FRAMEWORK FOR ACTION
CHAPTER 2: PHYSICAL AND CHEMICAL PROPERTIES
BAY WATER AND SEDIMENT QUALITY

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Framework for Action
Chapter 2: Physical and Chemical Properties

Bay water and sediment quality

I. Executive Summary

Since 1968, Sarasota Bay has become less saline and the pH of the water has declined. This finding is consistent with increased freshwater inputs that are the result of increased urbanization. General water quality trends show some improvement. In general, nutrients are declining, with the exception of nitrate and nitrite nitrogen. Chlorophyll a is declining in 93% of the segments showing trends. Secchi depth is increasing in the six segments that showed significant trends. Color is increasing in some segments and decreasing in others. Nutrients and chlorophyll a exhibit an expected decline along an east to west transect.

Three areas of immediate concern, north Sarasota Bay in the vicinity of Tidy Island, eastern Sarasota Bay near Whitaker Bayou, and Little Sarasota Bay, were identified in both the nomination document for the NEP and an early version of the monitoring plan. Water quality in the first two areas is improving. Little Sarasota Bay shows some conflicting trend results. Decreases in chlorophyll a and suspended solids, coupled with the increase in Secchi depth, tend to indicate improvements in water clarity in this segment. The increased turbidity, however, indicates just the opposite.

Trend results for east Sarasota Bay (Segment 8) indicate that a water quality in this segment may be declining. Chlorophyll a, nitrates and nitrites, total nitrogen, total phosphorus, and total organic carbon are all increasing over time for this area.

In Sarasota Bay, non-point sources of pollution, in particular stormwater, apparently influence many areas. Tributaries to the bay act as pipelines for dispensing stormwater and suspended matter into the estuary. Although the overall Trophic State Index for Sarasota Bay is "good", the segments that receive water from the tributaries have the poorest water quality.

Toxic contaminants such as chlorinated pesticides, PAH, and metals were found in tributary sediments, as opposed to sediments from open water. Tributaries with the highest levels of these contaminants are Hudson Bayou, Cedar Hammock Creek, and Whitaker Bayou. These areas also are contaminated by more than one of these classes of toxic compounds. While the percentage of contaminated sediments is comparatively small with respect to the Bay bottom of the entire study area, the tributaries are vital low salinity habitats for larval and juvenile life stages of many fish. Adverse biological impacts attributed to these contaminants would be directed against these more sensitive life stages.

II. Monitoring program

II.A. History

The overall monitoring plan developed for the Sarasota Bay study area (Estevez, 1989) included a total of 26 elements or tasks for routine or continuous monitoring. Four of these tasks were recommended for immediate implementation by the Water Quality Monitoring Subcommittee. The full Technical Advisory, Management and Policy Committees approved the ranking and the tasks were implemented. Three of those four will be discussed here. These are 1) a bay-wide monitoring of nutrients and light-related parameters, 2) a characterization of past and present water quality, and 3) a collection and partial characterization of sediment contamination. The fourth, a study of whitening in Whitaker Bayou was completed in 1990.

II.B. Scope

II.B.1. Monitoring light and light related parameters

Nutrients support increased phytoplankton growth and indirectly contribute to light attenuation in the water column. Particulate matter scatters and absorbs light. Increased loadings of sediments and nutrients to the Bay system can, therefore, reduce the total amount of light received by the bay floor in waters of a fixed depth. Alterations in circulatory patterns caused by dredging can also act to resuspend and transport existing sediments, decreasing light penetration in areas at some distance from potential dredging projects.

Quarterly baywide sampling events provide a synoptic water quality data set for the Sarasota Bay study area. These "snapshots" of the Bay for nutrients and other light-related parameters have provided some insight into the stresses due to lowered light levels that have been proposed as a primary cause for the regional trend of decreasing seagrass coverage. The monitoring addresses program goals of describing the bay in an integrated fashion as well as identifying problem areas.

II.B.2. Summary of existing water quality and sediment data

The primary objective of this task was to characterize the existing and historic water quality and sediment quality data within the Sarasota Bay study area. The task met the general objective of the National Estuary Program of determining temporal trends within the study area, helping to identify pressing problems in the Bay and possible causes, and describing the Bay in an integrated fashion. Sources of data for this characterization included the STORET (EPA's STOrage and RETrieval system) database, published and unpublished studies within Sarasota Bay that had not been entered into the STORET database, and the first four quarterly Baywide Monitoring Events. Data analysis was primarily conducted on a segment basis.

II.B.3. Sediment contamination assessment

Sediment analyses provide useful measures of long term water quality or chronic pollution climates. This is due to the preferential adsorption of toxic ions and compounds onto fine grained suspended particulates and the eventual incorporation of the suspended material into benthic deposits. In Sarasota Bay, non-point sources of pollution, in particular stormwater, apparently influence many areas. Rainfall runoff from urban areas is known to contain a number of toxic compounds, making the bottom sediments in and near tributaries the most likely repository for contaminants.

Due to the comparative lack of toxic contaminant data in either the water column or sediments of Sarasota Bay, a one-time scan of sediments was conducted for major classes of pollutants. The areas evaluated were to include the potentially worst cases of pollutant contamination and so emphasized the tributary areas over deeper, open water locations where the sediments were less likely to contain elevated levels of contaminants.

Parameter classes for analysis included: toxic metals, commonly associated with urban runoff; fecal sterols, commonly used as indicators of mammalian wastes; toxic organic compounds, such as chlorinated and organophosphate pesticides; and polynuclear aromatic hydrocarbons, indicative of petroleum or combustion product contamination. In addition to the analyses for contaminants, data on sediment grain size distribution, aluminum, moisture and organic content allowed normalization of raw station data, permitting spatial comparisons, and identification of basins for remedial efforts. Sarasota Bay sediments were compared with either State-wide norms or levels of potential adverse biological effects.

III. Summary of existing data

The data used for analysis of historical data covered the period from January 1, 1968 to May 14, 1991. The resultant database contained 8,562 records. Data sources were STORET and five other field and laboratory investigations.

III.A. STORET inventory

An inventory of the existing data for the study area was performed and the pertinent data were downloaded from the STORET database. The data was requested by polygons which corresponded to the segmentation scheme developed for the Sarasota Bay National Estuary Program. Data for the period between January 1, 1968 and December 31, 1989 were included. The parameters included were:

- Turbidity
- Secchi Depth
- Color
- Conductivity
- Dissolved Oxygen
- pH
- Salinity
- Total Suspended Solids
- Volatile Suspended Solids
- Chlorophyll a
- Copper
- Zinc
- Total Nitrogen
- Organic Nitrogen
- Ammonia Nitrogen
- Total Kjeldahl Nitrogen
- Nitrate t Nitrite Nitrogen
- Ortho Phosphate
- Total Phosphorus
- Total Organic Carbon
- Total Inorganic Carbon
- Chlorophyll b
- Lead

Data retrievals were limited to ambient stations, exclusive of ambient groundwater data. Review of the inventories revealed that, with three exceptions (copper, lead, and zinc) insufficient data exists on metals or organics within the STORET system to perform trend analyses.

III.B. Other data sources

FDNR/MML

During the period 1975-1980 Mote Marine Laboratory (MML) was under contract to the Florida Department of Natural Resources (FDNR) to provide near-shore surface truthing of airborne digital color scanners. The scanners were intended to identify outbreaks of red tide. Seven stations were sampled routinely, but only the near-shore station, two miles off the former Midnight Pass, falls within the present NEP study boundaries. Instrumental and physical data were collected in the field, and laboratory analysis for major nutrients, phytoplankton species composition and algal assays were performed.

Sarasota High School

In conjunction with the advanced marine science class at Sarasota High School, students and instructors routinely sampled open-bay waters in Sarasota Bay. The period of record is from 1975 to 1983. Measured parameters changed over time, but generally included instrumental parameters, physical parameters, ortho phosphate phosphorus, nitrite + nitrate nitrogen, and chlorophyll a. Stations were distributed roughly between the Siesta Key bridge and mid-Sarasota Bay.

Waste Load Allocation

In 1981-1982, a wasteload allocation study (WLA) of Sarasota Bay was funded by the Florida Department of Environmental Regulation (FDER) and implemented by Priede-Sedgwick, Inc. (PSI). The monitoring program was designed by PSI, which contracted with MML to conduct the field and laboratory analyses. Parametric coverage varied with station location and sampling episode, but stations were established from Cortez bridge to Phillippi Creek.

WCIND Upper Sarasota Bay Study

Manatee County and MML jointly conducted a baseline water quality study of upper Sarasota Bay during 1987 and 1988 through grant funding provided by the West Coast Inland Navigation District (WCIND). Twenty two water quality stations, ranging from Anna Maria Sound to mid-Sarasota Bay, were sampled for nutrients, bacteriological parameters, instrumental and physical parameters, and total organic carbon.

Baywide Monitoring Events

The data from the first four sampling events conducted for the Sarasota Bay Project were also included in the database. Each sampling event involved 101 stations sampled synoptically during a 4-hour high tide "window". The events took place on 8/8/90, 11/14/90, 2/12/91 and 5/14/91. The parameters measured and the results obtained are described in detail elsewhere in this report.

III.C. Trends

Linear regression analysis can show increases or decreases that may occur over time for a parameter. Whether an increasing or decreasing trend over time indicates an improvement or degradation of water quality depends on the parameter in question. For example, a decreasing, or negative, trend in the concentration of chlorophyll present in the water column can indicate a decrease in the biomass of phytoplankton in the water column, a positive trend relative to water quality. Conversely, an increasing trend for Secchi depth, which is a measure of the effective penetration of light into the water column, is also a positive trend relative to water quality.

Linear regression analyses were performed using time as the independent variable, and the measure of each parameter as the dependent variable. The analyses were performed by individual segment, and on a bay-wide basis. Trends were considered significant at the 0.05 probability level.

In general, the results of the trend evaluation by segments agree with the trends in water quality developed in for the SARABASIS Symposium (Heyl and Dixon, 1986). The results also agree with the non-parametric evaluations of Sarasota Bay performed by FDER and reported in the Sarasota Bay Technical Report [Appendix to: 305(b) Water Quality Assessment for the State of Florida] (FDER, 1988). The percent of segments showing increasing or decreasing trends and the number of segments in which significant trends developed is summarized below.

Parameter	% of Segments with Significant Trends	Percent Improving	Percent Degrading
Chlorophyll a	67	93	7
Secchi depth	29	100	0
Total nitrogen	43	67	33
TKN	48	90	10
Ammonia	48	100	0
Nitrate+Nitrite	57	8	92
Total phosphorus	62	69	31
Ortho phosphate	52	91	9
Organic carbon	52	91	9
Color	52	45	55
Suspended solids	29	83	17

In general, the bay appears to be less saline and the pH of the water is declining. This finding is consistent with increased freshwater inputs that are the result of increased urbanization. Nutrients are declining, with the exception of nitrate t nitrite nitrogen. Chlorophyll a is declining. Secchi depth is increasing in all segments that showed significant trends. Color is increasing in some segments, and decreasing in others.

Three areas of immediate concern, north Sarasota Bay in the vicinity of Tidy Island, eastern Sarasota Bay near Whitaker Bayou, and Little Sarasota Bay, were identified in both the nomination document for the NEP and an early version of the monitoring plan. These areas are associated with segments 6, 11, and 14, respectively.

In segment 6, chlorophyll a, suspended solids, turbidity, ammonia, and organic carbon are decreasing with time with time. Salinity, color and phosphorus are increasing. These changes are likely due to the changes in irrigation practices that have occurred on this Bay segment appears to be improving.

All significant trends that developed for segment 11 were decreasing over time. The parameters that exhibited these relationships were color, pH, salinity, turbidity, total nitrogen, total phosphorus, and organic carbon. These changes may be linked to regulations that limit wastewater treatment plant effluent discharge into Whitaker Bayou. Water quality in this Bay segment also appears to be improving.

Segment 14 shows significant decreases in chlorophyll a, suspended solids, salinity and ammonia overtime. Turbidity, Secchi depth and nitrate plus nitrite nitrogen are increasing. Decreases in chlorophyll a and suspended solids coupled with the increase in Secchi depth tend to indicate improvements in water clarity in this segment. The increased turbidity, however, indicates just the opposite.

In addition to the conflicting results for trend analyses, the multivariate analysis for segment 14 indicate that something (total nitrogen, total phosphorus, turbidity, color and chlorophyll) was regressed against Secchi depth, and in all segments except segment 14, this particular group of parameters reasonably predicted Secchi depth.

Trend results for segment 8 (east Sarasota Bay) indicate that water quality in this segment may be declining. Chlorophyll a, nitrates and nitrites, total nitrogen, total phosphorus, and segment. Additional nutrient inputs in this segment could result in algal blooms that could stress the existing plant and animal communities through limiting light available for photosynthesis and lowering dissolved oxygen levels.

IV. Implementation of bay-wide water quality monitoring

The primary objective of the water quality monitoring effort was to provide a synoptic "snapshot' of the waters of the study area during selected seasons and conditions.

IV.A. Monitoring stations, parameters, and participants

Each event sampled 101 stations during a four hour high tide "window." Stations were as spatially balanced as possible to reflect both relative segment area and characteristics (Le., grassbeds, depth, tributaries). Quarterly samplings were scheduled to take advantage of seasonal hydrological conditions typical for this region of Florida, and accommodated the range of temperature and growth conditions for primary producers. Daytime high tides, although not indicative of the areal "worst case" conditions for the waters of the Bay, were selected for characterization in order to permit more rapid and economical sampling and to provide accessibility to the numerous shallow areas of the Bay. Diurnal tides were selected as being most representative of the study area.

Data was collected during the present monitoring program for the parameters listed below, with *in situ* observations generally made at surface and bottom. Water quality samples were collected at near surface depths only.

Dissolved oxygen, mg/l
Temperature, °C
Specific Conductance, mmhos
Secchi depth, meters
PAR, $\mu Em^{-2}s^{-1}$

The coordination of the baywide monitoring and monitoring support were performed by Mote Marine Laboratory for the Sarasota Bay National Estuary Program. Cooperators for the baywide monitoring for both field and laboratory work included Manatee County Utilities Central Laboratory, Manatee County Environmental Protection Commission Laboratory, Sarasota County Environmental Services Laboratory, and the Sarasota County Natural Resources Department. Additional help, primarily in the form of meters, was provided by Environmental Quality Laboratory of Port Charlotte, Florida Department of Natural Resources, Southwest Florida Water Management District, the City of Tampa, and the United States Geologic Survey.

IV.B. Bay-wide monitoring - Results and Discussion

The high spatial density of stations in the monitoring plan allowed the mapping of various parameters, such as total nitrogen or Secchi depth for the individual events. Through interpolation, lines of equal value or concentration can be computer generated. In addition to between segment and between station comparisons, within station comparisons were possible using surface and bottom *in situ* readings.

Figure 1 illustrates the turbidity results from the third sampling event, which occurred on 2/12/91. During this sampling event, treated wastewater and brine effluent from reverse osmosis was being discharged into the Whitaker Bayou/Hog Creek area and the resultant turbidity plume is in evidence. During the event on 5/14/91, turbidity plumes are in evidence along much of the eastern side of the bay (Figure 2), this time a consequence of runoff from a thunderstorm than occurred early that day.

The water quality data was also examined along suspected gradients. For example, Figure 3 shows nitrogen and chlorophyll a at four stations located between Cortez and Tidy Island to outside of Longboat Pass. Here, and in general baywide, these parameters decrease along an east to west gradient, with the strongest relationships observed for chlorophyll. The gradients observed reflect an increasing dilution of relatively nutrient-rich freshwaters with more oligotrophic coastal waters.

IV.B.1. Comparison of surface and bottom *in situ* data

Dissolved oxygen, salinity, and temperature observations were made at both near surface and near bottom depths within the water column and the information used to determine the degree of water column stratification. As expected from

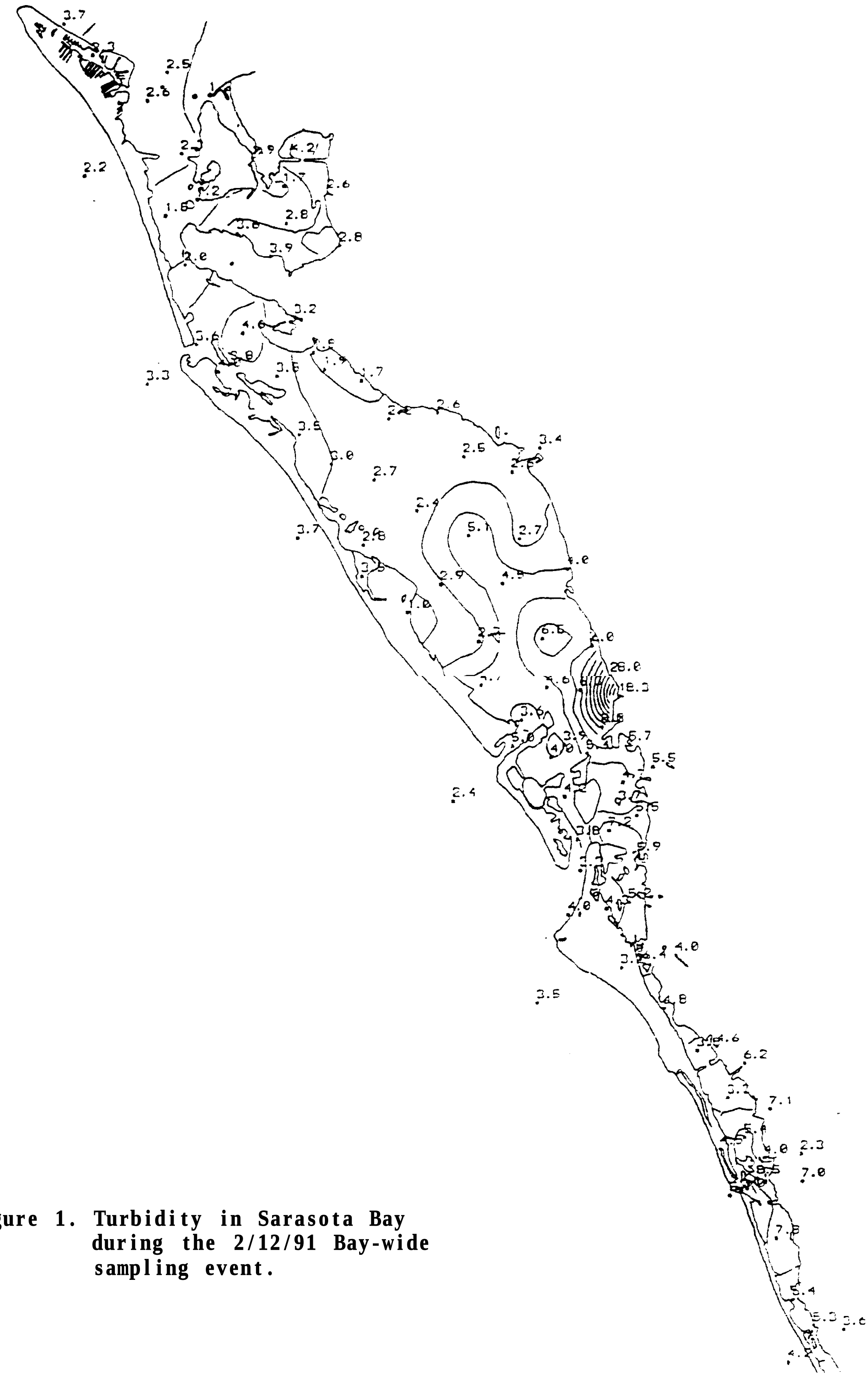

Figure 1. Turbidity in Sarasota Bay during the 2/12/91 Bay-wide sampling event.

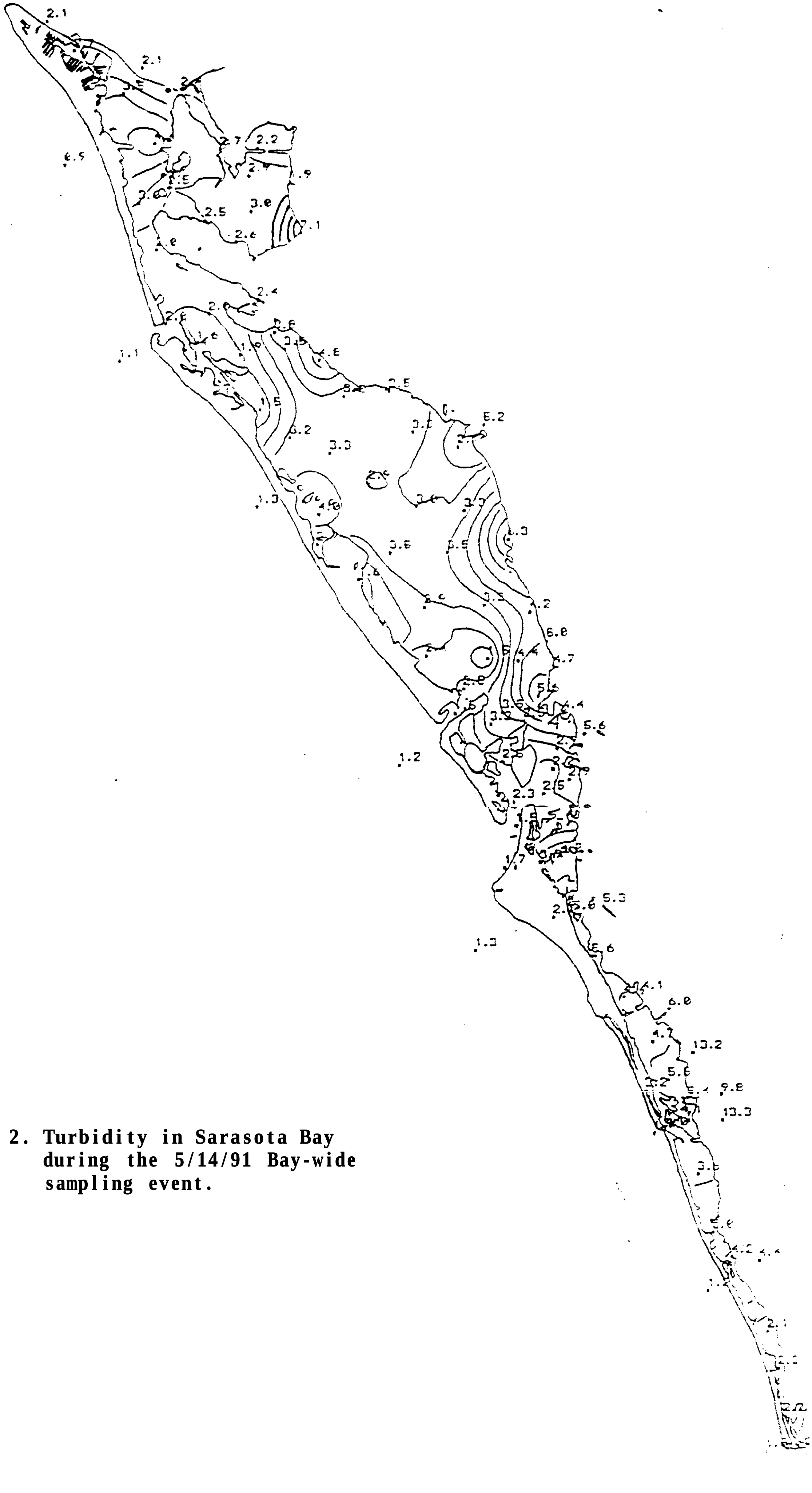

Figure 2. Turbidity in Sarasota Bay during the 5/14/91 Bay-wide sampling event.

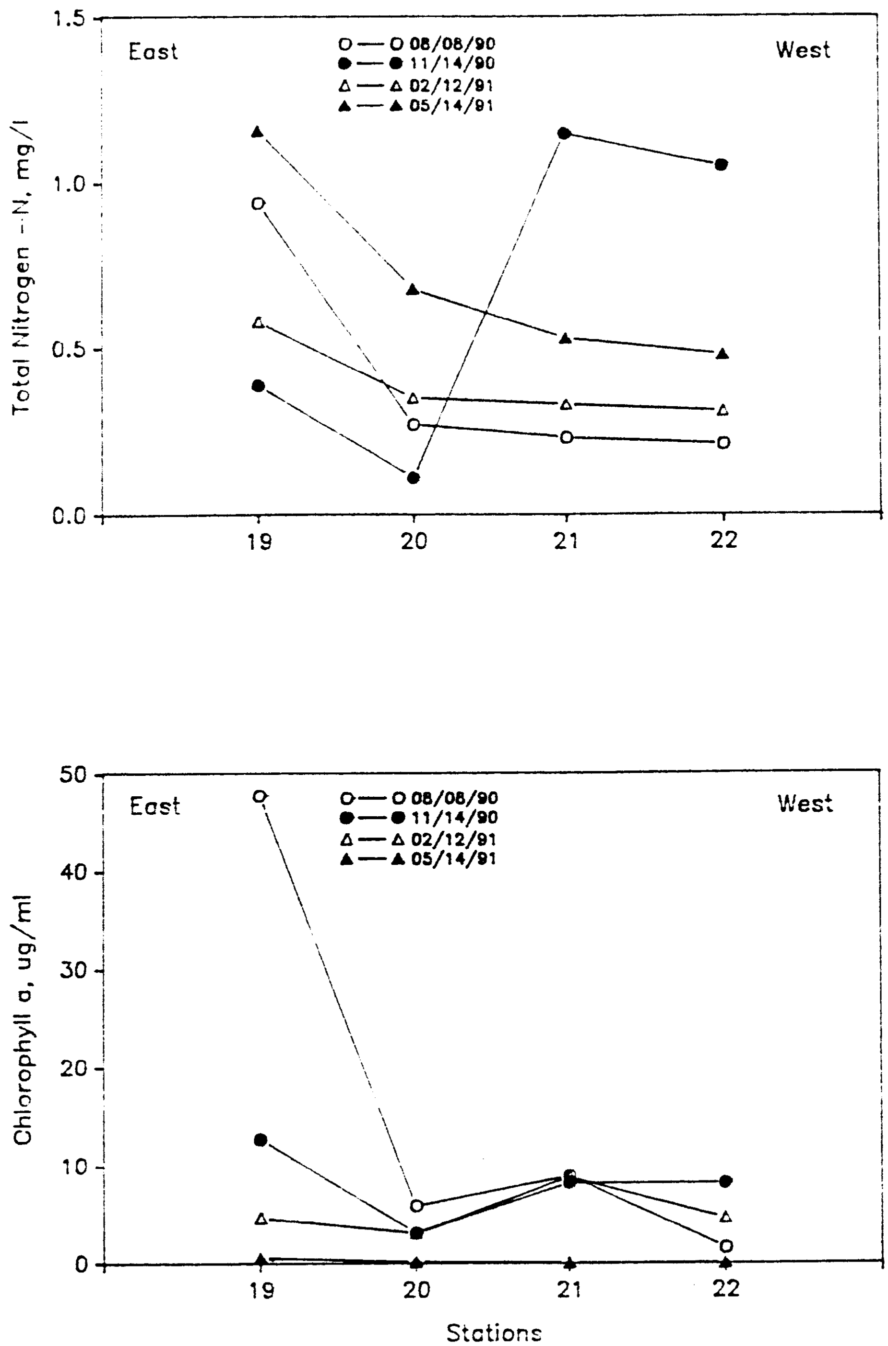

Figure 3. Nitrogen and chlorophyll a levels along an east-west gradient from Tidy Island to Longboat Pass.

the shallow nature of the estuary, little difference existed between the surface and bottom readings for the *in situ* parameters baywide. The stations located in tributaries (category 5) to the bay, where wind influence was minimal and freshwater was a larger percentage of the water column, generally showed larger differences between the surface and bottom readings than stations located in open water (category 1).

The *in situ* parameters also show seasonal differences in surface and bottom observations. Dissolved oxygen differences were greatest for all categories of stations during the first sampling event (August, 1990), and surface dissolved oxygen was generally higher than bottom. During the third event (February, 1991), the bottom dissolved oxygen was generally greater than surface. Although dissolved oxygen levels exhibit daily fluctuations, with daily minimums usually occurring just before sunrise and daily maximums occurring mid-afternoon, the timing for these two events does not account for the observed differences. The first event took place from 1130 to 1530, when the production of oxygen by phytoplankton and macrophytes and, consequently, dissolved oxygen in the water column, was near the daily maximum. The third event took place from 0945 to 1345, when dissolved oxygen was still approaching the daily maximum. This pattern is duplicated in surface and bottom temperature observations. Not surprisingly, bottom salinity readings are generally higher than surface readings.

Presenting the nutrient data as segment averages (Figure 4) shows little variation in total phosphorus among the sampling events. Total nitrogen tended to be highest in November, followed by May, August, and February. The variation in chlorophyll levels by sampling event and segment is quite pronounced, duplicating the pattern of increased chlorophyll a levels with increased rainfall found in Tampa Bay (Lewis and Estevez, 1988). The highest levels occurred during the first event in August and the lowest levels occurred in May. Organic carbon levels tended to be highest in February and lowest in May. These data are presented without inclusion of the Gulf and Pass segments to give a clearer representation of north-to-south variation within the Bay.

Secchi depth seasonality, however, does not demonstrate the same pattern as nutrients and chlorophyll. Secchi depth in general is highest during February when chlorophyll levels are low. The bay segments that are most influenced by water from the Gulf (segment 5, inside Longboat Pass; and segment 16, inside Venice Inlet) exhibit consistently higher Secchi depths during May (Figure 5). Segment 10 (inside New Pass and Big Pass) illustrates slightly increased Secchi depths on average, but this area is influenced by proportionately more stations in areas of lower flushing. Secchi depth generally tended to be higher in the northern segments than in the southern segments.

Salinity generally was lowest during the February monitoring event and highest during the August event (Figure 5). Segment 14 (Little Sarasota Bay) exhibited the lowest salinities during all events which is consistent with the relative size of the watershed. the number of tributaries contributing to smaller segments in the southern portion of the study area, and reduced flushing rates in this area (Sheng and Peene, 1992). High color values were also prominent in the southern segments, due to the increase tannins from the tributaries and reduced flushing rates.

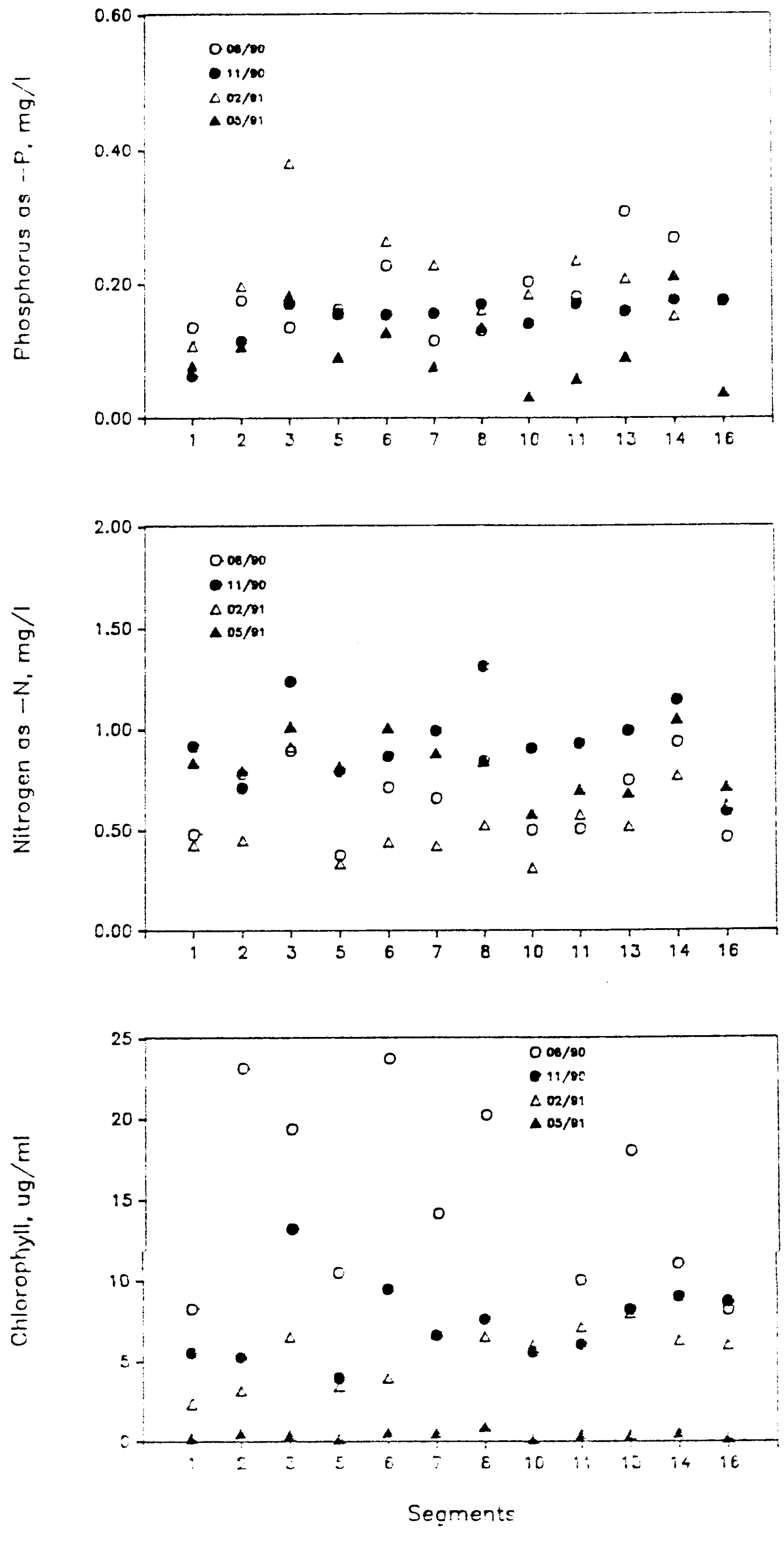

Figure 4. Total phosphorus, total nitrogen, and chlorophyll a for all Bay segments during each sampling event.

IV.B.2. Comparison of segments and categories

The results of the first four baywide monitoring events were compared by category using the Mann Whitney U test. Significant differences ($p \leq 0.05$) were found between category 5 (tributary) stations and all other categories (category 4 are stations with strong tributary influence; category 3 are near-shore stations with moderate tributary influence; category 2 are open water stations with minimum tributary influence; category 1 stations are open water) for the following parameters: depth; Secchi disk depth; extinction coefficient; color; turbidity; total phosphorus; ortho phosphate; nitrate plus nitrite; total Kjeldahl nitrogen; total inorganic carbon; total organic carbon; and, salinity. Significant differences between categories also existed for particle counts, total suspended solids, volatile suspended solids, and chlorophyll a. No significant differences between categories existed for ammonia, chlorophyll b or c, or phaeophytin. The tributary stations also had the highest average values for all parameters, except depth and Secchi disk depth.

The seventeen segments in the Sarasota Bay study area were compared to determine if significant differences existed between them by parameter. Due in part to the seasonal variation in many parameters, no significant differences existed for ammonia, chlorophyll b, chlorophyll c, and phaeophytin. The remaining parameters showed significant differences between segments at the 95% confidence interval.

IV.B.3. Segment Ranks

Establishing parameter means for the segments allows ranking and grouping the segments based on these rankings. Segments were ranked by mean value for the following light-related parameters: total Kjeldahl nitrogen, nitrate + nitrite nitrogen, ortho-phosphate, total phosphorus, extinction coefficient, turbidity, color, total organic carbon, total inorganic carbon, chlorophyll a, particle count, total suspended solids, and volatile suspended solids. The highest average value was ranked 1, the lowest 17. All segments were ranked twice, once with and once without tributary stations included. Comparison of these rankings illustrates the contribution of tributary stations, particularly in segment 13.

The ranks were summed for all parameters, and three groups of segments became apparent. The groups (Figure 6) were the top 25%, the bottom 25% and the middle 50% of the segments. The bottom 25%, with the highest concentration of nutrients and the poorest water quality overall, included segments 3 (eastern Palma Sola Bay), 13 (Roberts Bay), 14 (Little Sarasota Bay), 15 (Midnight Pass), and 8 (eastern Sarasota Bay between Bowlees Creek and Stephens Point). The top 25%, with the lowest concentrations of nutrients and the best water quality, were segments 4 (Longboat Pass), 9 (New Pass), 12 (Big Pass), and 17 (Gulf of Mexico). Segments 1 (Anna Maria), 2 (western Palma Sola Bay), 5 (north Longboat Key), 7 (middle Longboat Key), 10 (City Island), 11 (downtown bayfront), and 16 (Blackburn Bay) were in the middle 50% of the overall ranking.

The segments in the bottom 25% group, with the exception of Midnight Pass, are receiving waters for one or more tributaries. Even when the stations upstream of the mouths of the tributaries were excluded from the ranking, the

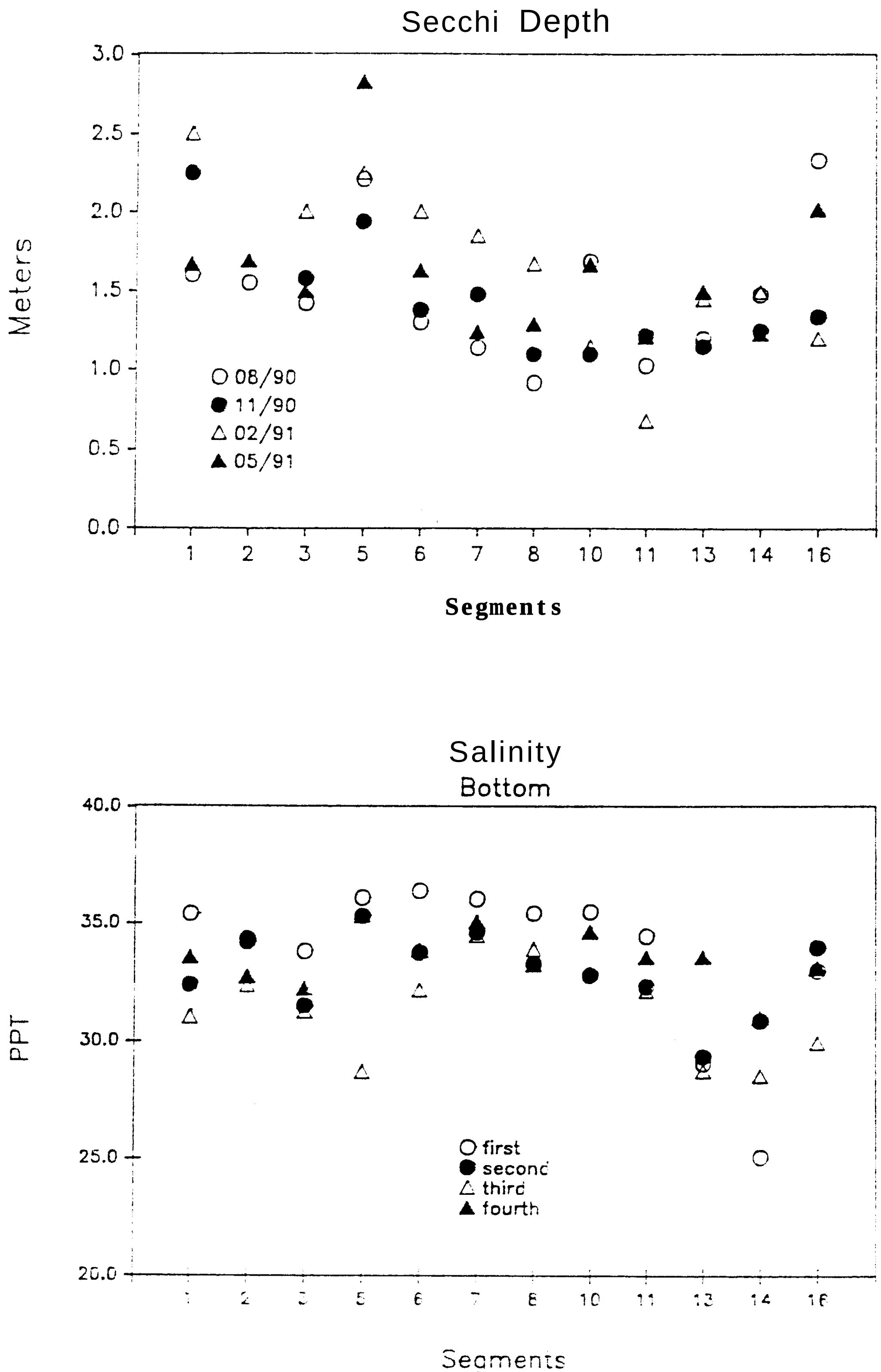

Figure 5. Secchi depth and salinity for all Bay segments during each sampling event.

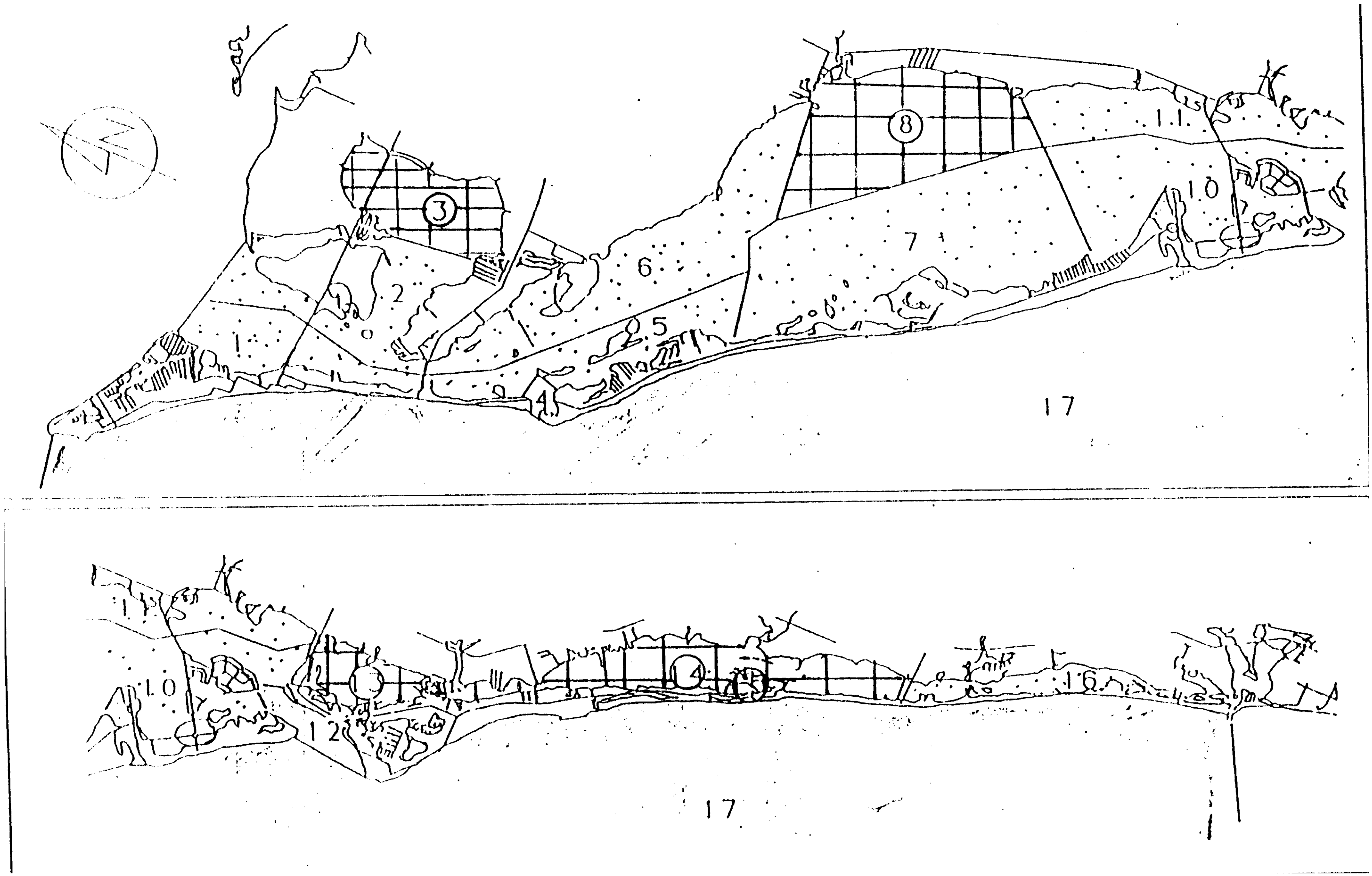

Figure 6. Relative water quality for Sarasota Bay segments. Shaded areas have the best; stipled areas have intermediate; cross-hatched areas have the poorest.

influence of the tributaries was apparent, with the same segments in the bottom 25% group either with or without tributary stations included. The degraded water quality in the tributaries also affects the segments that receive these waters. The effects are most apparent in areas of low flushing and high residence times (i.e., poor circulation).

IV.B.4. TSI

The trophic state index, or TSI, procedure is used routinely by the FDER in the biannual 305(b) water quality assessment to determine the trophic state of waterbodies throughout Florida. The procedure uses annual averages of chlorophyll a, Secchi depth, total nitrogen, and total phosphorus to determine trophic states. For estuaries, values of 0-49 are "good", 50-59 are "fair", and 60-100 are 'poor" (Hand, *et al., 1990)*. Although this procedure can lead to overly optimistic evaluations of water quality, it can be useful in comparing areas.

Overall the TSI for Sarasota Bay is "good". Segment TSI ranges from 33 (good) for segment 17 (Gulf) to 52 (fair) for segment 8 (east Sarasota Bay). Segments 3, 8, 13, 14 and 15 have TSI values in the 'fair' range when tributary stations are included in the calculation. Without tributaries included, only segment 15 (Midnight Pass) is still "fair"; the other segments are "good".

TSI values in Tampa Bay range from 74 (poor) in Delaney Creek to 39 (good) at the mouth of the Manatee River. TSI values in Charlotte Harbor range from 57 (fair) at the Caloosahatchee River mouth to 28 (good) in the north fork of Alligator Creek. Based on this index, water quality in Sarasota Bay is better than Tampa Bay and about the same as Charlotte Harbor.

V. Sediment Contamination Assessment

V.A. Station selection and sample collection

The scan was designed to emphasize potential areas of maximum contamination, and so the majority of the sites were on the eastern shore of the Bay. Station selection for the sediment scan emphasized Bowlees Creek, Hudson Bayou, Whitaker Bayou, and Phillippi Creek, and considered the location of water quality sampling locations, stations sampled for tissue contaminants during the Shellfish Contamination Assessment, or areas of interest to the Point and Non-Point Source Assessment Projects. A total of 35 areas were sampled (Figure 9). At each of the 35 areas, a suspected gradient in sediment quality was established and three stations were sampled at intervals along a transect.

Samples were collected from the upper 5 cm of the sediments, representing recent accumulations using a Ponar grab sampling device. Replicate samples from separate grabs were collected at each site to establish some measure of station variability.

Sediment deposition is typically heterogeneous and small scale variations in bathymetry, together with station location and sediment transport dynamics within a particular tributary, can produce widely ranging concentrations of contaminants in bulk sediments. Although researchers have taken various approaches to the problem of sediment data interpretation, most have relied on mathematical normalization techniques, such as presenting pollutant concentrations as a function of percentage of fines, percentage of organics, or amounts of geochemical tracers.

However, even normalized sediment data should be considered an approximate technique in the absence of detailed physical analysis of the estuary to identify deposition patterns and an intensive spatial sampling for contaminants. Sediments typically exhibit a gradient in pollutant content, which is produced by equilibrium partitioning and mobility of contaminants as controlled by sediment type, salinity, pH and other water quality parameters. In addition, sediment transport and deposition will effect the eventual fate of contaminants. The position of the gradient established reflects not only the composition and load of sediment and pollutants supplied, but also and the net and tidal flows effecting the transport. Gradients will differ for different contaminants.

The position of pollution gradients varies between tributaries. In some instances, the most upstream station is the most contaminated, but this is certainly not always the case. Within the three stations for a basin, for example, different metals may have maximum enrichment ratios at different stations. Some portion of the apparent difference in gradient position must undoubtedly be attributed to the presence of concentrations of non-point source impacts such as stormwater drains and marinas. Other influences may be actual station location,

Examination of the sediments collected during this study with respect to the expected metal content reveals that the bulk of the sediments are uncontaminated with the six pollutant metals evaluated for this study (arsenic, cadmium, copper, lead, mercury and zinc). This is particularly the case for arsenic, cadmium, and mercury, while more sediments are enriched with copper, lead, and zinc (20%, 33%, and 37% of the stations sampled, respectively). Figure 11 represents the enrichment ratios by basin for copper, lead, and zinc, and the most affected tributaries obviously are Hudson Bayou, followed by Cedar Hammock and Bowlees Creeks, followed by Whitaker Bayou.

The stations located farther upstream than the mouths of the tributaries (in Hudson Bayou, Cedar Hammock Creek, Bowlees Creek, Whitaker Bayou and Phillippi Creek)) are all enriched for a number of metals and form much of the upper percentiles when individual stations are considered by mean rankings of all metals. The portion of the tributary sampled must therefore be considered when comparing basins.

V.B. Metals

In Florida. the bulk of the metallic content in uncontaminated sediments resides in the fine clay fraction which is comprised of alumino-silicate minerals, rather than in the larger sized quartz sand fraction. Aluminum can be used as a tracer for naturally-occurring metals because the concentrations in naturally occurring soils are known. Previous work (Schropp and Windom, 1988) has identified the expected range of metal content in uncontaminated sediments for given aluminum concentrations. Values falling above the upper 95th percentile confidence interval for this relationship are considered anthropogenically enriched in the particular metals. Enrichment ratios for individual metals and stations were further computed as the observed metal concentration divided by the upper concentration which would be expected in pristine sediments, based on the observed aluminum concentration. Values of the ratio greater than 1.0 reflect data points outside the confidence intervals, and, therefore, enriched. The basin enrichment ratios are presented in Figure 7.

The overall relationship of sediment metals with aluminum content is cl ear, as there is a clear central tendency in the distribution of the Sarasota Bay data. The apparent increase in the slope of the relationship, as compared to the 95% confidence interval for pristine sediments, is most likely a product of station selection for the study, as similar results have been seen in other work in contaminated areas (Pierce, *et al.*, 1988; Hofmann and Dixon, 1988; NOAA Tampa Bay Sediments, 1991). Analytical bias was eliminated using spiked matrix and reference materials.

V.B.1. Mercury

Mercury demonstrated a strong metal:aluminum relationship within the Sarasota Bay data set, in contrast to the state-wide dataset which determined no significant relationship. Ranges of mercury and aluminum sampled were comparable in both the Sarasota Bay and pristine data sets. Relationships of mercury with percent organic content of the sediments were also apparent. The relationship observed in Sarasota Bay may reflect either a more uniform source of sediments or an enrichment process which is ubiquitous in the watershed, such as aerial deposition.

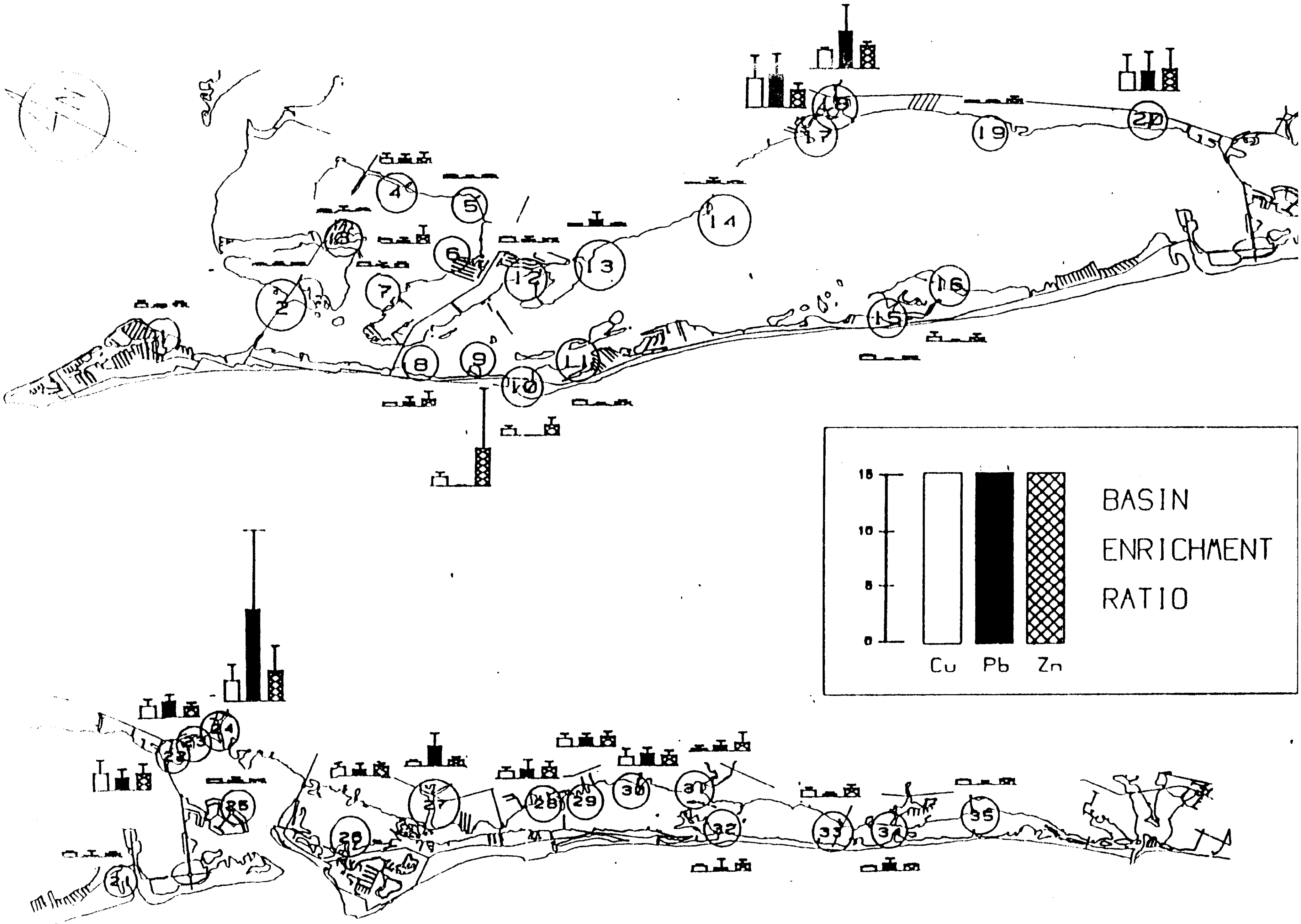

Figure 7. Enrichment ratios for copper, lead and zinc in Sarasota Bay sediments.

V.B.2. Relation to Basin Loadings

Basin loadings for lead and zinc together with land use types, as given in the Point/Non-Point Source Pollution Loading Assessment, Phase I Report (CDM, 1992) were tabulated and summed by watershed and compared to metal enrichment ratios for the basin, for the individual stations, and for the station within a basin that was nearest the mouth of the tributary.

No statistically significant linkage appeared between either pounds, pounds per acre, or runoff concentrations and the basin enrichment ratios for either metal (Figure 8).

Based on the figures of runoff concentrations and basin enrichments, Hudson Bayou, and to a lesser extent, Cedar Hammock and Phillippi Creeks, appear to have more lead in the sediments than might readily be explained by predicted loadings. The sediments in these same three basins also appear to be elevated, in comparison to runoff concentrations, with respect to zinc. The above comparisons again depend on the assumption that comparable areas of the pollution gradient within each watershed have been sampled.

V.B.3. Relation to Oyster Tissue Contaminant Levels

A number of the sediments sampled during this study were also from quite near the location of oysters collected during the Bivalved Shellfish Contamination Assessment. For the comparison of shellfish tissues with sediment data, the same cautions apply as for the comparison with basin loadings. For correspondence to be expected, both samplings (sediment and tissue) at all stations must represent similar portions of the pollution gradient.

In Figure 9, the correspondence between sediment enrichments and shellfish tissues appears quite high for lead, copper, and, to a lesser extent, zinc. Cadmium, arsenic, and mercury in shellfish appear to be dominated by factors other than sediment enrichment. Cadmium and mercury are two elements which frequently have high relationships with organic content in the sediment and the apparently varying bioavailability may well be related to between-basin differences in this parameter. These results indicate that the bioaccumulation of lead and copper in oysters is the most reflective of sediment enrichment ratios. Bioavailability of these two elements may be least affected by other sediment or water quality variables and they may therefore be the most readily used for interbasin comparisons and toxicity evaluations.

V.B.4. Potential Biological Impacts

Recent work (Long and Morgan, 1990) has synthesized the information available from various approaches determining biological impacts to provide a single 'yardstick' for use in evaluation of the National Oceanic and Atmospheric Administration's National Status and Trends sediment data. Data from many species, including freshwater and marine organisms: were compiled together whenever toxic effects were determined. The synthesis was not intended to represent official standards or regulatory criteria. The lowest 10th percentile was designated an Effects Range - Low (ER-L), or that concentration of contaminant, above which adverse biological effects may first be expected. The

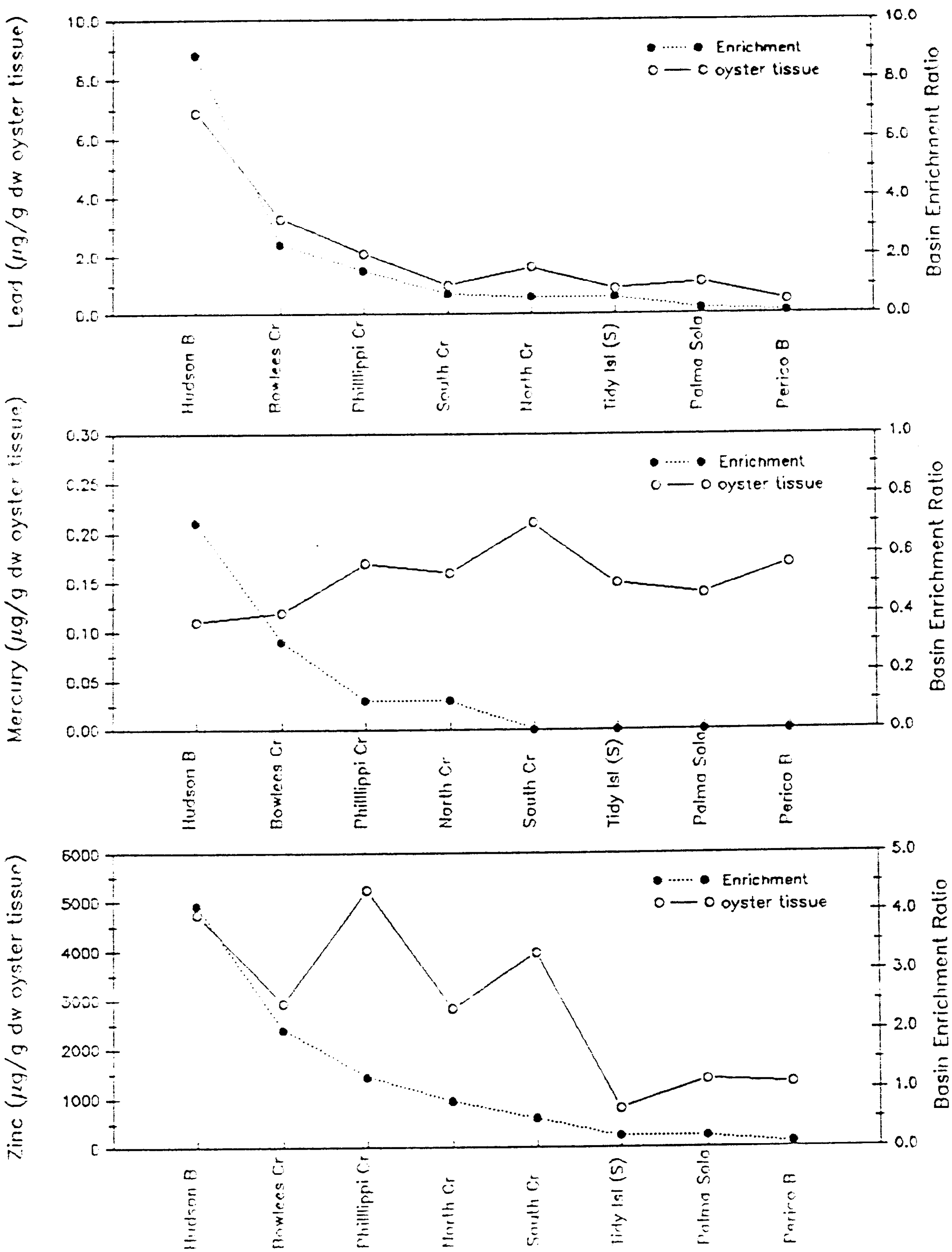

Figure 9. Relationship between sediment enrichments and shellfish tissues for lead, copper and zinc.

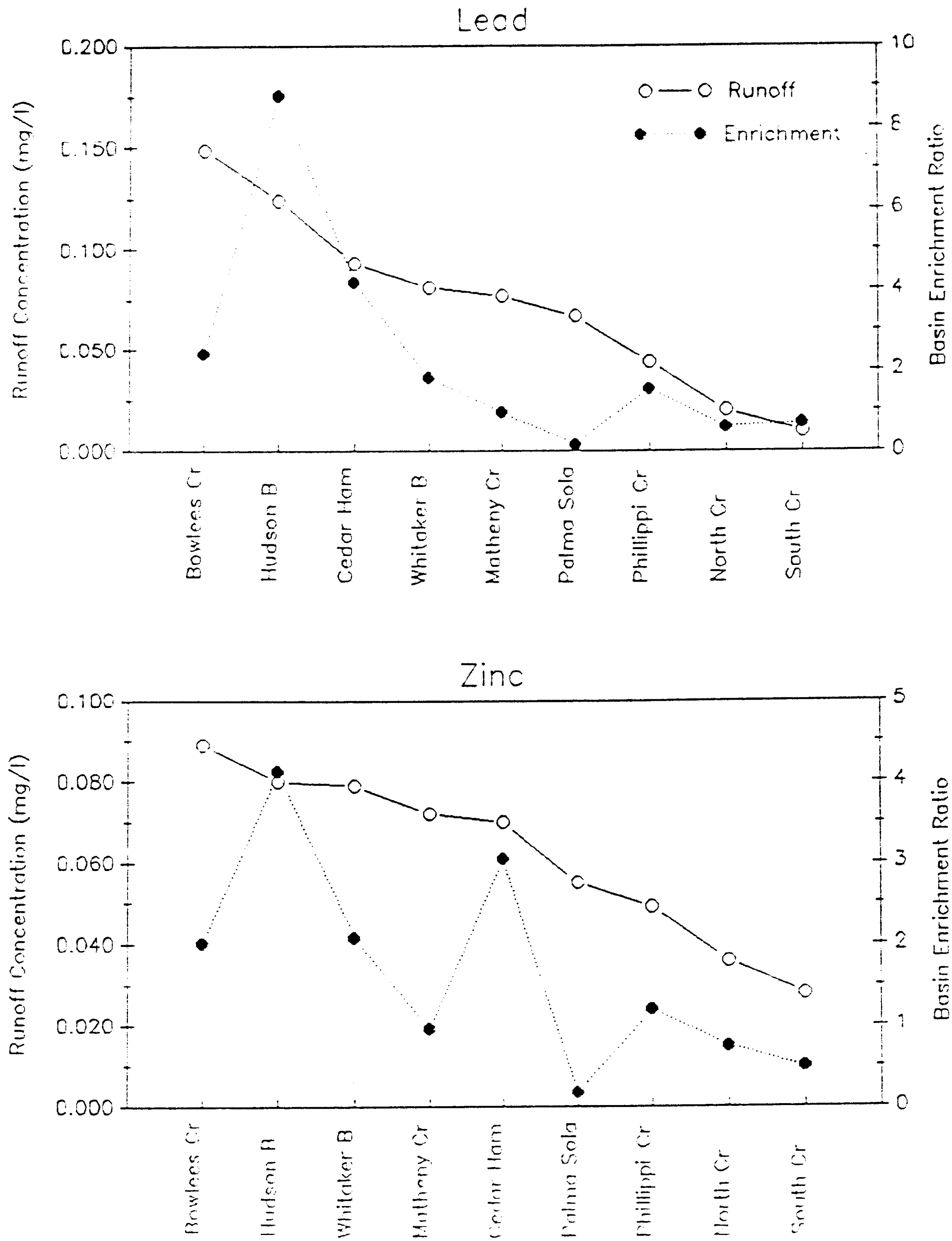

Figure 8. Relationship between runoff concentrations and basin enrichment ratios for lead and zinc.

50^{th} percentile was selected as the Effects Range - Median (ER-M), or that concentration above which adverse effects almost always would be expected.

The Effects Range Approach may be considered conservative, in that studies which determined no effects were not included in the ranking, resulting in the use of the most sensitive species, or of the sediments providing the highest degree of bioavailablity. The table below summarizes the ER-L and ER-M values for the metals determined in this study, together with the percentage of the sediment samples from this study which exceeded those threshold values.

Metal	Effects Range -Low (ug/g)	Percent Exceeded (%)	Effects Range -Median (ug/g)	Percent Exceeded (%)	Maximum Sarasota Bay ug/g
Arsenic	33.0	0.0	85.0	0.0	11.75
Cadmium	5.0	0.0	9.0	0.0	1.66
Copper	70.0	6.7	390.0	0.0	160.00
Lead	35.0	12.9	110.0	5.0	283.00
Mercury	0.15	6.3	1.3	0.0	0.325
Zinc	120.0	7.5	270.0	1.7	500.00

Arsenic and cadmium do not appear to be severe contaminants within the Sarasota Bay system. No samples exceeded the low effects range, as determined Long and Morgan (1990), and the maximum concentrations observed in Sarasota Bay sediments (14.9 for arsenic and 1.94 for cadmium) were less than the lowest value used to determine the ER-L and ERM values.

A number of stations exceed the effects range-low for lead with slightly fewer exceeding the ER-L for copper, mercury, and zinc. These stations were all within the basins of Cedar Hammock Creek, Bowlees Creek, Whitaker Bayou, and Hudson Bayou. Stations within Marina Jack were above the ER-L for lead and mercury, while some in Phillippi Creek were above the ER-L for lead and zinc.

A few stations exceeded the ER-Ms for lead and zinc, the concentrations above which adverse effects may almost always be expected. Stations in Hudson Bayou and Cedar Hammock Creek were in this category for lead, and stations in Hudson Bayou and Whitaker Bayou for zinc. One of the samples from Hudson Bayou (Station 24A) was almost three times the ER-M for lead, and over two times the ER-M for zinc. The biological effects noted in the studies used to establish the ER-Ms for these metals included toxicities to oyster larvae, amphipods, apparent effects thresholds noted for amphipods, bivalves, and benthic organisms, 100% mortality of some polychaetes, and reduced benthic species richness.

The stations which exceeded the various ER-L and ER-M levels were, in genera?. located upstream of the mouths of the various tributaries. While this indicates that the areal extent of contaminated sediments is comparatively small (with respect to the Bay bottom of the entire study area), the areas affected also represent some of the few low salinity habitats available for the region. Any adverse biological impacts would also be directed against the more sensitive larval or juvenile life stages which typically utilize the low salinity regions.

An additional concern is raised by the pattern of stations which exceeded the various effect ranges. Only five areas of the 35 sampled included stations which extended upstream of the mouths of the various tributaries. The bulk of the stations were directed towards evaluating the sediments within the Bay proper. There may potentially be additional low salinity habitats that are impacted and yet were unsampled. The sediment status of the upstream reaches of the remaining tributaries is unknown.

V.C. Organics

The survey of sediment samples from Sarasota Bay demonstrated that most areas had low concentrations of the target compounds. Usually, stations with moderate to high levels of contamination were within the more urbanized bayous and creeks. Organics data, due to the hydrophopic nature of the components, is often presented as normalized to the organic or carbon content of the sediment.

V.C.1. Pesticides

The highest mean total pesticide concentration, 192 ng/g dw, measured during this study was in Hudson Bayou, Station 24A. This station had individual and total pesticide concentrations which were as much as three to four times those measured at any other station. Mean total pesticide concentrations of roughly 70 ng/g dw were measured at both Hudson Bayou station 24B and Cedar Hammock Creek station 17A. Figure 10 represents the total chlorinated pesticides found in sediments for each of the areas sampled as a function of organic content. Using normalized data, Hudson Bayou is by far the most contaminated area. Cedar Hammock Creek, Phillippi Creek, Perico Bayou and Bishop's Point (Harborside) also show elevated levels of total chlorinated pesticides. The most abundant chlorinated pesticides were the DDT derivatives, DDE and DDD, the cyclodiene pesticides, aldric, dieldrin and heptachlor epoxide, and the chlorinated organophosphate, chlorpyrifos.

V.C.1a. Potential Biological Effects

The potential for adverse biological effects resulting from the concentrations of pesticides in Sarasota Bay sediment can also be assessed by comparison with Effects Range approach described above. Although effects have not been determined for all of the pesticides, the following are presented to assess potential adverse biological effects.

Pesticide	Effects Range-Low (ng/g)	Percent Exceeded %	Effects Range-Median (ng/g)	Percent Exceeded %	Maximum Sarasota Bay (ng/g)
DDT	1.0	5.7	7.0	1.0	13
DDE	2.0	6.7	15.0	3.8	27
DDD	2.0	5.7	20.0	1.9	43
Total DDT	3.0	11.4	350.0	0.0	70
Dieldrin	0.02	5.7	8.0	2.8	17
Endrin	0.02	1.0	45.0	0.0	1

Figure 11 Total PAH in Sarasota Bay sediments by area. Average PAH concentrations (normalized to sediment organic content) for stations were summed to obtain the area totals.

V.C.1b. Relation to shellfish contamination assessment

A comparison of sediment pesticide levels in sediments with pesticide levels in Sarasota Bay shellfish where both studies had common sites, indicates only one site where pesticides reached appreciable quantities in both shellfish and sediments. At this site (Hudson Bayou), a wide array of pesticides were measured in the sediment samples, while shellfish had quantifiable levels of p,p'-DDE and p,p'-DDD. The observed differences in the number of pesticides found in the two sample types likely either reflect the different time scales integrated by measurements in sediment and shellfish, or differences in the bio-availability of the pesticides being measured.

V.C.1c. Relation to Tampa Bay sediments

With no other major surveys of pesticides in the sediments from Sarasota Bay, the best available comparisons are pesticide concentrations observed in Tampa Bay sediments by the National Status and Trends Program (NS&T) conducted by NOAA, 1989. It should be noted, however, that stations for that program were selected with the specific aim of avoiding point sources or known areas of contamination. Total chlorinated pesticides in Tampa Bay NS&T samples ranged from below the limit of detection to 61.4 ng/g dw (including DDT's). Samples from Sarasota Bay also range from below the limit of detection for total chlorinated pesticide concentrations as do the Tampa Bay NS&T sites, but greatly exceed the Tampa Bay maximum at the most contaminated station (Hudson Bayou).

One area of concern for some of the more contaminated samples within this study was the observance of polychlorinated biphenyls (PCB's) as potentially interfering peaks. While PCB's were not target analytes in this study, PCB congeners were tentatively identified in several of the samples, and the toxicity of these compounds well known. They should be specifically targeted for analysis in selected samples.

V.C.2. Polynuclear Aromatic Hydrocarbons (PAH)

Polynuclear aromatic hydrocarbons (PAH) have both natural and anthropogenic sources to the marine environment, although the man-made sources, petroleum spills, combustion by-products predominated. Combustion derived PAH could enter the Bay through atmospheric deposition, surface runoff, effluents, and direct exposure to vehicular exhaust (e.g. motor boats). Uncombusted petroleum products could enter the Bay via the same routes, with the additional route of spillage or leakage of petroleum products. Used motor oil contains significant concentrations of PAHs, both alkylated and parent low and medium molecular weight (Pruell and Quinn, 1988; Takada *et al.*, 1991) and can be introduced to the Bay through surface runoff or illicit disposal. The relative significance of each of the sources mentioned would vary with location in the Bay.

In Sarasota Bay sediments, the highest total PAH concentration (as a station mean} occurred at Station in in Cedar Hammock Creek (26.8 µg/g dw), followed by Stations 24A, and 24B in Hudson Bayou (18.1 and 8.3 µg/g dw). Stations in Whitaker Bayou (20A) and Bowlees Creek (18B) also had elevated concentrations of these compounds. Normalizing total PAH to organic content produced a ranking of areas with Hudson Bayou, Bowlees Creek and Cedar Hammock

Creek far ahead of other areas of the Bay. Total PAH values adjusted for organic content are illustrated as basin means (the average of all three stations) in Figure 11. This figure demonstrates the variability of PAH contamination in the Bay, and the fact that extremely high concentrations were restricted to relatively few of the stations and areas sampled (Hudson Bayou, and to a lesser extent, Bowlees and Cedar Hammock Creeks).

Five of the 35 study sites exhibited no quantifiable PAH at any of the 3 stations. Ten stations showed moderate to high PAH concentrations and usually contained not only methly-substituted PAH but also ethyl- and propyl-substituted PAH, indicative of gross petroleum contamination. These stations included those in Cedar Hammock Creek (2), Bowlees Creek (2), Hudson Bayou (2), Matheny Creek (2), and Whitaker Bayou (1).

V.C.2a. Potential Biological Effects

As for the pesticides, the toxic levels of PAH can al so be assessed from the sediment effects ranges defined by Long and Morgan (1990), which are listed below for the PAH compounds identified in this study.

PAH	ER-L (ng/g)	Percent Exceeded %	ER-L (ng/g)	Percent Exceeded %	Sarasota Bay max. (ng/g)
Acenaphthene	150	0.0	650	0.0	BDL[1]
Anthracene	85	2.8	960	0.0	262
Benzo(a)anthracene	230	5.7	1600	1.9	1961
Benzo(a)pyrene	400	7.6	2500	0.0	2339
Chrysene	400	6.7	2800	1.9	3350
Dinezo(a,h)anthracene	60	ND[2]	260	ND[2]	ND[2]
Fluoranthene	600	5.7	3600	1.9	4740
Fluorene	35	1.0	640	0.0	38
Naphthalene	340	ND[2]	2100	ND[2]	ND[2]
Phenanthrene	225	4.7	1380	0.0	1176
Pyrene	350	5.7	2200	1.9	4540
Total PAH	4000	6.7	35000	0.0	26771

[1] BDL = Below Detection Limit
[2] ND = Not Determined

A comparison of PAH concentrations in Sarasota Bay sediment with their effects thresholds shows that, although several stations throughout the Bay exhibited PAH levels above "background" levels, most of the concentrations are below that considered to pose an adverse biological effect.

Three sites were found to contain sufficient concentrations of PAH to represent an adverse biological effect of organisms in contact with sediment. These sample sites, including Cedar Hammock Creek, Bowlees Creek, and Hudson Bayou, should be considered "hot spots" for PAH contamination. Stations exhibiting PAH concentrations above the ER-L, but below ER-M concentrations for one or <u>more</u> PAH, include sediments from Whitaker Bayou, Marina Jack's Island Park, Matheny Creek, and Cedar Creek.

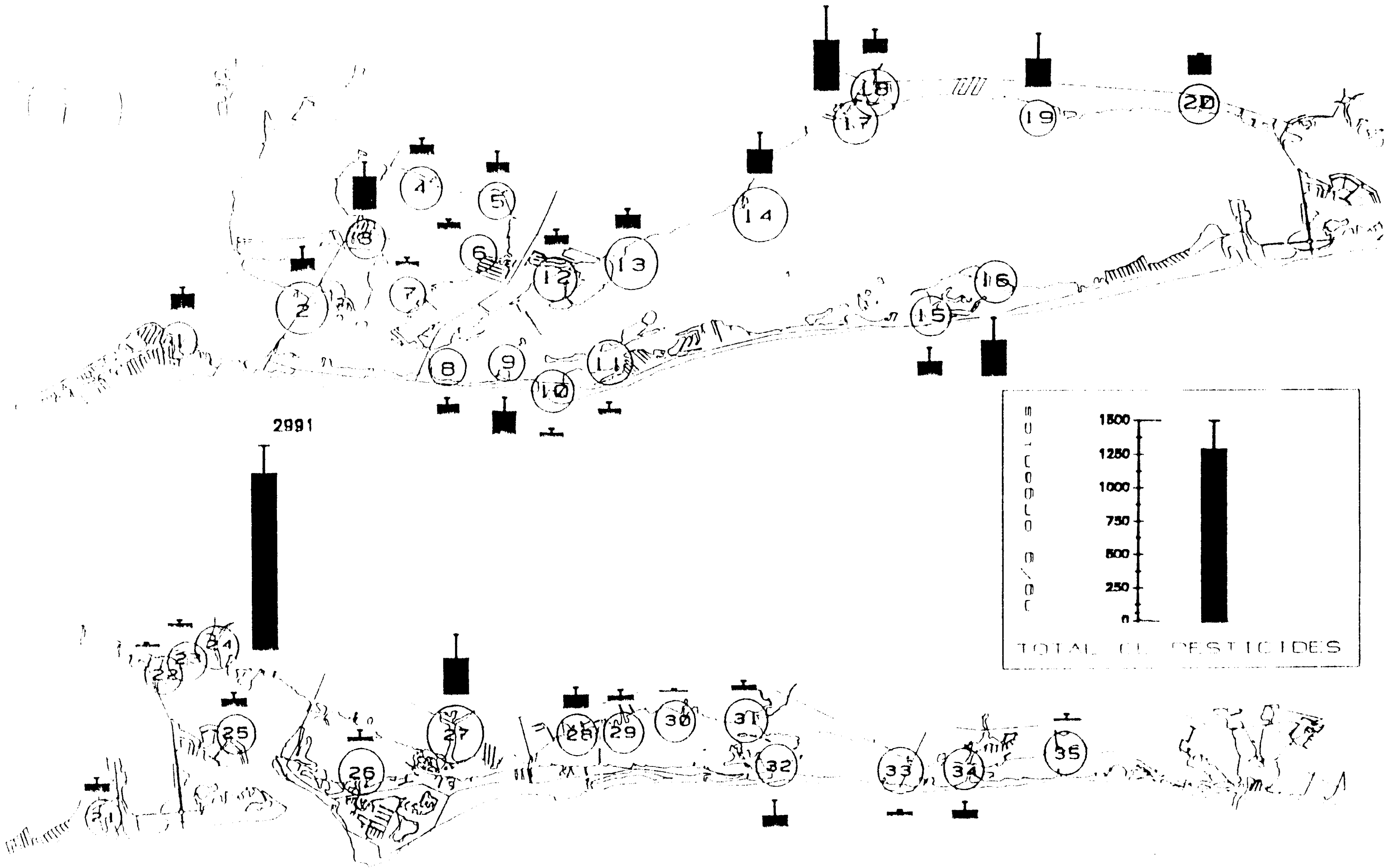

Figure 10. Total chlorinated pesticides in Sarasota Bay sediments by area. Average pesticide concentrations (normalized to sediment organic content) for stations were summed to obtain the area totals.

V.C.2b. Relation to Shellfish Contamination Assessment

Comparison of the sediment PAH concentrations with the concentrations determined in shellfish from Sarasota Bay showed that all but one of the sites where shellfish were reported to have trace levels of PAH, also contained measurable quantities of PAH in sediment.

V.C.2c. Relation to Tampa Bay Sediments

A comparison of the average mean total PAH concentrations of Sarasota Bay sediments (941 ng/g dw) with the concentrations reported for Tampa Bay NS&T sites (NOAA, 1989) places Sarasota Bay sediments in the middle of the range of concentrations observed at the six NS&T Tampa Bay sites (90 to 1900 ng/g dw). Since the Sarasota Bay average mean is significantly affected by the few extremely high stations we may conclude that Sarasota Bay sediment concentrations compare favorably with concentrations observed in Tampa Bay.

V.C.3. Fecal Sterols

Coprostanol is primarily produced by the enteric bacteria of higher animals (Walker *et al.*, 1982) and there is little decay of this material in anaerobic sediments. Anthropogenic contamination is more readily visible in coprostanol concentrations as a function of sediment organic content.

Both coprostanol and epicoprostanol are produced during anaerobicmicrobial action on sewage sludge (McCalley *et al.*, 1980, 1981), and could potentially be produced in anaerobic sediments. During the anaerobic incubation of sludge, ratios of coprostanol to epicoprostanol were also reported to change, with epicoprostanol the favored product.

There are some indications that coprostanol can be produced *in situ* under anaerobic conditions in areas uncontaminated by mammalian fecal wastes (Taylor *et al.*, 1981; Toste, 1976; Smith *et al.*, 1982, 1983; Mackenzie *et al.*, 1982) from cholesterol precursors. The relative magnitude of this "environmental production of coprostanol has yet to be determined, but is likely to be strongly controlled by sediment composition and bacterial population. Comparable levels of coprostanol and epicoprostanol with depth in anthropogenically uncontaminated sediment cores (Vankatesan and Santiago, 1989) would seem to indicate that the process of either total coprostanol production or shift in epimere dominance does not continue indefinitely.

Treatment plants for domestic effluents rely on a variety of processes for solids, biochemical oxygen demand, and nutrient removal. Advanced waste treatment plants (AWT) in particular, use a series of anaerobic digestions of clarified effluents for nitrogen removal. For secondary treatment, anaerobic conditions may be fess frequent, but both processes experience anoxia in the initial stages of sludge settling. The formation of epicoprostanol is apparent?) favored by the anaerobic digestion process based on the analysis of sludqes from a variety of treatment plants (Eganhouse, *et al.*, 1988).

Sarasota Bay sediments displayed a wide range in both epimere and total coprostanol concentrations. Stations in the upper 10^{th} percentile (>500 ng/g dw) included one each from the Grand Canal, Cedar Creek, Whitaker Bayou, and the area immediately to the north of Tidy Island, and two stations from each of Cedar Hammock Creek and Bowlees Creek areas. Over half of the stations in the upper 10^{th} percentiles were located near the mouths of the various tributaries. Bulk coprostanol concentrations, as for metals and other organics, undoubtedly reflects the distribution and relative organic content of sediments.

In Sarasota Bay, the relationship of total coprostanol with organic content of the sediments was highly significant (r^2 = 0.556, n=76). The station in Clower Creek (Station 29A) appears to have lower total coprostanol concentrations than would be expected from study-wide norms (at the 95% confidence intervals), while stations to the north of Tidy Island (12A) and at the Grand Canal (26C) appear to have an enrichment in coprostanol beyond that expected for the remainder of the study area.

Before concluding, however, that the remaining stations are unimpacted, St should be restated that the sampling design emphasized stations which were suspected to have substantial amounts of contaminants. Access to a data base from pristine areas with similar sources and loads of organic matter and climatological conditions could develop an "enrichment ratio" approach similar to that used for metals contamination. Any selection of a "pristine" subset of stations with respect to coprostanol from this study would be very subjective. The use of the other contaminants to identify "impacted" and "unimpacted" stations was not considered to be useful since domestic effluents and the major contributors of metals and synthetic organics do not necessarily coincide.

Normalization of total coprostanol data resulted in a differing suite of stations in the upper 10th percentile and the distribution of fecal sterols in Sarasota Bay is shown in Figure 12. Plotted are the mean total coprostanol (summed means of coprostanol and epicoprostanol) by region. A station to the north of Tidy Island, the upstream station in Bimini Bay (Anna Maria), one at Long Bar Point, Buttonwood Harbor, and two stations from the Grand Canal and Palma Sola Creek were those stations with the highest total coprostanol concentrations per weight of organic matter. The stations to the north of Tidy Island and at the Grand Canal were both apparent outliers to the coprostanol/organic relationship determined for Sarasota Bay sediments (more coprostanol than expected).

The coprostanol to epicoprostanol ratios were determined for Sarasota Bay sediment samples where both compounds were quantified. The values of this ratio in Sarasota Bay sediments ranged from 0.1 to 1.5 with almost all values below 0.3. Coprostanol was typically one-third of the epicoprostanol levels. This is illustrated graphically in Figure where the correlation of epicoprostanol with coprostanol is highly significant (r^2 = 0.874, n = 76).

The two notable exceptions to this relationship were for stations at Cedar Hammock Creek (more coprostanol than would be expected) and to a lesser extent at Station 18B at Bowlees Creek (more epicoprostanol than predicted).

The predominance of low ratio values determined in these samples could suggest several processes for coprostanol in Sarasota Bay sediments. Coprostanol and epicoprostanol may be produced *in situ* by the anaerobic microbial degradation

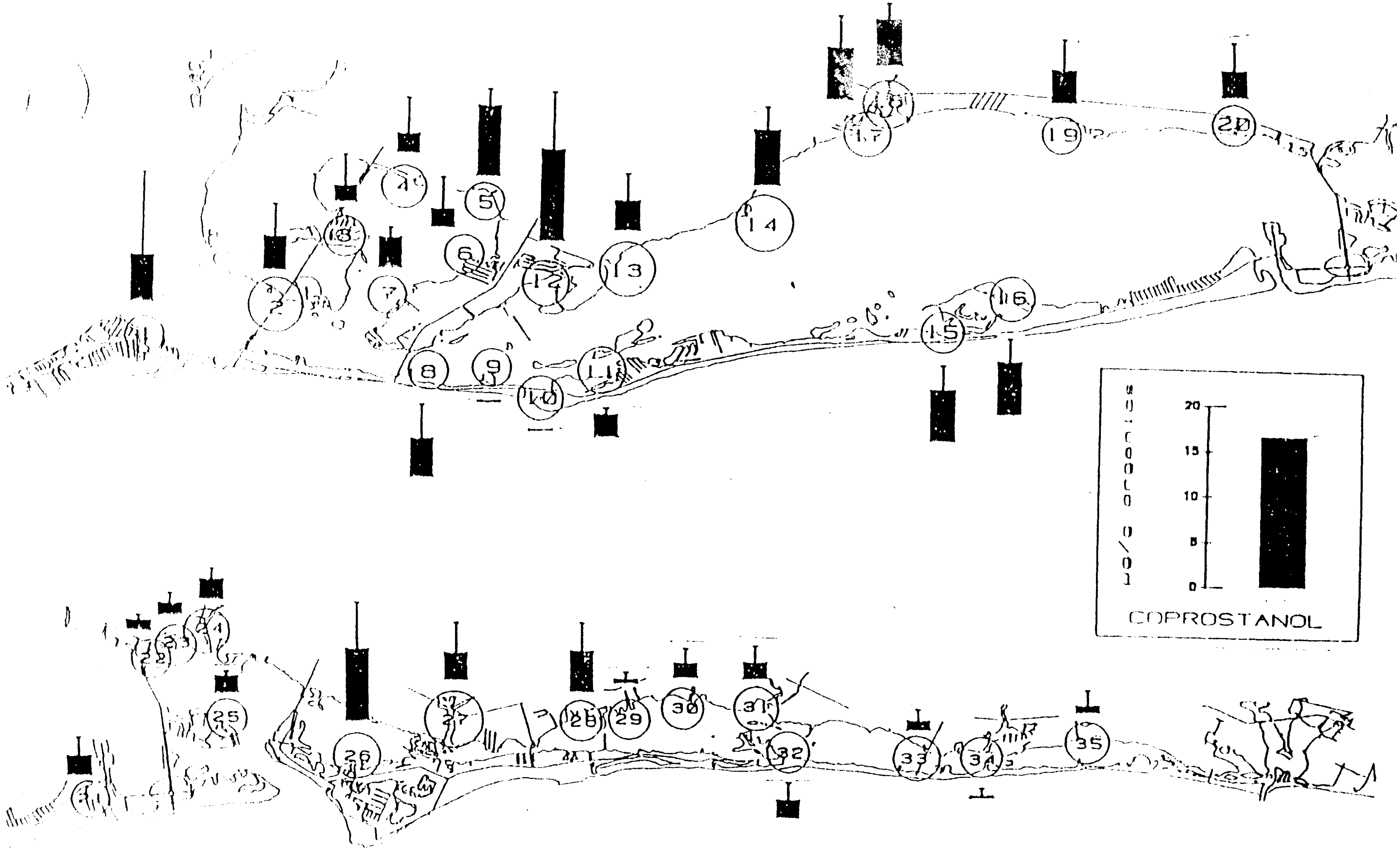

Figure 12. Total coprostanol in Sarasota Bay sediments by area. Average coprostanol (normalized to sediment organic content) for stations were summed to obtain the area totals.

of cholesterol. Cholesterol sources include not only animal wastes, but plant detritus as well, although in lesser proportions. Alternatively, the waste sources discharging directly to the Bay consist of AWT discharges under which anaerobic conditions favor epicoprostanol production. Subsequent incorporation into reduced sediments maintains the favored status of epicoprostanol. In this instance, higher coprostanol/epicoprostanol ratios may indicate more recent inputs of aerobically or relatively untreated wastes. To examine and rank areas which receive domestic effluents, the use of total cholesterol normalized to sediment organic content appears to be more useful.

VI. Options

Although temporal trends by segment indicate that water quality in Sarasota Bay is improving, water quality problems still exist in the tributaries and the segments receiving water from the tributaries. Tributary stations were significantly higher in nutrients, chlorophyll, turbidity, and light attenuation than any other category of station. Sediment collection and analysis, designed to assess recent inputs of contaminants to the benthos, revealed sediments enriched in pollutant metals and containing sufficient chlorinated pesticides, PAH's, or metals to make impacts on organisms likely.

VI.A. Management

In order to control water quality in the tributaries, the quality of water entering the tributaries must be controlled. Water enters the tributaries as rainfall, either directly or indirectly as runoff from the land. Water also may come from point sources such as wastewater discharge or brine effluent. Groundwater also enters the tributaries.

Rainfall entering tributaries directly can carry a wide range of atmospheric pollutants with it. These may include nitrogenous compounds and metals from automobile exhausts. Treating rainfall before it enters the tributaries is not feasible, but controlling levels of atmospheric pollutants is possible.

Runoff carries with it nutrients, oil, grease, solids, and debris into tributaries. All stormwater should be treated before it enters either the tributaries or the Bay. Vegetated buffers along creeks slow the rush of water, allowing particulates to settle. Stormwater detention areas provide similar functions.

Sediment quality in the tributaries is subject to the same inputs as water quality and can benefit from the same management approaches. Contaminated sediments also could be removed or capped.

VI.B. Additional Research Needs

Areas where additional information is needed include:

1) Water and sediment quality studies in the tributaries that extend further upstream than current efforts:

2) The quantity of freshwater entering the system and the timing of those inputs, particularly as it relates to historical inputs;

3) Investigating the possibility that PCB's exist in the sediments of Sarasota Bay.

4) Develop a database from "pristine areas" for coprostanol so an enrichment ratio approach (as used for metals) could be used for coprostanol.

References

Camp, Dresser & McKee, Inc. 1992 .Point/Non-Point Source Pollution Loading Assessment - Phase 1. Draft. Submitted to Sarasota Bay National Estuary Program.

Camp, Dresser & McKee. Inc. 1989. Sarasota Bay Water Quality Evaluation. Submitted to WCIND.

Dixon, L.K., J.M. Sprinkel, N.J. Blake, G.E. Rodrick, and R.H. Pierce. 1992. Bivalved Shellfish Contamination Assessment. Draft. Submitted to Sarasota Bay National Estuary Program. Technical Report No. 244. Mote Marine Laboratory. Sarasota, FL.

Estevez, E.D. 1989. A baywide monitoring program developed for the National Estuary Program Sarasota Bay Project. Mote Marine Laboratory Technical Report No. 149. Sarasota, FL.

Florida Department of Environmental Regulation. 1988. 305(b) Water Quality Assessment Project for the State of Florida. Tallahassee, FL.

Heyl, M.G. and L.K. Dixon. 1986. Water quality status and trends in Sarasota Bay (1966-1986). <u>In:</u> Proceedings, Sarasota Bay Area Scientific Information Symposium.

Hofmann, S. and L.K. Dixon. 1989. Metals Characterization of Sediments at Port Manatee. Final Report submitted to Manatee Port Authority. Technical Report No. 135. Mote Marine Laboratory. Sarasota: FL.

Lewis, B.R., III and E.D. Estevez. 1988. The ecology of Tampa Bay, Florida: An estuarine profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.18), 132 pp.

Long, E. R., D. MacDonald, and C. Cairncross. 1991. Status and Trends in Toxicants and the Potential for Their Biological Effects in Tampa Bay, Florida. National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 58. Seattle, WA.

Long, E. R. and L.G. Morgan. 1990. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 52. Seattle, WA.

Mackenzie, A.S., S.C. Brassell, G. Eglinton, and J.R. Maxwell. 1982. Chemical Fossils: The geological fate of steriods. *Science* 217:491-503.

McCalley, D.V., M. Cooke, G. Nickless. 1980. Coprostanol in Severn Estuary Sediments. *Bull. Environm. Contam. Toxicol.* 25:374-381.

McCalley, D.V., M. Cooke, G. Nickless. 1981. Effect of sewage treatment of Fecal Sterols. *Water Res.* 15:1019-1025.

Pierce, R.H. and R.C. Brown. 1984. Coprostanol Distribution from Sewage Discharge into Sarasota Bay, Florida. *Bull. Environ. Contam. Toxicol.* 32:75-79.

Pierce, R.H., L.K. Dixon, R.C. Brown, and G. Rodrick. 1988. Characterization of Baseline Conditions of the Physical, Chemical, and Microbiological Environments in the St. Johns River Estuary. Final Report submitted to Florida Department of Environmental Regulation. Technical Report No. 128. Mote Marine Laboratory. Sarasota, FL.

Priede-Sedgwick, Inc. 1983. Sarasota Bay Water Quality Study. 172pp.

Pruell, R.J. and J.G. Quinn. 1988. Accumulation of Polycyclic Aromatic Hydrocarbons in crankcase oil. *Environm. Pollution 49:89-97.*

Sarasota High School Marine Science. 1979. Hydrologic and Biological Monitoring of Lower Sarasota Bay, Sarasota, FL.

Schropp, S.J. and H.L. Windom, Editors. 1988. A guide to the interpretation of metal concentrations in estuarine sediments. Florida Department of Environmental Regulation. Tallahassee, FL.

Sheng, P. and S. Peene. 1992. Circulation model for Sarasota Bay. Draft. Submitted to the Sarasota Bay National Estuary Project.

Smith, D.J., G. Eglinton, R.J. Morris, and E.L. Poutanen. 1982. Aspects of the steroid geochemistry of a recent diatomaceous sediment from the Namibian Shelf. *Oceanologica Acta 5:365-378.*

Smith. D.J., G. Eglinton, R.J. Morris, and EA. Poutanen. 1983. Aspects of the steroid geochemistry of an interfacial sediment from the Peruvian upwelling. *Oceanologica Acta* 6:211-219.

Takada, H., T. Onda, M. Harada, and N. Ogura. 1991. Distribution and sources of polycyclic aromatic hydrocarbons (PAHs) in street dust from the Tokyo Metropolitan area. *Sci. Tot. Environm.* 107:45-69.

Taylor, C.D., S.O. Smith, and R.B. Gagosian. 1981. Use of microbial enrichments for the study of the anaerobic degradation of cholesterol. *Geochim. Cosmochim. Acta* 45:2161-2168.

Toste, A.P. 1976. The sterol molecule: It‘s analysis and utility as a chemotaxonomic marker and a fine geochemical probe into the Earth’s past. Ph.D. Thesis, Univ. of California, Berkeley.

Venkatesan, M.I. and C.A. Santiago. 1989. Sterols in sediments: novel tracers to examine habitats of pinnipeds, penguins and humans. *Mar. Biol.* 102:431-437.

Walker, R.W., C.K. Wun, and W. Litsky. 1982. Coprostanol as an indicator of fecal pollution. *CRC Critical Reviews in Environment Control* 10:91-112.