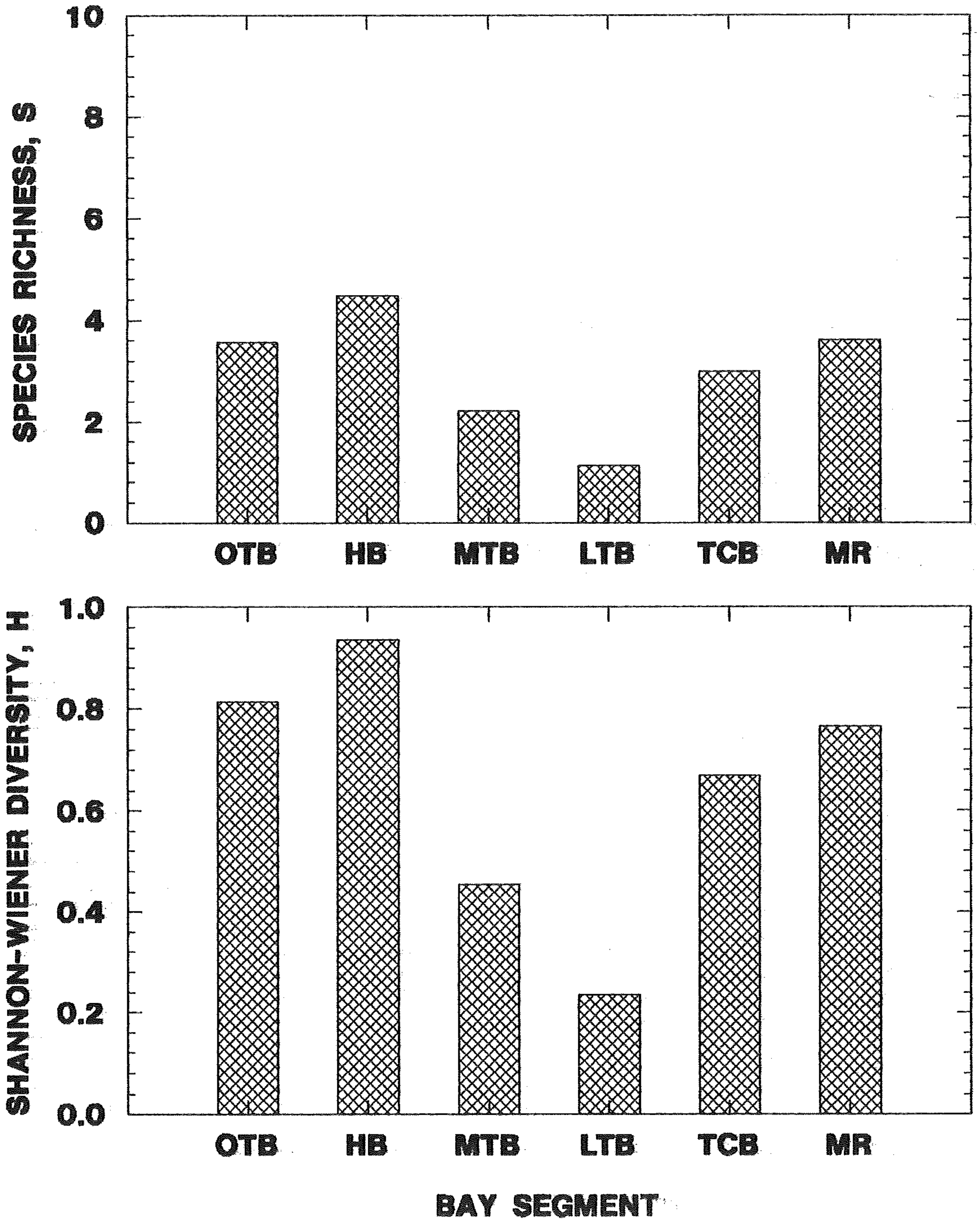

Figure 8. Average species richness (numbers of species, S) and Shannon-Wiener diversity (H') of demersal fish in the Tampa Bay estuarine system, by bay segment, September-October 1993.

Table 3. Average catch per trawl of the fish species contributing at least 3% of the total catch, by dissolved oxygen concentration category. Tampa Bay, September-October 1993.

Species	Dissolved oxygen (mg/L) <2.0	2.0-5.0	>5.0
1. Mojarras	0.0	19.1	4.5
2. Pinfish	0.0	3.8	2.2
3. Gafftopsail catfish	9.2	1.6	1.2
4. Atlantic bumper	0.0	0.9	1.3
5. Silver perch	0.0	0.3	1.5
6. Sand seatrout	0.0	1.6	0.6
7. Scaled sardine	0.5	0.5	0.9
8. Pigfish	0.0	1.1	0.6
9. Striped anchovy	0.0	1.3	0.5
10. Hardhead catfish	5.5	0.8	0.2

3.4 ANTHROPOGENIC TRASH

The absence of trash from any of the trawls, albeit a positive sign, should be tempered by the fact that this program was only able to cover a very small area of the entire bay bottom (less than 0.1%), and that the most common type of trash in coastal waters is plastic (USEPA 1993) and therefore likely to float. The overwhelming bulk of the debris recovered during "Coastal Cleanup" in Florida has been plastic (more than 60%), followed by metal objects (12%), and glass (10%) (Center for Marine Conservation 1994).

3.5 SEDIMENTS

The 58 sediment samples analyzed during 1993 uncovered little evidence of trace metal contamination-- for those areas sampled. The "Threshold Effects Level" (MacDonald Environmental Services, Ltd. 1994) is the concentration of a contaminant (such as trace metals) below which biological impacts are unlikely. "Biological impacts" may range from alterations in the composition of the benthic macroinvertebrate community, to direct mortality. Threshold Effects Levels were exceeded at four locations for four metals: arsenic, cadmium, chromium, and nickel (Figure 9). The Old Tampa Bay segment contained the exceedences for cadmium, chromium, and nickel and the elevated arsenic concentration was detected in the Lower Tampa Bay segment. There were no trace metal concentrations above the "Probable Effects Level", the concentrations at which biological effects become likely (MacDonald Environmental Services, Ltd. 1994). ***It is important to note that samples for sediment contamination were only analyzed from four of the 19 sample locations in the Hillsborough Bay segment and that it is this segment that has been characterized as having the most impacted sediments (see below).***

Sediment chemistry and toxicity studies conducted by the National Oceanographic and Atmospheric Administration and the Florida Department of Environmental Protection 1991 and 1992 (Long *et al.* 1994) found evidence of toxic sediments in Tampa Bay. Toxic sediments were primarily detected in Hillsborough Bay, but several smaller bays, creeks, canals, and western Old Tampa Bay, areas directly influenced by stormwater runoff and acting as depositional areas for fine-grained sediments, also had toxic sediments. Sediments in central and eastern Old Tampa Bay and Lower Tampa Bay were much less toxic. The NOAA/FDEP data also showed that in more than one third of the samples, concentrations of cadmium, chromium, copper, lead, mercury, and nickel were above the levels at which biological effects might occur.

Another approach to evaluating sediment quality is to compare the amount of the various trace metals to aluminum (one of the most common elements in the earth's crust). The relationship between metal concentrations and aluminum has been determined from uncontaminated sediments in Florida (Schropp *et al.* 1990). If the amount of a metal, such as lead, when compared to the concentration of aluminum exceeds that of "backgound" then those sediments are considered to be artificially enriched. This does not, however, necessarily mean that they are toxic-- only that the concentration is higher than is expected.

Cadmium enrichment (Figure 10) was observed at 18% of the sites in the Lower and Old Tampa Bay segments and at 10% of the Middle Tampa Bay sites. There was no evidence of enrichment for the other metals for which the metal to aluminum ratios were calculated. The small amount of data from the Hillsborough Bay segment (only four of 19 stations were analyzed for sediment contaminants) preclude any meaningful assessment of conditions in the one bay segment which has been shown to suffer from sediment contamination. Additionally, samples for sediment chemistry were not collected in either the Manatee River or Terra Ceia Bay segments.

The data collected for this program are not necessarily consistent with the results reported by Long *et al.* (1991 and 1994). The explanation lies, in part, with the differences in objectives and the designs of the two studies. This EMAP-based study employs a randomized design. Contaminated sites will only be sampled by chance, they will not be specifically targetted. Phase 2 (1992) of the Long *et al.* (1994) studies specifically targetted areas of the bay likely to have contaminated sediments. As a consequence of the random design, most of the sites sampled were not high in fine-grained sediments, and it is to fine-grained sediment particles that trace metals and other contaminants preferentially bind. Sandy sediments, which have a low percentage of fine-grained materials, are less likely to have elevated trace metal concentrations.
As more data become available, from a greater variety of locations and sediment types, the relationship between contaminant concentrations and the percentage of fine-grained sediments at that site can be analyzed.

The objectives of the present study design are to characterize and monitor the entire Tampa Bay estuarine system, stratified by the recognized bay segments. *The NOAA/FDEP efforts in 1992 were directed towards locating and characterizing contaminated sites.* Additional years of data, sampling new locations each year, will provide a better understanding of the overall extents of contaminated sediments in the Tampa Bay estuarine system as a whole.

3.6 BENTHIC MACROINVERTEBRATES

1993 saw the first bay-wide effort to characterize the soft-bottom (mud, sand) benthic macroinvertebrate community in Tampa Bay since the National Marine Fisheries Service collected samples at more than 400 locations during the period 1963-1969 (Taylor 1971; Sykes 1972).

Although data from only a single year are presently available, some basic statements and inferences about the benthic macroinvertebrates of Tampa Bay can be made. First, ***with approximately 500 different types of benthic macroinvertebrates identified (from less than 100 locations), it is clear that Tampa Bay supports a highly diverse assemblage of benthic macroinvertebrates***. That Tampa Bay should support such a large number of species is not unexpected since:

a. Tampa Bay is located where two biological "provinces", the Louisianian (northern Gulf of Mexico) and West Indian (Gulf of Mexico south to the Caribbean and up the east coast of Florida) converge, providing sources of both temperate and tropical organisms;
b. the salinity regime of Tampa Bay generally lacks wide, rapid fluctuations, except in localized areas during storm events;
c. The bay is generally shallow, with fine sandy sediments predominating;
d. there remains a fairly well-developed system of seagrass beds (Simon 1974).

Factors such as these all contribute to the diversity and richness of the benthic macroinvertebrate assemblage of Tampa Bay.

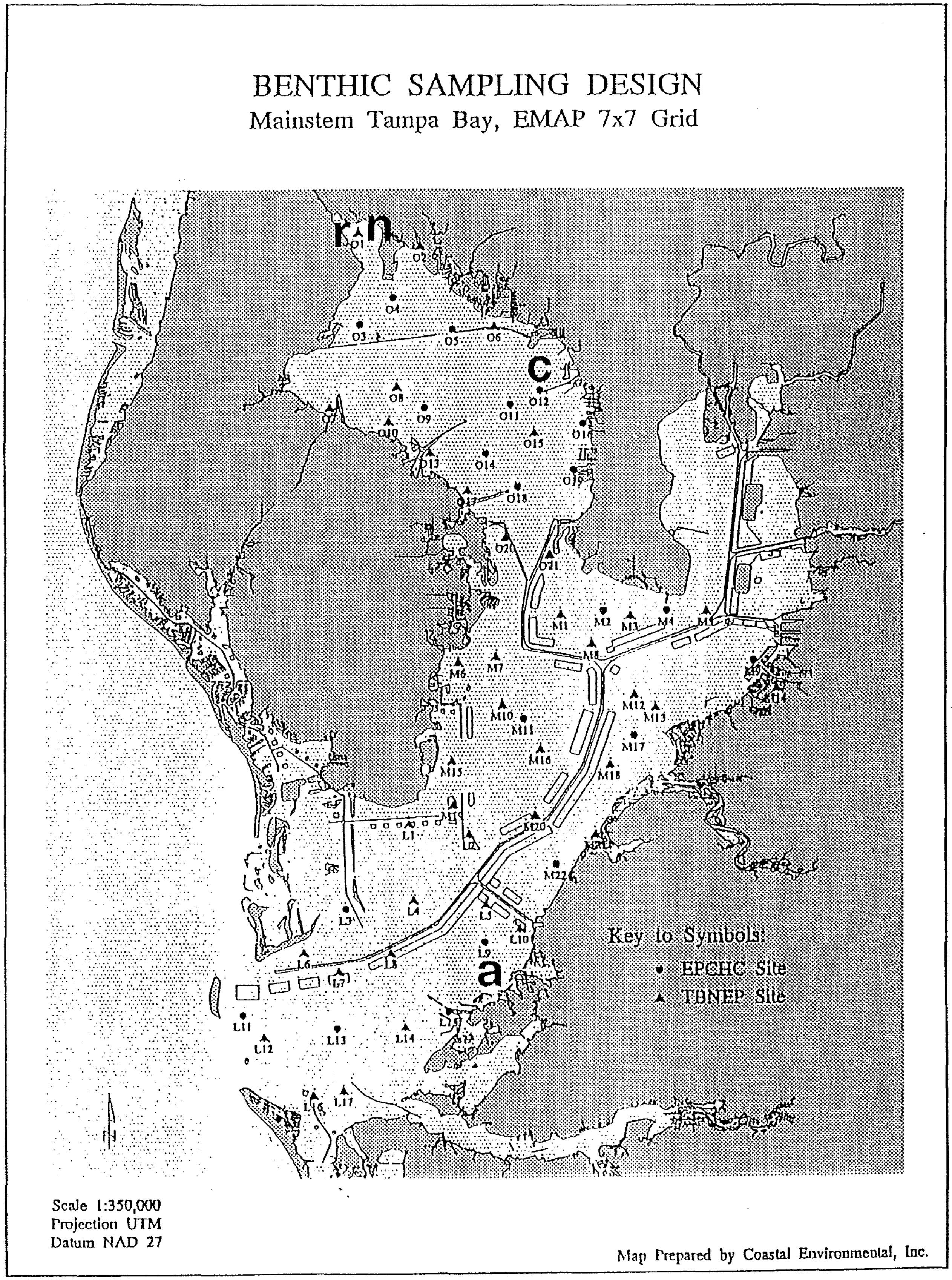

Figure 9. Stations in the Tampa Bay estuarine system at which metal concentrations exceeded the "Threshold Effects Levels" during September 1993. "a"= arsenic;"c"=cadmium; "r"= chromium; "n"= nickel.

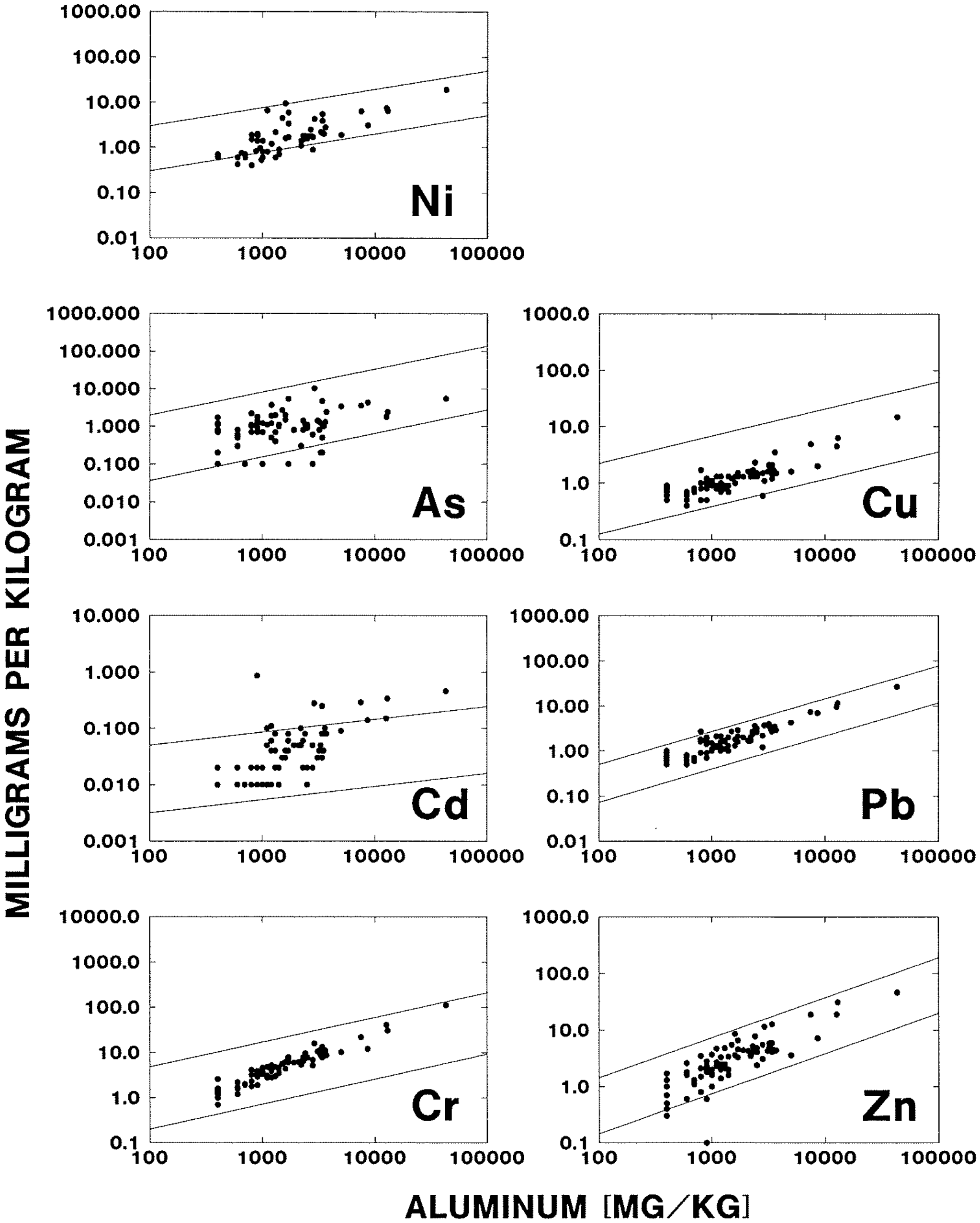

Figure 10. The relationship between trace metal and aluminum concentrations in the Tampa Bay estuarine system, September 1993. Points lying within the bands represent "backgound" concentrations; points falling above the upper line represent "enriched" sediments; points falling below the lower line may represent laboratory error.

These data demonstrate that ***the benthic macroinvertebrate assemblages differ between segments of Tampa Bay (Figure 11; Table 4). The Middle, Old, and Lower Tampa Bay segments were most similar.*** Species characteristic of these generally sandy segments included the cephalochordate *Branchiostoma*, the amphipods *Acanthohaustorius uncinus* and *Metharpinia floridana*, and the gastropods *Caecum cf. johnsoni* and *Nucula crenulata*. The dominance of amphipods (especially *Rudilemboides naglei*) served to separate the Old Tampa Bay segment from the Middle and Lower Tampa Bay segments.

The Hillsborough Bay segment differed from the Old, Middle, and Lower Tampa Bay segments primarily because *Branchiostoma* was less abundant and several polychaetes (*e.g., Mediomastus ambiseta, Nereis succinea, Carazziella hobsonae, Paraprionospio pinnata*, and *Podarkeopsis laevifuscina*) and the bivalves *Amygdalum papyrium* and *Mysella planulata* were considerably more abundant. ***The polychaetes dominant in the Hillsborough Bay segment include species considered to be indicators of a perturbed environment. Species such as these have been variously identified as "contaminant insensitive", "opportunistic", or "very tolerant" to "tolerant" of hypoxia.***

The benthic macroinvertebrate assemblages of the two Manatee County bay segments were "outliers" from the main body of Tampa Bay. Even though the Terra Ceia Bay and Manatee River segments differed considerably in terms of numbers of species, diversity, and the distribution of those species, their macroinvertebrate communities were most similar to each other. They shared with the Hillsborough Bay segment relatively high densities (more than 200 organisms/m^2) of the amphipod *Ampelisca holmesi*, and the polychaete *Paraprionospio pinnata*, and relatively low densities of other amphipods. The Terra Ceia Bay segment differed from the Manatee River segment in that the number of species was greater and the abundances of those species were more evenly distributed (*i.e.*, there were no clear numerical dominants). Three species (the amphipod crustacean *Ampelisca abdita* and the bivalve molluscs *Amygdalum papyrium*, and *Mulinia lateralis*) were present at much higher densities in the Manatee River segment than in any other segment of Tampa Bay.

Physical factors such as salinity (influenced by the timing and volume of stormwater runoff as well as direct rainfall), sediment characteristics (the amount of fine-grained sediments), and the dissolved oxygen concentration of near-bottom waters were all shown to affect benthic macroinvertebrate community parameters. For example, salinity and the number of species (species richness) in the Old Tampa Bay segment were associated as was salinity and diversity in the Manatee River segment. ***The general relationship was for a richer (more species), more diverse assemblage of benthic macroinvertebrates in higher salinity than lower salinity areas.***

The amount of fine-grained sediments, expressed as the percent of silt+clay, had a general effect on the numbers of species in some parts of Tampa Bay: ***as the percentage of fine-grained sediments increased, species richness decreased.*** This was seen in both the Old Tampa Bay and Hillsborough Bay segments. Benthic macroinvertebrate assemblages in habitats where the percentage of silt+clay was greater than 10% were generally dominated by polychaetes such as *Monticellina dorsobranchialis, Prionospio perkinsi*, and *Carazziella hobsonae*; other types of animals, especially crustaceans, were generally absent.

Dissolved oxygen concentration of the near-bottom waters has been well-documented as a factor affecting benthic macroinvertebrate communities. Hypoxia and anoxia have been associated with reductions in, even short-term extermination of, the benthic macroinvertebrate community (Santos & Simon 1980; Gaston 1985). During September-October 1993, anoxic conditions were not encountered, but more than 20% of the sampling locations in the Hillsborough Bay segment were hypoxic. In addition, 70% of the Manatee River segment sampling locations had bottom dissolved oxygen concentrations below the State standard for Class II and III waters (5 mg/L).

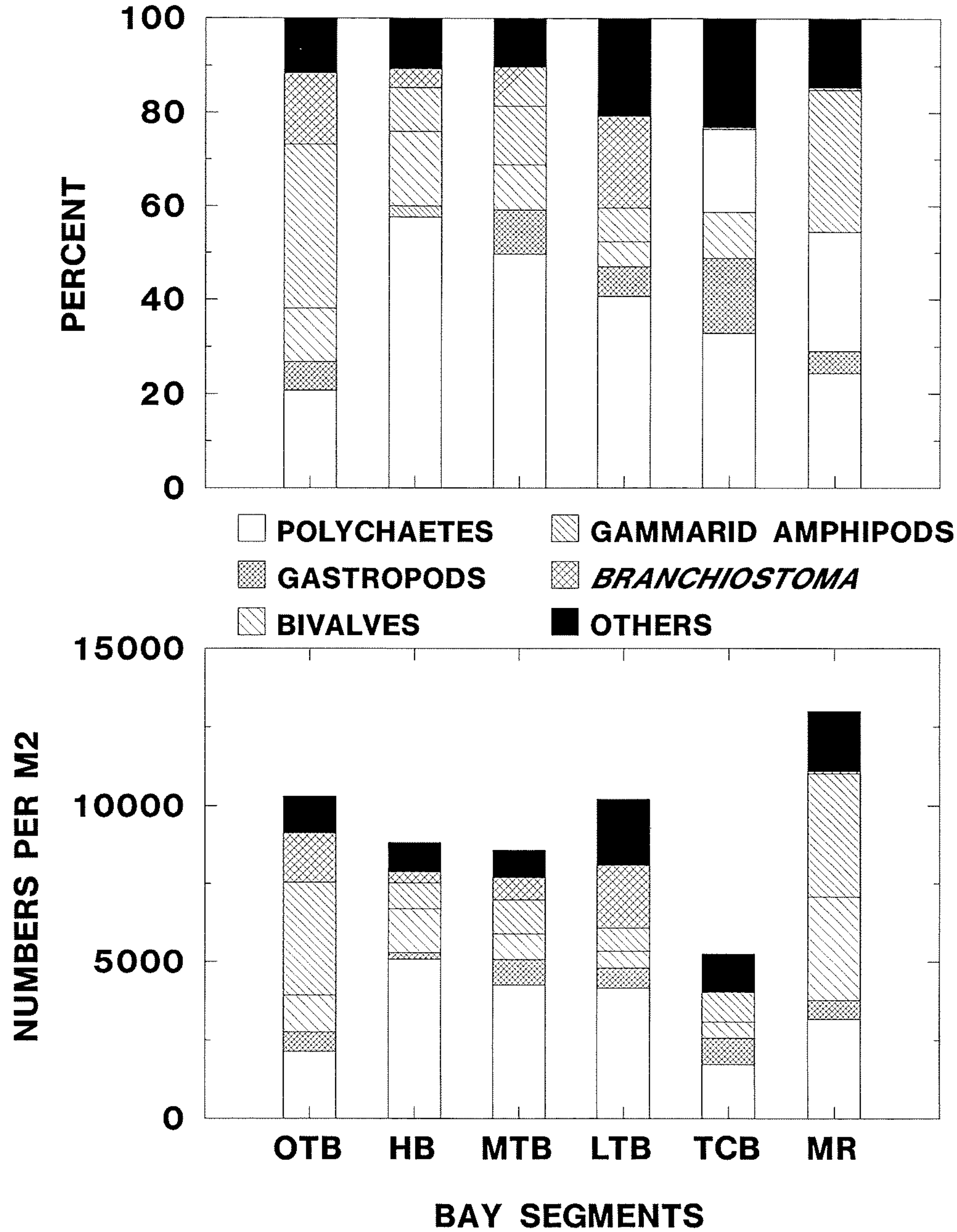

Figure 11. Percent composition (bottom) and density (numbers/m^2) (top) of major taxonomic groups of benthic invertebrates, by bay segment, from the Tampa Bay estuarine system, September-October 1993.

Table 4. Ten dominant[a] benthic macroinvertebrates of each bay segment in the Tampa Bay estuarine system, September-October 1993.

Species	OTB	HB	MTB	LTB	TCB	MR
Class Anthozoa						
Thenaria (genus undetermined)						10.8
Class Polychaeta						
Brania sp. A				10.0		
Carazziella hobsonae		23.0			11.2	
Fabriciola trilobata						11.5
Goniadides carolinae				10.6		
Mediomastus spp.			11.6		20.0	12.9
Mediomastus ambiseta		33.9				
Mediomastus californiensis			12.3			
Monticellina dorsobranchialis		12.3	25.8		14.9	
Nereis succinea		11.8				
Paraprionospio pinnata		18.7			15.1	11.8
Podarkeopsis levifuscina		12.3				
Prionospio perkinsi	21.8	17.7	25.4			
Prionospio pygmaea					13.4	
Prionospio steenstrupi			10.9	18.2		
Spio pettiboneae				13.7		
Travisia hobsonae				12.5		
Class Oligochaeta						
Tubificid (genus undetermined)				10.1	19.0	
Class Gastropoda						
Caecum cf. johnsoni			17.2	13.4		
Olivella sp.					13.1	
Turbonilla conradi					14.6	
Class Bivalvia						
Amygdalum papyrium						23.9
Mulinia lateralis						28.2
Mysella planulata		26.9				
Mysella sp. A						
Nucula crenulata	19.0			11.3		
Class Crustacea						
Order Cumacea						
Cyclaspis cf. varians						19.2
Order Isopoda						
Amakusanthura magnifica	12.4					
Order Amphipoda						
Acanthohaustorius uncinus			12.7	10.5		
Ampelisca abdita						36.8
Ampelisca holmesi		16.1			29.1	18.8
Ampelisca sp. C	16.8		12.8			
Cerapus sp. C	12.0					
Eudevenopus honduranus	16.4					
Grandidierella bonneroides						12.4
Lysianassidae B	11.9					
Metharpinia floridana	15.0					
Rudilemboides naglei	28.5					
Order Decapoda						
Pinnixa sp.					13.9	
Phylum Echinodermata						
Ophiuroid (genus undetermined)			12.2			
Phylum Chordata						
Branchiostoma sp.	34.2	15.2	25.1	44.5		

[a] Dominance is defined as: $[(\% \text{ of total density}) \times (\% \text{ occurrence})]^{0.5}$ (after Windell 1971)

Species richness in two segments, Old Tampa Bay and Hillsborough Bay, was positively associated with dissolved oxygen concentration. Species richness in the Middle Tampa Bay segment was highest when dissolved oxygen concentrations were at least equal to 5 mg/L and the sediments contained intermediate percentages of silt+clay.

Different assemblages of benthic macroinvertebrates could be identified when the bay segments were partitioned into four groups based upon dissolved oxygen and silt+clay regimes. ***The most diverse benthic macroinvertebrate assemblages were in habitats in which dissolved oxygen met the State's designated use standard (5 mg/L) and the percentage of fine-grained sediments was less than 10%. The poorest quality habitats, based upon a reduced number of species and relative contributions of the major taxonomic groups, were those in which dissolved oxygen concentrations were low and the percentage of fine-grained sediments above 10%.***

What may be an approximation of the composition of a "backgound" or "reference" assemblage of benthic macroinvertebrates for the Tampa Bay system, exclusive of specialized soft-bottom habitats such seagrass beds and mangals (*i.e.*, mangrove communities) may eventually be determined from this type of analysis (Table 5). As the database becomes more comprehensive, the numbers of dissolved oxygen and silt+clay categories which can be partitioned can increase and other strata can be introduced (*e.g.*, trace metal concentrations).

Table 5. Benthic macroinvertebrate species (ranked by abundance) characteristic of habitats of the Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, and Terra Ceia Bay segments of the Tampa Bay estuarine system with bottom dissolved oxygen concentrations equal to or greater than 5 mg/L and sediments with a percentage of silt+clay less than 10%.

1. *Branchiostoma* sp. (Cephalochordate; "lancelet")
2. *Mediomastus ambiseta* (Polychaete worm)
3. *Rudilemboides naglei* (Amphipod crustacean)
4. *Ampelisca holmesi* (Amphipod crustacean)
5. *Acanthohaustorius uncinus* (Amphipod crustacean)
6. *Nucula crenulata* (Gastropod mollusc)
7. *Mediomastus californiensis* (Polychaete worm)
8. Nemertea sp. F (Proboscis worm)
9. *Metharpinia floridana* (Amphipod crustacean)
10. *Eudevenopus honduranus* (Amphipod crustacean)

These preliminary data have also shown statistically significant associations between sediment characteristics (percent of silt+clay, depth at which oxygenated sediments are replaced by anoxic sediments [the RPD, the redox potential discontinuity layer], and trace metal concentrations) for several of the dominant species. Three of these "models" show potential as an analytical tool. These models, developed for the polychaetes *Mediomastus ambiseta* and *Monticellina dorsobranchialis* (Figure 12) and the cephalochordate *Branchiostoma* sp. (Figure 13), explained 43%-55% of the "variability" of their abundance.

Among the more interesting relationships was the positive association between silver and densities of the polychaetes *Mediomastus ambiseta* and *Monticellina dorsobranchialis* (Figure 12). Silver is among the most toxic of the trace metals (Long & Morgan 1990), although concentrations in the 1993 sediments were all below toxic levels (Long & Morgan 1990; MacDonald 1995). Silver is often used as a marker for wastewater treatment plant discharges but it is also associated with humic substances, which are released when plants decompose (Bryan & Langston 1992). It is possible that, within non-toxic concentrations of silver, these polychaetes are not responding to the silver *per se*, but are responding to the organic enrichment typically associated with wastewater treatment plant discharges and decomposition of plant materials introduced during storms.

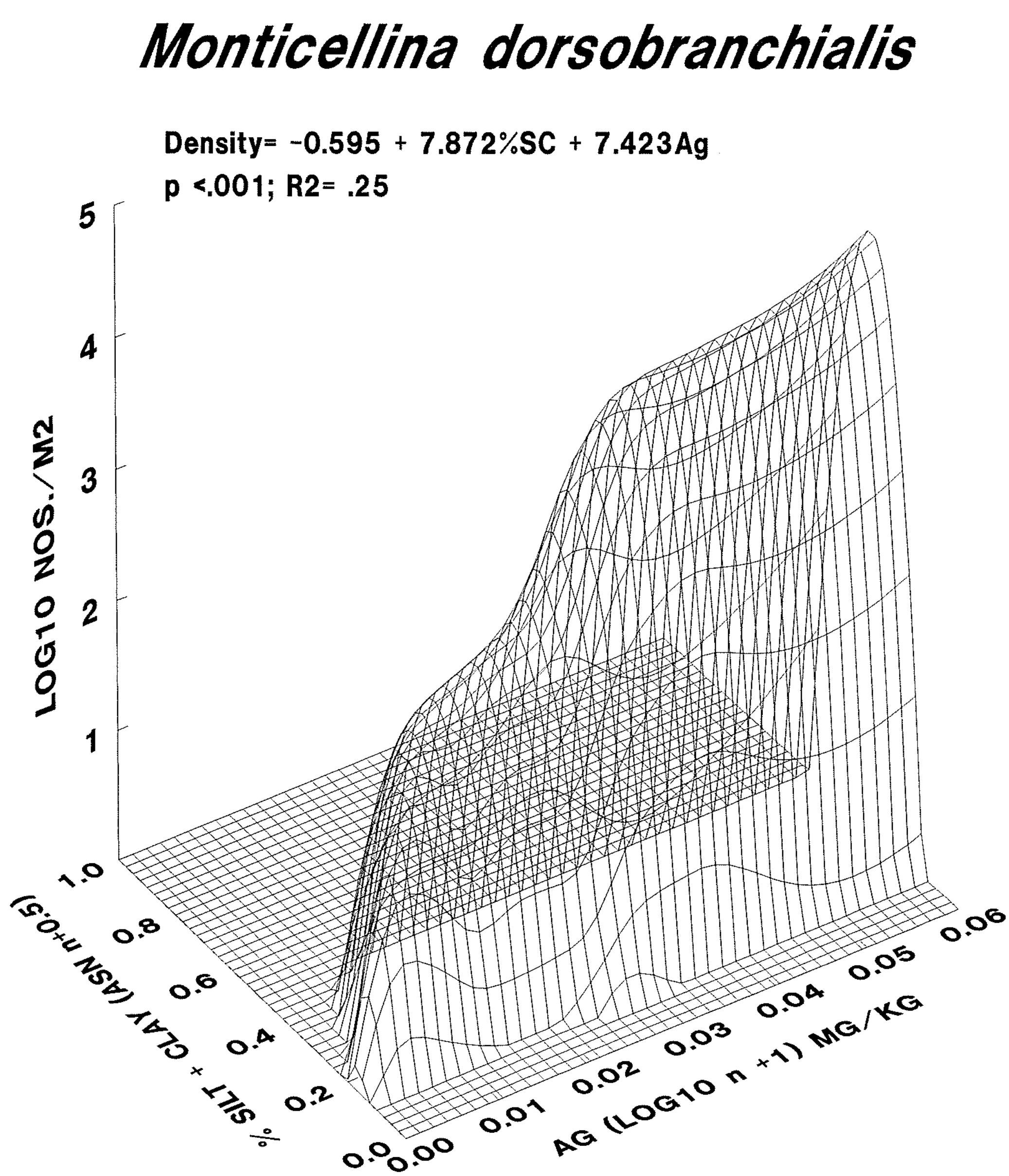

Figure 12. Relationship between *Monticellina dorsobranchialis* (Polychaeta, Cirratulidae) (Log_{10} n+1 numbers/m^2), percent silt+clay (arcsin $\%SC^{0.5}$), and silver (Log_{10} n+1 mg/Kg). Tampa Bay estuarine system, September 1993.

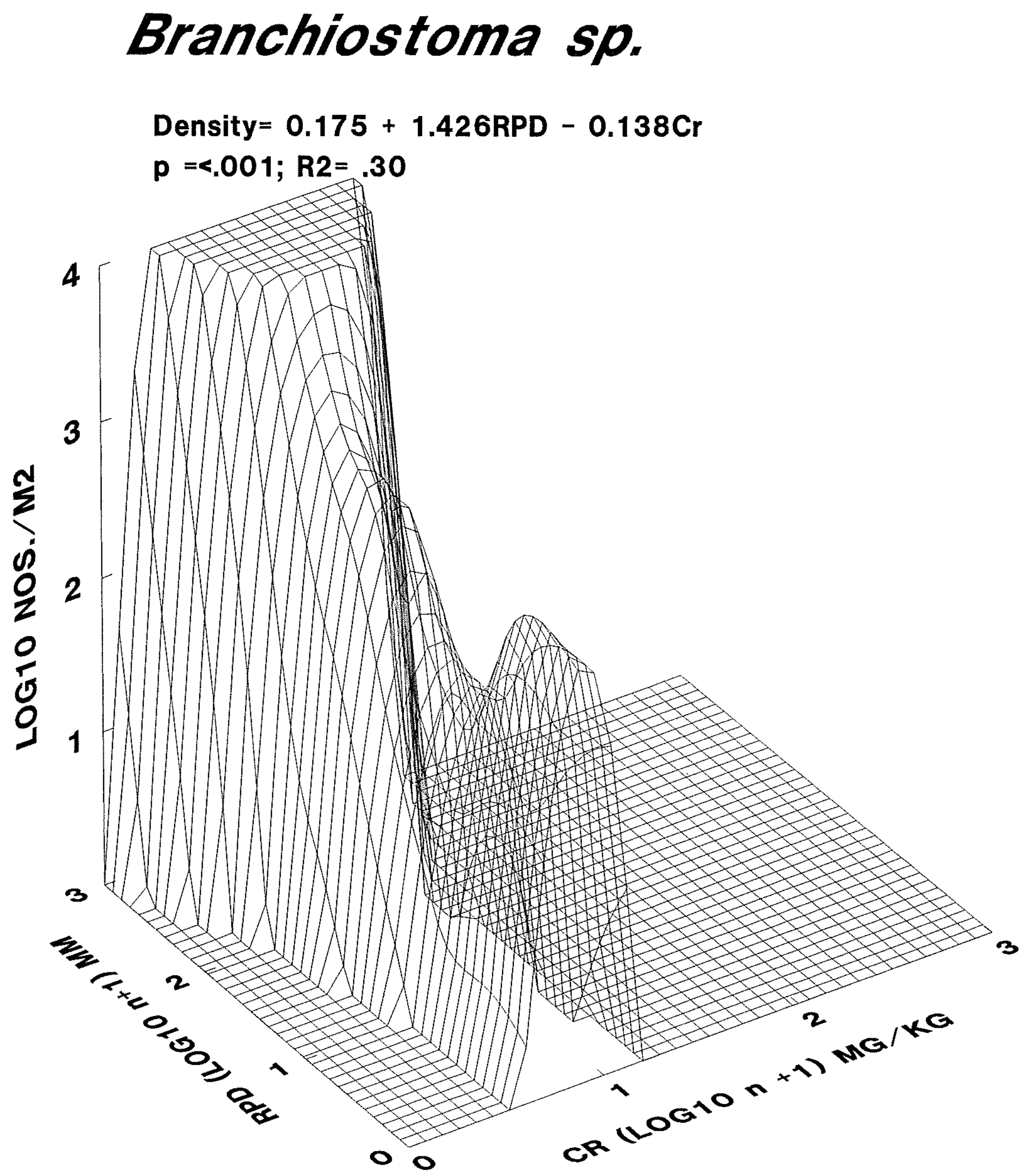

Figure 13. Relationship between *Branchiostoma* sp. (Cephalochordata) abundance (Log_{10} n+1 numbers/m^2), Redox Potential Discontinuity layer [RPD] (Log_{10} n+1 mm) and chromium (Log_{10} n+1 mg/Kg). Tampa Bay estuarine system, September 1993.

The primary product for this program is intended to be a Benthic Index which will successfully discriminate between "healthy" and "unhealthy" (or "subnominal") benthic habitat. Three approaches are examined in this report: a modification (Coastal Environmental, Inc. 1995) of the Benthic Index developed by EPA-EMAP for the northern Gulf of Mexico (Engle *et al.* 1994), the index used to define "biological integrity" in the Florida Administrative Code (FAC 62-302), and the Florida Marine Index, developed by the late Dr. Douglas Farrell of the Florida Department of Environmental Protection.

The EMAP Index (Table 6) pointed to the overall lower environmental quality of the Hillsborough Bay segment of the system; highest mean scores occurred in the Manatee County segments. Although at this stage of development it is not possible to clearly discriminate "healthy" benthic habitat from "subnominal" benthic habitat with this index, some trends did emerge. Statification by dissolved oxygen and the percentage of silt + clay in the sediments produced results consistent with other observations: benthic habitat is more degraded in areas characterized by low concentrations of dissolved oxygen and higher percentages of fine-grained sediments.

The "biological integrity" approach (Table 7) suggested that almost 40% of the locations sampled in Tampa Bay did not meet the State standard. The Terra Ceia Bay segment showed no evidence of impairment whereas more than 50% of the sites in the Manatee River segment did not meet the standard.

Table 6. Estimated Benthic Index values, mean by bay segment and stratified by near-bottom dissolved oxygen concentration and the percentage of silt+clay in the sediments, within the Tampa Bay estuarine system, September-October 1993. Adapted from Coastal Environmental, Inc. 1995.

Segment	Overall	Dissolved Oxygen		% Silt+ Clay	
		≤5 mg/L	>5 mg/L	≤10%	>10%
OTB	10.0	8.3	10.6	10.5	8.0
HB	8.1	8.2	8.1	8.3	7.9
MTB	9.7	9.3	9.8	10.0	8.2
LTB	9.8	9.4	10.0	9.8	na
TCB	11.6	11.0	11.8	11.8	10.4
MR	10.2	10.1	10.4	10.6	9.1

na= no data available for this stratum

Table 7. Summary of the percentage of stations in Tampa Bay, by bay segment, whose "biological integrity", measured as Shannon-Weiner diversity [H'], was below the criterion set in FAC Chapter 62-302. September-October 1993. The criterion is that H' be 75% of a "reference" location's value. In this example, the "reference" condition is the second highest H' in the bay segment.

Segment	Reference H (75%)	% <75% of Reference H'
OTB	3.55 (2.66)	41.2
HB	3.09 (2.32)	26.3
MTB	3.46 (2.60)	50.0
LTB	3.79 (2.84)	35.3
TCB	3.88 (2.91)	0.0
MR	3.59 (2.69)	54.5

Farrell's Florida Marine Index was designed to be a measure of organic enrichment and assigns numerical scores to a number of polychaete, mollusc, crustacean, and echinoderm species common to Florida's estuarine and coastal waters. The species score is based upon the expected tolerance of a species to various dissolved oxygen regimes. Farrell's Index merits additional scrutiny in the future as more data become available.

This Index appears to produce results which are generally consistent with the results of the community analyses (lowest scores in the Hillsborough Bay segment, indicative of a "tolerant" assemblage of benthic macroinvertebrates, and highest scores in the Old Tampa Bay segment, indicative of a fauna more "sensitive" to reductions in dissolved oxygen) (Table 8). Results of the Florida Marine index are also generally consistent with the results of the community analyses, when habitats were stratified by dissolved oxygen and the percentage of fine-grained sediments. Scores were markedly different for the two dissolved oxygen categories, consistent with the intent of the Index. Scores for the two silt+clay categories were more similar. Amphipod crustacean scores differed for each of the four category combinations suggesting that amphipods may be more sensitive indicators than other groups of benthic macroinvertebrates.

Table 8. Summary of Farrell's Florida Marine Index, by bay segment and major taxonomic category. Tampa Bay 1993. Scores are based upon average segment density.

Bay Segment	Polychaeta	Gastropoda	Bivalvia	Amphipoda	Overall
OTB	1.75	2.35	2.14	3.37	2.75
HB	1.20	2.13	2.68	2.12	1.95
MTB	1.45	2.25	1.93	3.79	2.40
LTB	1.84	2.67	2.06	3.88	2.40
TCB	1.64	2.38	2.21	3.06	2.41
MR	2.03	2.15	1.59	2.28	2.09

There is some inconsistency with regards to the status of the bay segments based upon these three indices. The Terra Ceia Bay segment has the highest mean Benthic Index, and its "biological integrity" is wholly acceptable. However, a component of the Benthic Index is Shannon-Weiner diversity-- the measure of "biological integrity". In the Florida Marine Index, Terra Ceia Bay scores below the Old Tampa Bay segment. The Manatee River segment shows general consistency between "biological integrity" and the Florida Marine Index whereas the Hillsborough Bay segment performs similarly in the Benthic and Florida Marine indices. The Hillsborough Bay segment scores better on "biological integrity" primarily because the scores were scaled for each bay segment. These three metrics merit additional study and perhaps modification.

SECTION 4

CONCLUSIONS

The synoptic survey of the benthic macroinvertebrate and finfish assemblages recommended by the Technical Advisory Committee to the Tampa Bay National Estuary Program as a means of evaluating the status of the Tampa Bay estuarine system commenced in September-October 1993. This regional monitoring program was a cooperative effort between the USEPA, Manatee County's Environmental Action Commission, and the Environmental Protection Commission of Hillsborough County.

Elements of this program included profiles of the water column, determination of the minimum daily dissolved oxygen concentration, sediment quality, composition of the fish community, pathology of selected species of fish, collection of flotsam and jetsam, and the investigation of the composition and distribution of benthic macroinvertebrates in Tampa Bay.

There were significant differences in water-mass characteristics (temperature-salinity) of the six segments of Tampa Bay investigated (Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, Lower Tampa Bay, Terra Ceia Bay, and the Manatee River) during the study period. Water temperatures of the Middle, Hillsborough and Lower Tampa Bay segments were similar and greater than those of the other bay segments; water temperatures of the Manatee River segment were coolest.

Average salinity was lowest in the Old Tampa Bay, Manatee River, and Hillsborough Bay segments and highest in the Lower Tampa Bay and Terra Ceia Bay segments. Overall, most salinities were in the polyhaline range (15-28 parts/thousand).

Dissolved oxygen concentrations below the 5 mg/L Florida State standard for Class II and III waters were most common in bottom waters of the Hillsborough Bay segment. Hypoxia (dissolved oxygen less than 2 mg/L) was only evident in the Hillsborough Bay segment and was estimated to occupy 21% of the bay bottom in this segment; 73% of the Manatee River segment and 63% of the Hillsborough Bay segment had near-bottom dissolved oxygen concentrations below the State standard for Class III waters (5 mg/L).

A total of 36 species of fish were identified and the most abundant fish included mojarras (46.7%), pinfish (11.9%), and gafftopsail catfish (8.3%). The fish collected during this survey were those commonly identified as "typical" residents of Tampa Bay.

Overall fish catch was highest in the Hillsborough Bay segment and lowest in the Lower Tampa Bay segment. Both species richness and diversity generally declined as salinity decreased although there were no differences in segment averages for either species richness or diversity. There were notable differences in the fish composition of the various bay segments. The Old Tampa Bay, Hillsborough Bay, and Terra Ceia Bay segments each had at least three species which were unique to that bay segment.

Low concentrations of dissolved oxygen in the near-bottom water appears to affect the composition of the fish assemblages. The catch of most species was lower where dissolved oxygen levels were below 2 mg/L (hypoxia). Exceptions were the two catfish species (gafftopsail and hardhead catfish), which were considerably more abundant at stations with low oxygen concentrations than at stations with normal oxygen concentrations.

Other than a low incidence of external parasites, no fish were collected which exhibited any gross pathology such as lesions, tumors, and skeletal abnormalities.

The sediment samples analyzed uncovered little evidence of trace metal contamination. Threshold Effects Levels were exceeded at four locations for four metals: arsenic, cadmium, chromium, and nickel. The Old Tampa Bay segment contained the exceedences for cadmium, chromium, and nickel and the elevated arsenic concentration was detected in the Lower Tampa Bay segment. Enrichment of sediments by cadmium was observed at 18% of the sites in the Lower and Old Tampa Bay segments and at 10% of the Middle Tampa Bay sites. The small amount of data from the Hillsborough Bay segment (only four of 19 stations were analyzed for sediment contaminants) preclude any meaningful assessment of conditions in this industrialized segment of the bay.

Approximately 500 different types of benthic macroinvertebrates were identified during this survey, demonstrating that Tampa Bay supports a diverse fauna. These data also demonstrated that the benthic macroinvertebrate assemblages differed between segments of Tampa Bay. Factors such as salinity, dissolved oxygen, and the amount of fine-grained sediments all contributed to these differences; there is also evidence that, at the species level, metal concentrations in the sediments also had an effect.

The Middle, Old, and Lower Tampa Bay segments were most similar. Species characteristic of these generally sandy segments included the cephalochordate *Branchiostoma*, the amphipods *Acanthohaustorius uncinus* and *Metharpinia floridana*, and the gastropods *Caecum cf. johnsoni* and *Nucula crenulata*. The dominance of amphipods (especially *Rudilemboides naglei*) served to separate the Old Tampa Bay segment from the Middle and Lower Tampa Bay segments.

The Hillsborough Bay segment differed from the Old, Middle, and Lower Tampa Bay segments primarily because *Branchiostoma* was less abundant and several polychaetes and bivalves were considerably more abundant. The polychaetes dominant in the Hillsborough Bay segment include species considered to be indicators of a perturbed environment.

The benthic macroinvertebrate assemblages of the two Manatee County bay segments were "outliers" from the main body of Tampa Bay. Even though the Terra Ceia Bay and Manatee River segments differed considerably in terms of numbers of species, diversity, and the distribution of those species, their macroinvertebrate communities were most similar to each other.

Different assemblages of benthic macroinvertebrates could be identified when the bay segments were partitioned into habitats characterized by different dissolved oxygen and silt+clay regimes. The most diverse benthic macroinvertebrate assemblages were in habitats in which dissolved oxygen met the State's designated use standard (5 mg/L) and the percentage of fine-grained sediments was less than 10%. The poorest quality habitats, based upon a reduced number of species and relative contributions of the major taxonomic groups, were those in which dissolved oxygen concentrations were low and the percentage of fine-grained sediments above 10%.

Three separate, but somewhat related, indices were applied to these data to evaluate the status of the various bay segments. There was a general inconsistency between the indices. Two of the indices (Benthic Index developed by Coastal Environmental, Inc. and Dr. Douglas Farrell's Florida Marine Index) identified the Hillsborough Bay segment as among the most impacted. Conversely, the Benthic Index and application of FAC's "biological integrity" criterion identified the Terra Ceia Bay segment as least impacted. The Florida Marine Index appears to produce results which are generally consistent with the results of the community analyses (lowest scores in the Hillsborough Bay segment, indicative of a "tolerant" assemblage of benthic macroinvertebrates, and highest scores in the Old Tampa Bay segment, indicative of a fauna more "sensitive" to reductions in dissolved oxygen).

Other inconsistencies emerged, but physical factors such as the concentration of dissolved oxygen in the near-bottom waters and the amount of fine-grained materials in the sediments profoundly affected index values. Florida Marine Index results were also generally consistent with the community analyses, when habitats were stratified by dissolved oxygen and the percentage of fine-grained sediments. Scores were markedly different for the two dissolved oxygen categories, consistent with the intent of this index. Scores for the two silt+clay categories were more similar. Amphipod crustacean scores differed for each of the four category combinations suggesting that amphipods may be more sensitive indicators than other groups of benthic macroinvertebrates.

Modification of the "biological integrity" approach suggested that almost 40% of the locations were degraded to the extent that they might not meet the State standard for Class III waters.

This program was envisioned to be a long-term tool which will be used to assess changes in habitat status over time. The study design was intended to be rigorous enough that should improvements in habitat quality manifest themselves subsequent to pollution control activities, they will be detectable. As this program matures and the database becomes more extensive, and as analytical tools (e.g., selection of a Benthic Index) are refined, this program's potential as an effective barometer of environmental improvements to the Tampa Bay estuary and its watershed may be realized.

SECTION 5

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