BIOLOGICAL AND CHEMICAL STUDIES ON THE IMPACT OF STORMWATER RUNOFF UPON THE BIOLOGICAL COMMUNITY OF THE HILLSBOROUGH RIVER, TAMPA, FLORIDA

Final Research Report

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

The present research was initiated as part of the City of Tampa Nationwide Urban Runoff Program (NURP) studies and was intended to assess the impact of urban runoff upon endemic biological communities. Principal activities included laboratory bioassay experiments using both plants and animals exposed to stormwater runoff and sediments and limited field studies on the receiving water body. Biological field studies included benthic infaunal samples taken at four sites during wet and dry seasons; phytoplankton and zooplankton samples collected at four sites during wet and dry seasons; tidal stage sampling of the plankton community at one station; Hester-Dendy multiple plate epifaunal samples; and a survey of shoreline vegetation along the lower river. Laboratory bioassay experiments included algal assays employing both natural and cultured species and animal bioassays using fish and invertebrate species. All bioassays were conducted using urban runoff collected from selected drainage basins prior to entering the Hillsborough River. Chemical characterization of stormwater runoff, river sediments and suspended particulate matter was carried out with emphasis placed upon identification of potentially toxic organic and inorganic forms. Petroleum hydrocarbon analyses were carried out on stormwater, sediments and suspended particulates in order to trace the origin and movement of stormwater associated pollutants. To the best of our knowledge, this study represents a unique approach to the biological and chemical characterization of the relationship between stormwater runoff and pollution problems in an urban receiving water body.

Benthic Studies

The mean densities of all benthic infaunal invertebrates collected in the quantitative samples indicated that during the dry season, all stations except the one furthest upriver were dominated by estuarine species. Moving upstream, freshwater organisms, especially insect larvae, appeared in increasing abundance. During the wet season, the total number of species and density of individuals generally decreased at each station with the most upriver station least affected by the dry to wet season transition. The largest number of species collected at any station was at

the river mouth during the dry season. The stations closest to the river mouth contained several pollution indicator species suggesting organically enriched and/or polluted sediments.

Hester-Dendy multiple plate samplers revealed a similar trend as did benthic samples. A higher proportion of aquatic insects and crustaceans were collected on the plates than were present in benthic infaunal samples.

The overall results present a rather typical picture of what would be expected in a system which seasonally oscillates between an estuarine salinity gradient and an essentially freshwater habitat. When under estuarine conditions, more individuals of more species are present than when under freshwater conditions. The system must constantly be readjusting as salinities change. In general, benthic estuarine species are present further upriver than would be expected based upon water column salinities alone.

Animal Bioassays

Laboratory bioassay experiments were conducted using three primary and two secondary standard test species. All bioassay animals were raised in the laboratory under controlled conditions and were ecologically representative of endemic species in the Hillsborough River. The three primary species included a polychaete worm, *Neanthes arenaceodentata*, a mysid, *Mysidopsis bahia*, and a fish *Cyprinodon variegatus*. The secondary species were tested with wet season runoff only and included the stone crab, *Menippe mercenaria* and a copepod, *Pseudocyclops* sp.

Laboratory toxicity tests included three separate wet season runoff samples from two different drainage basins, one dry season runoff sample, one series of sediment bioassays involving composite sediment collected from three sites in the river, and a series of suspended particulate phase bioassays prepared from the above sediment samples. A total of 78 separate animal bioassays were completed during the course of this project.

Wet season stormwater runoff was found to be generally non-toxic to test species in both short term and long term experiments. The only significant toxicity for wet season runoff occurred with *Mysidopsis* after 7 days exposure to 100% stormwater at low salinity.

Dry season stormwater runoff was significantly toxic for two out of four species tested in short term experiments at low salinities. One of two species tested in long term bioassays displayed significant adverse effects at low salinities. In general, stormwater runoff was less toxic than expected based upon chemical composition alone.

Bioassays with sediments from the Hillsborough River produced significant adverse effects in two of three species tested. Suspended particulate phase tests revealed significant toxicity in one of three species tested. As with stormwater, sediments and suspended particulate matter were less toxic than expected based upon chemical composition alone.

General conclusions which can be drawn from these experiments include: 1) wet season runoff contains relatively low levels of toxic chemicals and does not appear to be toxic to estuarine animals; 2) dry season runoff contains significantly higher concentrations of heavy metals and hydrocarbons and can be acutely toxic to estuarine animals; 3) stormwater displays greater toxicity under low salinity conditions; 4) Hillsborough River sediments contain high concentrations of heavy metals and hydrocarbons and can be acutely toxic to estuarine animals.

Algal Assays

Laboratory bioassays were conducted to determine the effect of stormwater runoff upon field collected and cultured phytoplankton. The stormwater runoff samples tested were from the same collection as the wet season sample used in animal bioassays. In all cases, addition of wet season stormwater stimulated phytoplankton growth relative to control treatments. This suggests that wet season stormwater runoff may serve as a source of nutrients and stimulate phytoplankton growth in the Hillsborough River. Dry season stormwater was not tested in algal assays due to unavailability of runoff samples.

Plankton Studies

Zooplankton and phytoplankton samples were collected at three week intervals from May 7 through August 16, 1982, spanning the dry season to wet season transition for that year. Four stations on the Hillsborough River were sampled on each collection trip. The furthest downstream station was sampled intensively during a low tide to high tide transition.

Zooplankton and phytoplankton densities were higher at all stations during the dry season than during the wet season. Marine organisms were predominant at all but the most upstream station during the dry season and decreased in relative abundance during the wet season. The most downstream station maintained a dominance of marine zooplankton and phytoplankton even during the wet season, indicating that Hillsborough Bay has a strong effect upon the plankton community throughout the year. The Hillsborough River plankton community appears to be controlled largely by physical factors such as tidal forces and river flow rates.

Lower Hillsborough River Shoreline Inventory

The Hillsborough River, from the dam to the bay, has been moderately to severely altered by urbanization. Calculations reveal that 54% of the shorelines have been hardened. Of the hardened portions, about 47% are composed of bulkhead, while about 8% are riprap. Approximately 13% of the river's shores are filled but unhardened, and 34% are more or less native (a total of 102% for these figures is due to their nonexclusive nature). Native vegetation along the river shows a general transition from salt-tolerant species downriver to salt-intolerant forms upriver, although this pattern has been modified due to historical and natural causes.

Four main recommendations can be made based upon the information collected during this survey. These include:

1) The City of Tampa should concentrate on the river section between Sligh Avenue and North Boulevard as the preferred area for immediate shoreline improvements;

2) A three phase plan for shoreline improvements should be developed for the target segment including: (a) creation or restoration of vegetated shorelines on public lands; (b) removal of exotic plant species from natural and filled shorelines; and (c) enhancement of riprap shorelines with native vegetation;

3) The City of Tampa should involve citizens and shoreline owners in waterfront improvement through development of homeowner's guides and incentive programs; and

4) The City of Tampa should seek a formal role in the permit review and approval process affecting dredging, filling or shoreline construction in the Hillsborough River, beyond that currently exercised through planning, review or code enforcement programs.

Hydrocarbon Studies

Sediment samples for petroleum hydrocarbon analysis were collected at 12 stations spanning the distance from Hillsborough Bay up the river and into the Hillsborough Reservoir. Seven of these stations were also sampled for suspended particulate matter in the water column. Analyses revealed that all sediments sampled contained high levels of hydrocarbons. Petrogenic hydrocarbons increased in relative concentration with increasing distance downriver from the dam and were highest in the vicinity of the downtown I275 bridge. The petrogenic hydrocarbons identified in river sediments were very similar to those identified in stormwater runoff samples from the Artic Street basin and strongly resembled weathered crankcase oil. Stormwater runoff appears to be the principal source of petroleum hydrocarbons found in river sediments.

Wet season and dry season stormwater runoff samples were analyzed for petroleum hydrocarbons and revealed that dry season composite samples were similar to wet season composite samples in concentrations but that dry season "first flush" stormwater was extremely high in petroleum hydrocarbons.

Analysis of suspended particulate matter from the bay, river and reservoir indicated that little hydrocarbon is redistributed due to tidal forces in the lower river during periods of low river flow.

Petroleum hydrocarbons provide a good tracer material for stormwater associated particulate matter, and these results suggest that sediment and pollutant accumulation in the river is directly related to stormwater runoff.

General Conclusions and Recommendations

Stormwater runoff entering the lower Hillsborough River does not pose an acute toxicological problem to most endemic biota. Rapid dilution rates of stormwater and chemical complexion of pollutants into insoluble forms in the river water reduce the direct toxicity of runoff. Based upon chemical composition alone, the acute toxic potential of stormwater runoff would be over estimated, since much of the potentially toxic material is bound in non-bioavailable form. Most state and federal water quality standards are based upon chemical composition of receiving waters and thus urban stormwater runoff may contribute significantly to water quality violations.

The most significant contribution that stormwater runoff makes to chemical and biological pollution problems in the river comes from more or less continuous input of particulate matter containing high levels of potentially toxic chemicals such as heavy metals and petroleum hydrocarbons. This particulate matter accumulates in river sediments and may act as a sink contributing to long term water quality problems. Once deposited in sediments, factors such as lowered salinity, lowered dissolved oxygen, low pH, microbial activity and bioturbation may cause release of toxic chemicals into river water. This deposited particulate matter is also likely responsible for lowered dissolved oxygen levels periodically observed in bottom water.

The City of Tampa should explore appropriate methods for limiting the input to the river of particulate matter from stormwater runoff as a long term goal for improving water quality. Removal of contaminated sediments from the river may provide short term improvements in water quality. Specific recommendations include: 1) removal of existing contaminated sediments from the river; and 2) implementation of the stormwater management plan (Metcalf and Eddy, 1983a) and the recommended improvements in the Hillsborough River shoreline to provide a long-term system for limiting pollutant input into the river.

Future research in the Hillsborough River should concentrate on physical and chemical dynamics of sediment input and accumulation. The depth and chemical composition of existing sediments along the river need to be determined before any mitigative action is taken.

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Urban stormwater runoff has been identified as a significant source of pollution in numerous receiving water bodies throughout the country (Burke, 1971; Vitale and Sprey, 1974; Laws, 1981). The sources and concentrations of pollutants carried by urban stormwater runoff (hereinafter referred to as urban runoff) vary tremendously with the characteristics of the drainage basin. In most cases, however, urban runoff can be expected to contain measurable quantities of suspended particulate material, nutrients, bacteria, heavy metals, pesticides and hydrocarbons (Christensen et al., 1978; MacKenzie and Hunter, 1979; Laws, 1981; Miller and Mattraw, 1982; Browne et al., 1982; EPA, 1982). These constituents can have a severe effect upon water quality in receiving waters (Metcalf and Eddy, 1983) and may affect biological communities through direct toxicity of heavy metals, pesticides and hydrocarbons or indirectly through reduced light penetration, reduced dissolved oxygen and excessive phytoplankton growth.

Numerous studies throughout the U.S. have documented the changes in water quality associated with urban runoff but relatively few studies have considered the effects of these water quality changes upon the biological communities in receiving water bodies. The biological studies that have been undertaken were mostly ecological surveys and have attempted to relate community parameters such as species diversity and species richness to the effects of urbanization and urban runoff. Pratt and Coler (1979) studied changes in benthic macroinvertebrate communities along portions of the Green River, Massachusetts representing relatively nonurbanized and urbanized sections. They documented changes in benthic communities which they attributed to increasing urban runoff. Pitt and Bozeman (1980) analyzed water quality, sediment quality and biological communities along urbanized and nonurbanized sections of Coyote Creek, California. Their results indicate that pollution loads increase with increasing urbanization and that the number of species and community composition change with increasing urbanization. These authors also demonstrated that tissue loads of lead and zinc increased in certain organisms along with sediment concentration in urbanized portions of the river. Tomlinson et al. (1980)

studied the effects of storm drains and combined sewer outfalls on marine and freshwater systems and reported significant disruption of biological communities near outfalls relative to unaffected areas.

A number of research projects have approached the biological effects of runoff through bioassays using natural or cultured phytoplankton (algal assays). Yousef et al. (1980) analyzed runoff from Orlando, Florida flowing into Lake Eola and determined its effect upon natural and cultured phytoplankton in laboratory experiments. Their results indicated, among other things, that high stormwater concentrations inhibited algal productivity while diluted runoff significantly increased productivity.

The present biological studies were initiated as part of the City of Tampa Nationwide Urban Runoff Program (NURP) and were intended to assess the impact of urban runoff on endemic biological communities through laboratory bioassay experiments combined with limited field studies. Biological field studies included benthic infaunal samples taken at four sites during wet and dry seasons; phytoplankton and zooplankton samples collected at four sites during wet and dry seasons; tidal stage sampling of the plankton community at one station; Hester-Dendy multiple plate epifaunal samples; and a survey of shoreline vegetation along the lower river. Laboratory bioassay experiments included algal assays employing both natural and cultured species and animal bioassays using fish and invertebrate species. All bioassays were conducted using urban runoff collected from selected drainage basins prior to entering the Hillsborough River.

The biological studies were supplemented with organic and inorganic chemical analyses of runoff, sediments and suspended particulate matter. A detailed analysis of petroleum hydrocarbons in these fractions was undertaken in order to determine the origin of sediment associated pollutants in the river.

The present research has added a significant component to our understanding of the biota within the Hillsborough River and how it may be affected by short term and long term input of stormwater runoff and associated pollutants. Some of the remaining problems that need attention include analysis of the synergistic effects of combined pollutants, as are found in runoff and sediments, upon receiving water organisms; the effects of pulse-loading of pollutants upon endemic organisms; the bioavailability of sediment associated pollutants; the sediment input and export budget of the river; the mobility of pollutants in sediments under varying physical and chemical conditions; and the food chain dynamics associated with urban runoff pollutants.

Artic Street Drainage Basin

The Artic Street watershed covers an area of 0.34 mi^2 and is located in Sulphur Springs, 5.5 miles north from downtown Tampa (Figures 1 & 3). The watershed is elongated, about 1.4 miles in length and 0.5 mile wide, draining southward through an underground stormsewer system with grated street inlets. The drain is tributary to the Hillsborough River. Land development is about evenly divided between older single unit residences and commercial businesses with several large shopping centers making up most of the commercial development. Florida Avenue, a heavily traveled four-lane street, runs the length of the watershed and is highly developed commercially, including fast-food restaurants and car dealerships. USGS streamflow, rainfall and water quality data are collected at a station installed in a 72 inch diameter stormsewer under Yukon Street.

Cass Street Drainage Basin

The Cass Street watershed covers an area of 0.02 mi^2 and is located within downtown Tampa (Figures 2 & 3). The drainage basin is elongated and drains westward through an underground stormsewer system with grated street inlets. Land use is commercial, with a large percentage of paved streets contributing to its 100% impervious area. USGS measurements are taken at the stormsewer outlet under the Cass Street-Hillsborough River Bridge.

Stormwater Runoff Collection

Four discrete samples of stormwater runoff were collected by City of Tampa personnel for use in bioassay experiments and chemical analyses. Three of these stormwater samples were collected from the Artic Street watershed and were obtained on July 16 and October 14, 1982, and May 4, 1983. The July 16 storm event produced a total of 0.44 inches of rainfall (averaged between two rain gauges) and lasted for one hour, 18 minutes. Similar rainfall events had occurred on July 14 and 15 with a larger event recorded on July 13 at one of the rainfall collection sites (0.75 inches at the northern boundary of the watershed). The October 14 storm dropped 0.55 inches of rain and lasted for two hours, 14 minutes. Previous rain events included a 1.70 inch storm on October 1 and three storms (0.05; 0.08; and 0.12 inches) between October 2 and 14. The stormwater samples collected from the July 16 and October 14, 1982 events were composed of time-composite subsamples obtained at two minute intervals throughout the event and then pooled.

The May 4, 1983 storm event resulted in 0.12 inches of rainfall (measured at the northern boundary of the watershed) and lasted for one hour. This sample was collected as a flow-composite with subsamples obtained every three minutes throughout the event. Each subsample was pooled in proportion to flow rate measured at the time of sample collection. One gallon of "first flush" stormwater runoff was collected and retained for chemical analysis.

One stormwater sample, collected on January 21, 1983, came from the Cass Street watershed. This event produced 0.50 inches of rain and lasted for one hour, 50 minutes. A storm recorded for the previous day produced 0.95 inches of rain. The Cass Street stormwater represented a time-composite sample.

All stormwater samples were mixed thoroughly in the field and placed into 5 gallon polyethylene containers for transport. These containers were stored in the laboratory at $4^{o}C$. Based upon the chemical analyses and relative toxicities of the various stormwater samples, the Artic Street stormwater collected on July 16 and October 14 and the Cass Street stormwater, are considered to represent "wet season runoff". The Artic Street sample collected on May 4, 1983 is considered to represent "dry season runoff".

<u>Sediment Samples Used in Bioassays</u>

Sediment samples for use in whole sediment and suspended particulate phase bioassays were collected from the Hillsborough River on May 16, 1983. These samples were collected with a petite Ponar sampler and placed into acid washed polyethylene containers on ice. Care was taken to avoid any sediment that had come into direct contact with the sampling device.

Sediment samples were collected from three sites on the river: 1) upstream of the I275 Bridge (downtown) near the west bank; 2) just downstream of the Buffalo Avenue bridge near the west bank; and 3) downstream of the Sligh Avenue bridge. These samples were kept on ice during transport and stored at 4°C in the laboratory.

Lower Hillsborough River Sampling Sites

The City of Tampa and the lower Hillsborough River are shown in Figure 3. The main sampling stations for the biological studies on the lower river are presented in Figure 4. These four stations were used in the benthic studies, zooplankton studies and phytoplankton studies, and are described further with regard to exact location and sampling methodologies under the appropriate section of this report.

Sediment and water column samples collected for petroleum hydrocarbon analysis were obtained from 12 stations identified in Figure 5. These stations were sampled on December 1, 1983. Procedures for sample collection, processing and analysis are presented in the appropriate section below.

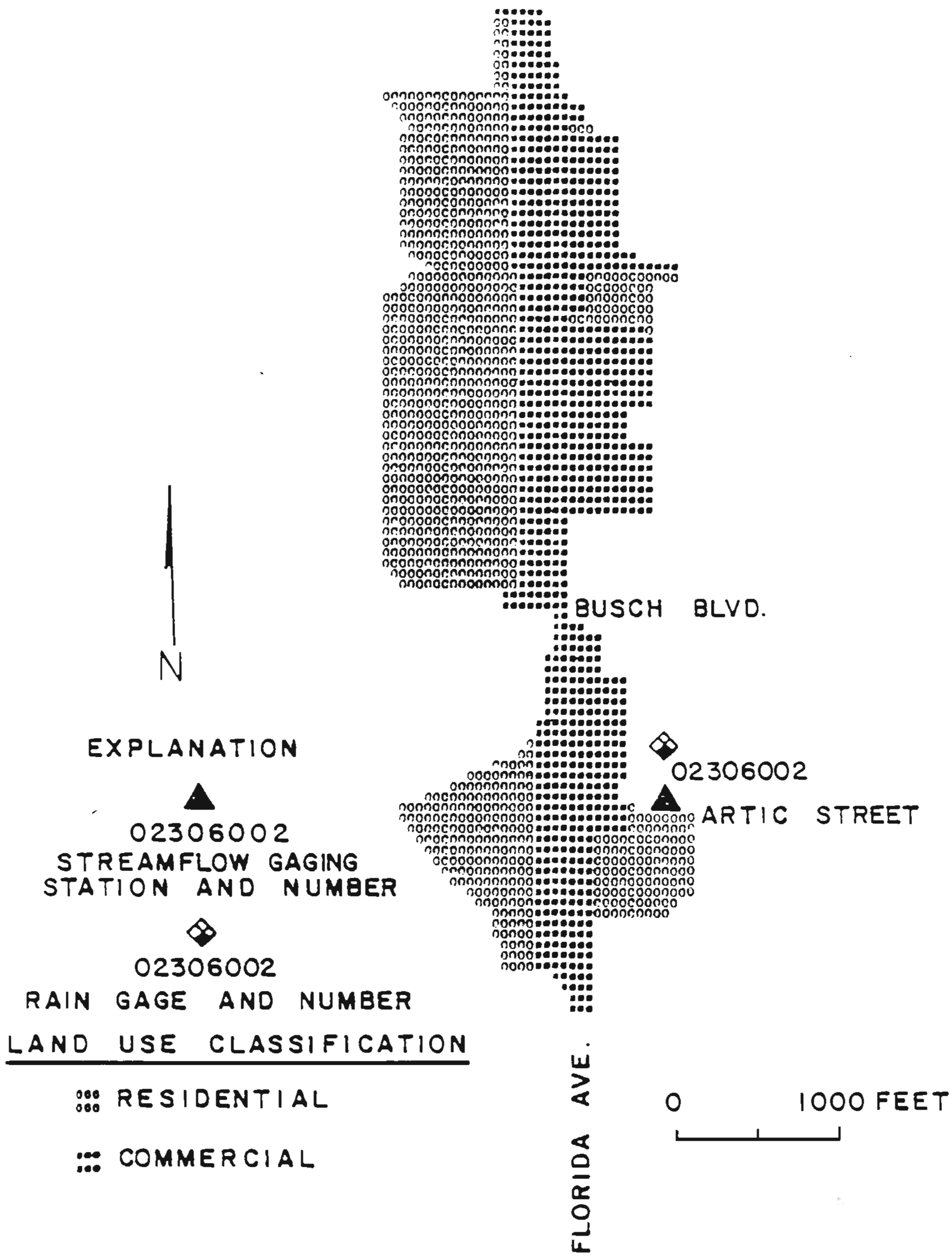


Figure 1. Land use in Artic Street Storm Drain watershed.

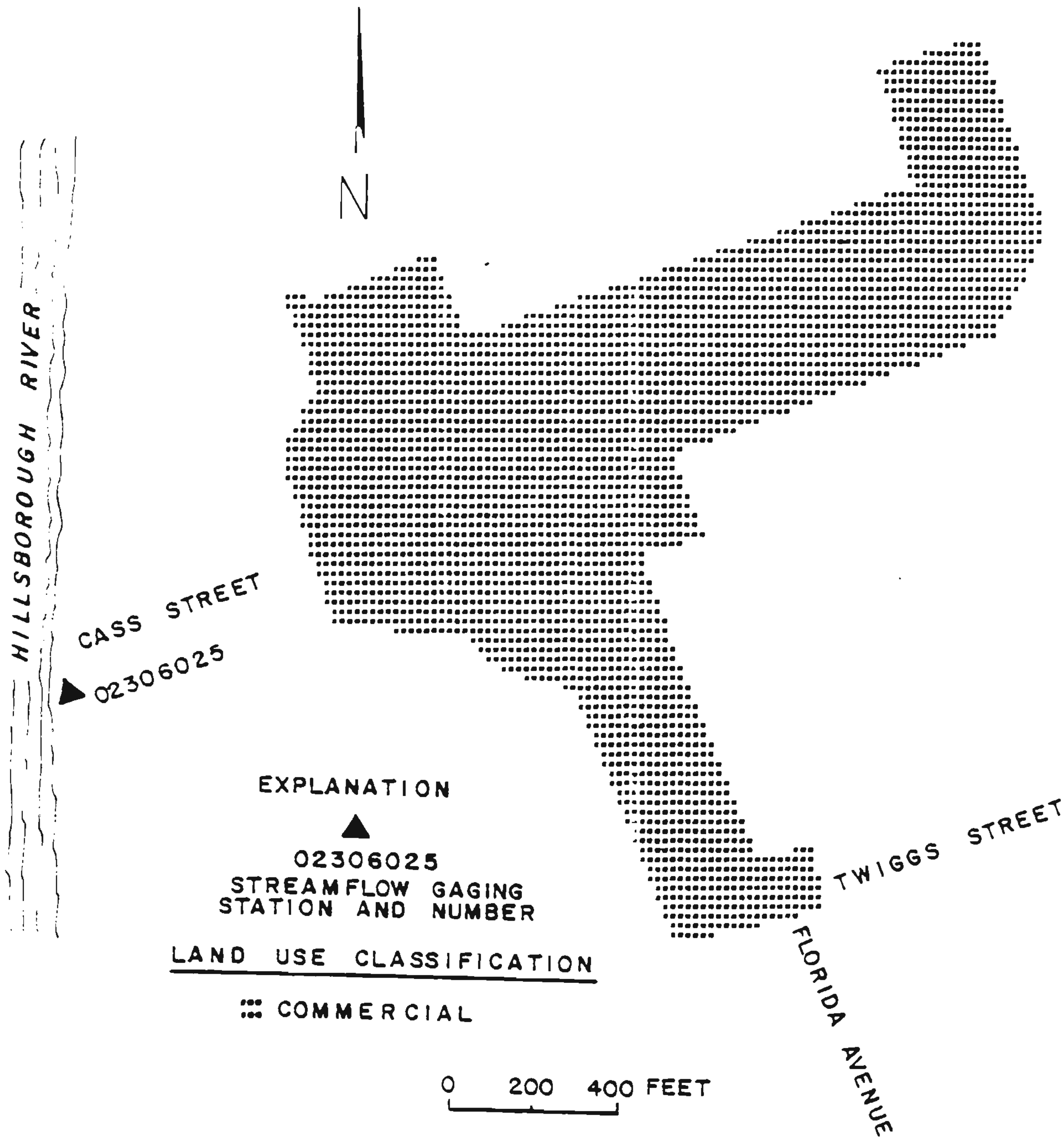


Figure 2. Land use in Cass Street Storm Drain watershed.

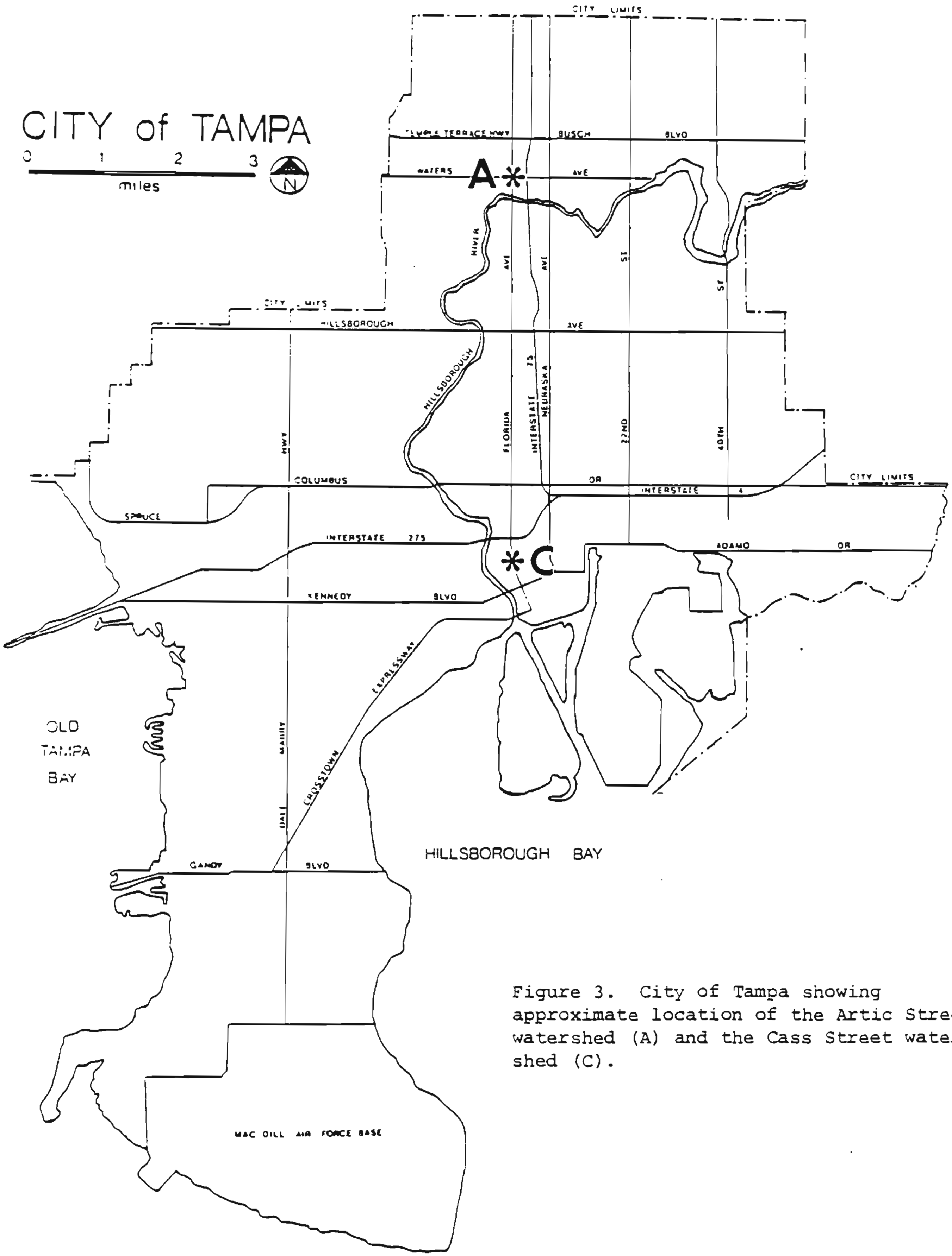


Figure 3. City of Tampa showing approximate location of the Artic Street watershed (A) and the Cass Street watershed (C).

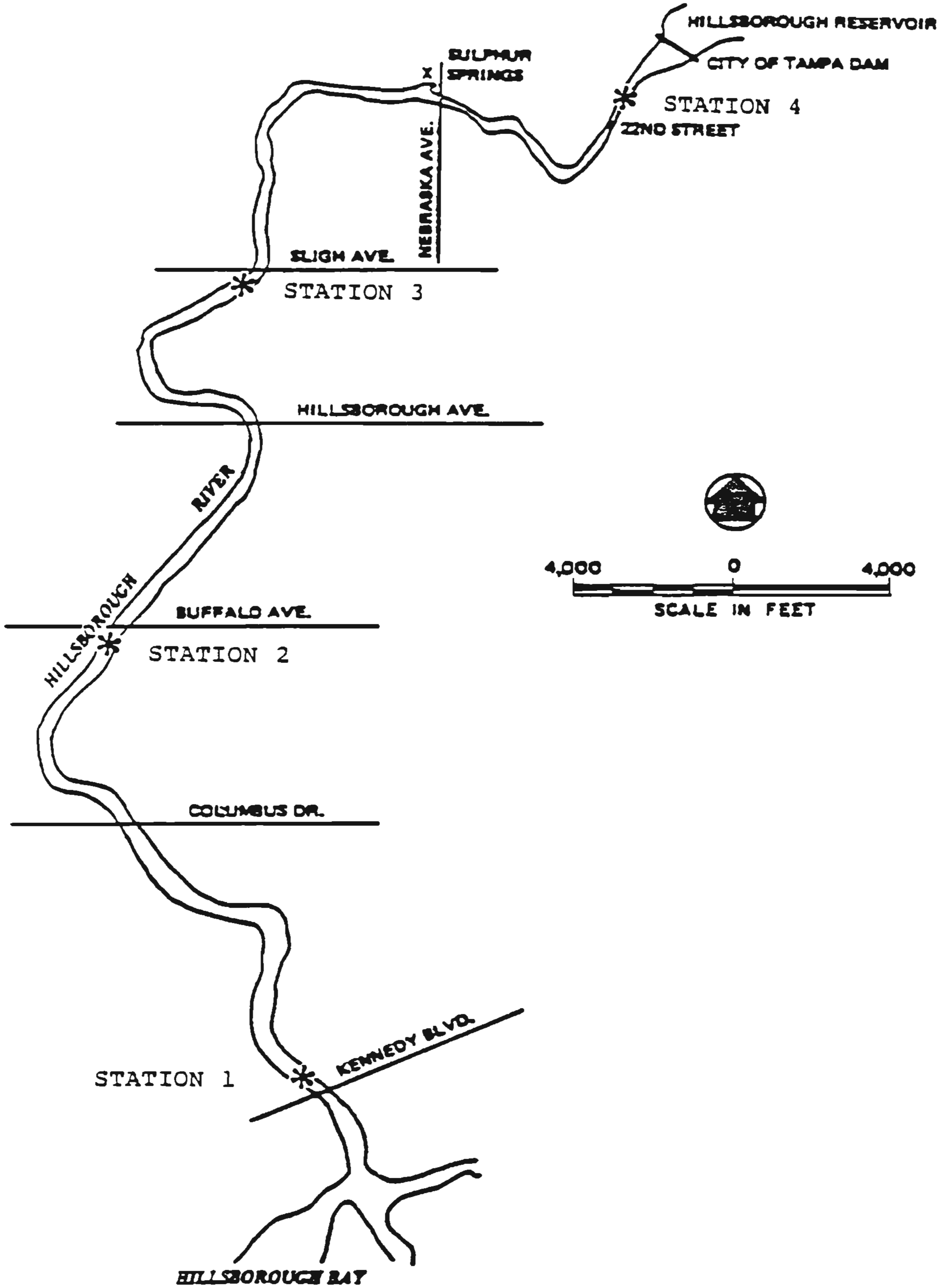


Figure 4. Plan of lower Hillsborough River showing sampling locations for biological studies.

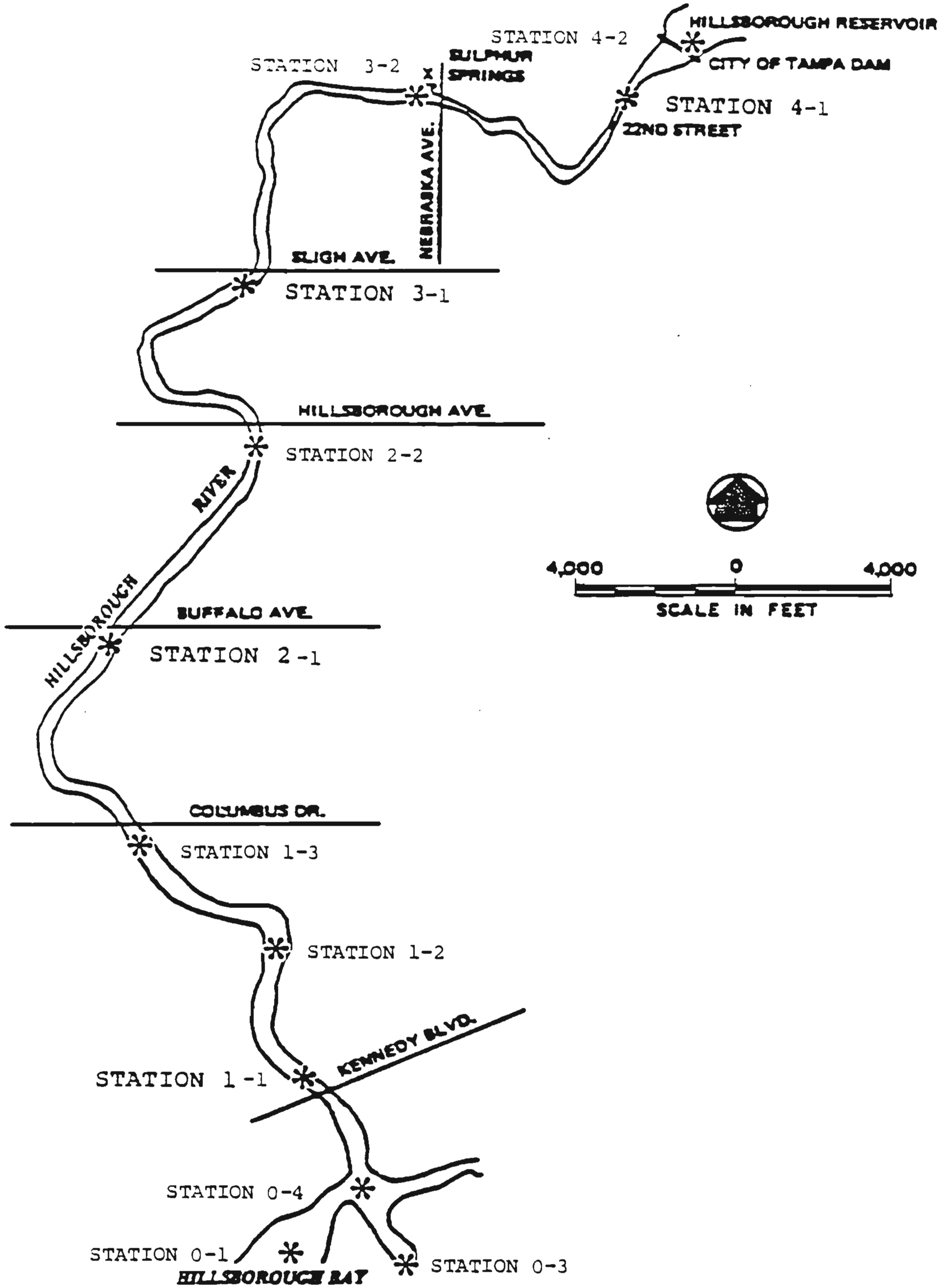


Figure 5. Location of sampling stations for hydrocarbon studies. All stations sampled for sediments; stations 1-1,1-3,3-1,0-1,0-2,4-2,4-1 sampled also for suspended particulate matter.

II. BENTHIC INFAUNAL AND EPIFAUNAL STUDIES

A. Introduction

The purpose of this investigation was to document quantitatively and qualitatively the distribution of benthic invertebrates along the Hillsborough River and any seasonal changes accompanying the shift from dry to wet seasons. These data were to serve as the first quantitative sampling of this part of the river system and as a guide in selection of organisms for subsequent or simultaneous bioassay studies on toxicity of stormwater runoff.

B. Methods

Quantitative benthic samples were taken at four sites along the Hillsborough River (Table 1) during the dry season (May 5, 1982) and the wet season (August 6, 1982). At each site, two cross-river transects perpendicular to the flow were established approximately 33 meters apart. Three samples were obtained along each transect, one at mid river and one approximately 5 meters from each shoreline. Six replicate samples were taken at each site with a 15.25 x 15.25 cm Ekman grab sampler. The contained material was washed through a 0.234 mm mesh screen and all retained material was narcotized with 0.15% propylene phenoxytol, stained with rose bengal and preserved in 10% formalin. Upon return to the laboratory, all animals were sorted from the samples using a dissecting microscope, identified to the lowest possible taxon (usually species) and counted.

During field sampling, the sediments obtained in the Ekman grabs were visually described. Surface water temperature was measured with a mercury bulb thermometer and surface salinity was measured with a hand-held refractometer.

Additionally, up to 4 Hester-Dendy multiple plate samplers were set out at each site (see Table 5). During the dry season, plate samplers were deployed on May 5 and collected on May 12, 1982, an *in situ* period of one week. During the wet season, samplers were deployed on August 6 and collected on August 20, an *in situ* period of two weeks. Upon collection, samplers were returned to the laboratory, dismantled, and all organisms washed from the plates and treated as above. Species were identified and relative abundance recorded.

Species saturation curves were constructed to document that the number of quantitative samples taken was adequate. Due to the late starting date of the project a set of preliminary samples to determine sample size adequacy was not taken. Instead, species saturation curves were calculated for both wet and dry season samples.

Data were summarized as: total number of species present; total number of individuals present (mean and S.D. of 6 samples/site); number of "freshwater" species; number of "estuarine" species; H' (Shannon-Weaver diversity index); and E (equitability = H'/H_{max}). The Shannon-Weaver Index represents the number of species collected relative to the total number of individual organisms collected, while the equitability index represents the distribution of individuals among the species present (see Krebs, 1972, pp. 500-536, for a discussion of diversity). These indices are most useful in the present study for comparisons of community composition at individual stations between wet and dry seasons.

C. Results

Station locations, temperature and salinity, and sediment descriptions are presented in Table 1 and Table 2. Sediments varied both from site to site and within sites with season. During the dry season, there was a gradual salinity gradient from Hillsborough Bay salinities (22 o/oo) at Station 1 to almost freshwater (3.5 o/oo) at Station 4. During the wet season, the river water was essentially freshwater.

Species saturation curves constructed for each site and each sampling period are presented in Figures 6 & 7. Since all curves reached an asymptote after 2 or 3 samples, six samples were more than adequate to describe the fauna.

The mean densities (and standard deviations) for all benthic invertebrates collected in the quantitative samples are presented in Table 3 and summarized in Table 4. During the dry season, the fauna at all but Station 4 was dominated by estuarine species. Among the dominant estuarine species represented were the polychaete, Laeonereis culveri, and the amphipod Grandidierella bonnieroides. Moving upstream, freshwater organisms, especially insect larvae, as well as the bivalve Corbicula manilensis, and the amphipods Gammarus palustris and Hyalella azteca, appeared in increasing abundance.

During the wet season, the total number of species decreased at all sites except Station 4. The density of individuals followed a similar pattern, with marked depression in the number of individuals accompanying the wet season shift in salinity and species (Note: the densities, H' and E values at Station 4 were roughly equal during dry and wet seasons).

The largest number of species collected (36) was at the mouth of the river (Station 1) during the dry season, indicating the importance of the influence of Hillsborough Bay and estuarine salinities. Transport of marine invertebrate larvae from the bay into the river during low river flow periods is likely responsible for the high occurrence of marine species at Station 1. The largest number of individuals collected was at Station 2 site during the dry season. The site was dominated by Laeonereis culveri and Grandidierella bonnieroides, both estuarine species commonly found in organically enriched sediments.

Species collected in Hester-Dendy multiple plate samplers tracked those collected in the benthic samples (Table 5). In addition, several small "fouling" species were added to the total faunal list. Many fewer polychaetes and more insects and crustaceans were collected by the Hester-Dendy plates.

The overall results present a rather typical picture of what would be expected in a system which seasonally oscillates between an estuarine salinity gradient and an essentially freshwater habitat. When under estuarine conditions, more individuals of more species are present than when under freshwater conditions. The system must constantly be readjusting as salinities change. To better understand the dynamics of the river biota, the changes in salinity, species density and species composition need to be considered with regard to wet season and dry season values (Table 4). Station 1 appears to be most affected by the dry season to wet season transition with notable reductions occurring in salinity, total number of species, total density, number of marine species present, species diversity and equitability. Station 4 displayed the least change in these parameters following the dry to wet season transition. The ability of sediments to buffer water column salinity changes and to maintain higher interstitial salinities probably account for the presence of estuarine species further upriver than might be expected based on water column salinities alone. In this study, only surface salinities were measured. A saline wedge (Metcalf and Eddy, 1983b) underlying the surface freshwater and moving upriver with rising tides would also help buffer benthic organisms against freshwater flow.

Table 1: Site and sample locations along the Hillsborough River at which quantitative benthic invertebrate samples were collected. At each site, two transects approximately 33 meters apart were sampled. Samples were taken approximately 5 meters from each shore and at mid-river. Six 15.25 X 15.25 cm Ekman grabs were obtained at each sampling site.

DESIGNATION — **DESCRIPTION**

Station 1 — Opposite the University of Tampa boat dock

DRY SEASON — Temp. = 24°C — Salinity = 22 ‰

Upstream transect
- East shore: depth 1.3m; sediment = sand, detritus
- Mid-river: depth = 3.6m; sediment = sand, shell, detritus
- West shore: depth 1.8m; sediment = sand, shell, detritus

Downstream transect
- East shore: depth = 3.0; sediment = sand,shell, detritus
- Mid-river: depth 3.8 m; sediment = sand,shell, detritus
- West shore: depth 1.7 m; sediment = detritus

WET SEASON — Temp. = 29°C — Salinity = 2 ‰

Upstream transect
- East shore: depth 2.5 m; sediment = sand, shell, detritus
- Mid-river: depth 4.8 m; sediment = sand, shell, detritus
- West shore: depth 1.2 m; sediment = sand, shell, detritus

Downstream transect
- East shore: depth 3.0 m; sediment = detritus, sand, shell
- Mid-river: depth 4.0 m; sediment = shell, sand, detritus
- West shore: depth 1.3 m; sediment = detritus

Station 2 — Just north of River Club Apartments, Buffalo Avenue.

DRY SEASON — Temp. = 24°C — Salinity = 11 ‰

Upstream transect
- East shore: depth 2.0 m; sediment = detritus, little sand
- Mid-river: depth 3.8 m; sediment = detritus, shell
- West shore: depth 1.2 m; sediment = detritus, sand

Downstream transect
- East shore: depth 1.9 m; sediment = shell, detritus, sand
- Mid-river: depth 3.5 m; sediement = shell, detritus, sand
- West shore: depth 0.3 m; sediment = clean sand

WET SEASON — Temp. = 28°C — Salinity = 1 ‰

Upstream transect
- East shore: depth 2.0 m; sediment = detritus
- Mid-river: depth 4.2 m; sediment = detritus, shell
- West shore: depth 1.2 m; sediment = sand, detritus

Downstream transect
- East shore: depth 2.0 m; sediment = detritus, shell, sand
- Mid-river: depth 4.0 m; sediment = detritus, sand
- West shore: depth 1.0 m; sediment = detritus, sand

Station 3 — Either side of the Sligh Ave. bridge

DRY SEASON — Temp. = 23°C — Salinity = 10 ‰

Upstream transect
- East shore: depth 2.5 m; sediment = detritus, sand
- Mid-river: depth 3.0 m; sediment = shell, rock
- West shore: depth 2.4 m; sediment = shell, detritus

Downstream transect
- East shore: depth 1.0 m; sediment = shell, sand, pebbles
- Mid-river: depth 3.3 m; sediment = rock bottom
- West shore: depth 1.1 m; sediment = shell, detritus, pebbles

WET SEASON — Temp. 28°C — Salinity = 2 ‰

Upstream transect
- East shore: depth 2.2 m; sediment = detritus, shell
- Mid-river: depth 4.0 m; sediment = detritus, shell, sand
- West shore: depth 2.5 m; sediment = sand, detritus

Downstream transect
- East shore: depth 1.7 m; sediment = detritus, shell
- Mid-river: depth 4.0 m; sediment = detritus, sand
- West shore: depth 1.3 m; sediment = detritus, sand, shell

Station 4 — Between 22nd street bridge and city dam

DRY SEASON — Temp. = 22°C — Salinity = 2.5 ‰

Upstream transect
- East shore: depth 2.1 m; sediment = clay, shell, detritus
- Mid-river: depth 3.2 m; sediment = sand, pebbles
- West shore: depth 1.0 m; sediment = detritus, shell

Downstream transect
- East shore: depth 1.3 m; sediment = moss
- Mid-river: depth 0.8 m; sediment = moss
- West shore: depth 1.0 m; sediment = rocks, plants

WET SEASON — Temp. 28°C — Salinity = 1 ‰

Upstream transect
- East shore: depth 2.5 m; sediment = rock, pebbles
- Mid-river: depth 1.0 m; sediment = plants, shell
- West shore: depth 1.0 m; sediment = detritus, sand

Downstream transect
- East shore: depth 2.5 m; sediment = shell, detritus
- Mid-river: depth 2.0 m; sediment = rock, sand, pebbles
- West shore: depth .75 m; sediment = rock, sand, detritus

Table 2: Temperature (^{o}C) and Salinity ($^{o}/_{oo}$) at each sampling location, both wet and dry season.

STATION	DRY SEASON Temp	DRY SEASON Salinity	WET SEASON Temp	WET SEASON Salinity
1	24	22	29	2
2	24	14	28	1
3	23	10	28	2
4	22	3.5	28	1

TABLE 3: Mean densities of benthic invertebrates per 15.25 X 15.25 cm Eckman grab quantitative samples at four stations along the Hillsborough River (number of samples/site = 6; number in parentheses = standard deviation).

Freshwater species are indicated by a *; estuarine/marine species by at +.

Species	Station 1		Station 2		Station 3		Station 4	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
POLYCHAETA								
Polydora ligni+		.33(.82)	.50(.84)		.33(.82)			
Polydora juveniles+	2.0(3.2)							
Pectinaria gouldii+	1.0(.67)							
Nereis succinea+	3.7(2.3)		.33(.81)					
near Nicon sp.+		.50(1.2)	13.2(23.7)	.17(.41)	3.5(5.0)			
Laeonereis culveri+			108.8(239.2)	1.8(1.7)	5.7(9.8)	6.0(5.9)	9.8(19.9)	.17(.41)
Mediomastus californiensis+	23.8(26.6)							
Capitella capitata+		1.0(2.0)		7.3(15.2)				
Heteromastus filiformis+		1.6(4.1)						
Phyllodoce arenae+	.83(.15)							
Eteone heteropoda+			.17(.41)					
Glycinde sp.+	1.7(1.5)							
Glycera americana+	.33(.51)							
Mellina maculata+	1.8(2.1)							
Parahesione luteolata+	.33(.82)							
Scoloplos rubra+	.33(.52)							
Spiochaetopterus costatus+	33(.81)							
Nereis acuminata+			.33(.81)					
Nereid juvenille+				34.0(59.6)				
Syllid sp.+	.50(1.2)							
Megalomma bioculatum+	.67(1.2)							
Branchiomma nigromaculatum+	.17(.41)							
Terebella sp.+	.17(.41)							
Isolda puchella+			.17(.41)					
MOLLUSCA								
Amygdalum papyra+	.67(1.2)							
Mulinia lateralis+	.17(.40)							
Mytilopsis leucophaeta*		53.5(74.0	.67(1.6)	3.2(4.6)	1.5(1.8)	11.2(13.6)	.83(1.3)	.50(112)
Lyogyrus sp.*		.83(1.2)	18.2(39.4)		.33(.52)	4.0(4.6)		5.8(9.3)
Polymesoda carolinae?*				.17(.41)				

Corbicula manilensis*	.17(.40)				20.8(32.0)	140.8(192.7)	20.8(17.8)	
Graulus*								.17(.41)
Unid. bivalve+	.33(.81)							
Crepidula sp.+	.17(.40)							
Nudibranch sp.+	.17(.40)							
Planorbid sp.*								.17(.40)
CRUSTACEA								
Ampelesca verilli+	1.2(1.3)							
Grandidierella bonnieroides+	19.0(23.0)	.83(2.0)	233.8(440.5)	12.3(20.3)	51.3(103.3)	20.12(16.0)	.33(.82)	
Melita nitida+	5.3(13.1)							
Gammarus palustris*							57.3(114.7)	6.8(7.4)
Hyalella azteca*							15.8(37.8)	17.3(41.5)
Edotea montosa+	.33(.52)	1.0(2.0)	1.7(3.6)					
Cyathura polita+			.50(1.2)					
Munna sp.*						1.2(2.0)		
Cyclaspis varians+	16.7(15.9)							
Campylaspis sp.+			5.7(10.1)	2.2(5.3)				
Tanaid sp.+	.33(.81)					.17(.41)		
Mysidopsis bigelowi+	3.5(4.8)		4.2(4.2)	.83(1.3)	1.7(2.6)	.33(.82)		
Pagurus sp.+	.33(.81)							
Neopanope texana+	.33(.81)		4.2(5.0)	.17(.41)				
Callinectes sapidus+					.17(.41)			
Ostracod spp+*				4.5(8.3)		2.3(5.2)		50.2(117.1)
INSECT LARVAE								
Enallagma sp.*							.50(.84)	
Negomphodes ambigua*							.17(.41)	
Peltodytes sp.*								.83(2.0)
Chironomus sp.*		.17(.40)						
Chironomus carus*			1.67(3.2)		6.8(16.7)	2.8(4.8)		.17(.41)
Cryptochironomus fulvus*			.17(.41)			.33(.82)		1.2(1.9)
Pseudochironomus sp.*								.17(.41)
Procladius sp.*		.50(1.2)	5.7(7.7)			2.3(5.2)	.67(1.6)	
Glyptotendipes sp.*								.33(.82)
Dicrotendipes sp.*								.33(.82)
Polypedilum halterale*			3.0(4.2)			.83(1.2)		.83(1.2)
Chaoborus punctipennis*			1.0(1.26)			.17(.41)	.67(1.0)	

MISC

Rhynchocoela spp.+*	1.2(1.6)						6.2(7.3)	
Flatworm spp.*+	1.5(1.4)	.33(.82)	23.8(27.9)	1.0(2.4)			16.3(21.7)	2.5(4.3)
Oligochaeta spp.+*		.33(.82)		5.8(8.3)	16.0(12.9)		21.3(50.8)	29.3(44.8)
Leech sp.*								.33(.52)
Hydroid (solitary)+			.17(.41)					
TOTAL NUMBER OF SPECIES	36	13	23	14	12	14	13	18
TOTAL NUMBER OF INDIVIDUALS	252.3	146.9	468.8	67.1	109.0	192.4	101.0	100.8

Table 4: Summary of quantitative benthic samples allong the Hillsborough River. H' = Shannon-Weaver Diversity Index; E - Equitability (H'/H_{max}). Total Density = mean # of individuals/15.25 X 15.25 cm Ekman Grab.

TIME OF SAMPLING	STATION	TEMP (°C)	SALINITY (°/oo)	TOTAL # SPECIES	TOTAL DENSITY	# MARINE SPECIES	# FRESH WATER SPECIES	H'	E
DRY SEASON									
	1	24	22	36	252.3	35	1	2.53	.49
	2	24	14	23	468.8	16	7	1.62	.37
	3	23	10	12	109.0	7	5	1.92	.52
	4	22	2.5	13	101.0	2	11	2.48	.62
WET SEASON									
	1	29	2	13	146.9	9	4	.942	.25
	2	28	1	14	67.1	10	4	2.96	.76
	3	28	2	14	192.4	6	8	2.94	.75
	4	28	1	18	100.8	1	17	2.45	.59

TABLE 5: Species collected in Hester-Dendy plate samplers along the Hillsborough River. X = present; * = present in high abundance for that taxon.

SPECIES	LOCATION Station 1 Dry	Station 1 Wet	Station 2 Dry	Station 2 Wet	Station 3 Dry	Station 3 Wet	Station 4 Dry	Station 4 Wet
Number of Samplers	3	3	3	4	3	4	2	2
POLYCHAETA								
Capitellides jonesi	X							
near Nicon sp.	X							
Streblospio benedicti	*							
Polydora ligni	*		X		X			
Neanthes arenaceodentata	X							
Neanthes succinea	X							
Autolytus cornutus	X							
Spirorbis spirillum			X		X			
Laeonereis culveri				X	X			
MOLLUSCA								
Mytilopsis leucophaeta	*	*	*	*	*	X		
Leucoplax diaphenus		X		X		X		X
Amygadalyum papyra	X							
Lyogyrus sp.				X			X	
Helisoma sp.				X				
Nudibranch sp.	X							
CRUSTACEA								
Grandidierella bonnieroides	*		X		*		X	
Hyalella azteca		X		X		X	X	X
Orchestia sp.	*		X	X				
Munna sp.						X		
Gammarus palustris							*	
Caprellid sp.	X							
Tanaid sp.	X			X		X		
Neopanope texana	X			X		X		
Palaemonetes sp.	X	X	X					
Crangonyx sp.	*	X	X					
Mysis sp.					X			
Barnacle juv.	X	X	X				X	

Cassidinea lunifronds		X	X					
Ostracod spp.		X						
Cladocera spp.				X		X		X
INSECT LARVAE								
Enallagma sp.		X		X		X		X
Chironomus carus		X		X	X	X	X	
Chironomus sp.		X						
Parachironomus sp.		X						
Pseudochironomus sp.				X		X		
Procladius sp.		X		X		X		
Glyptotendipes sp.						X		
Dicrotendipes sp.		X		X		X		
Dicrotendipes leucoscelis			X		X		X	
Dicrotendipes nervosus								X
Polypedilum convictum		XX		X				
Polypedilum illinoense		X				X		X
Dianesa sp.		X						
Ischnura posita				X			X	
Stenonema proxima				X				
Cyrnellus sp						X	X	X
Paroponyx sp						X		
Baetis intercalaris					X	X	X	
Anomalagrion hastatum							X	
Callibaetis floridanus							X	
Cheumatopsyche sp.								X
unid. Coleoptera							X	
MISC								
Rhynchocoela sp.							X	
Flatworm spp.	X		X	X	X	X	X	
Oligochaeta spp.		*		*	*	*	*	*
Hydroid (solitary)			X		X		X	
Hydroid (colonial)	X				X			
Hydra sp. I				X		X		
Hydra sp. II				X				
TOTAL NUMBER OF SPECIES	21	19	13	22	12	19	17	9

Figure 6. Species saturation curves for wet and dry season samples at Stations 1 & 2 (Univ. of Tampa and Riverclub Apartments.

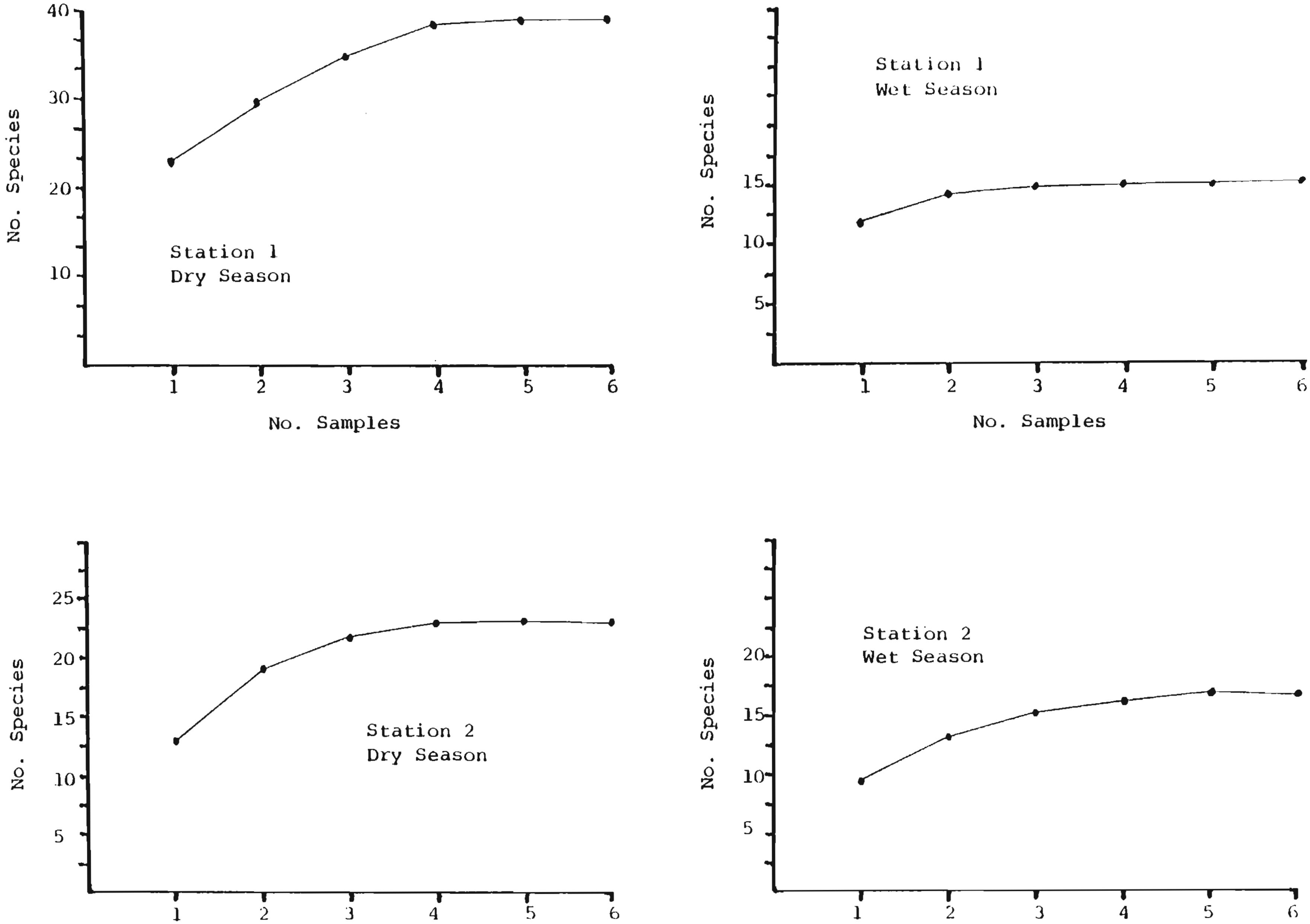
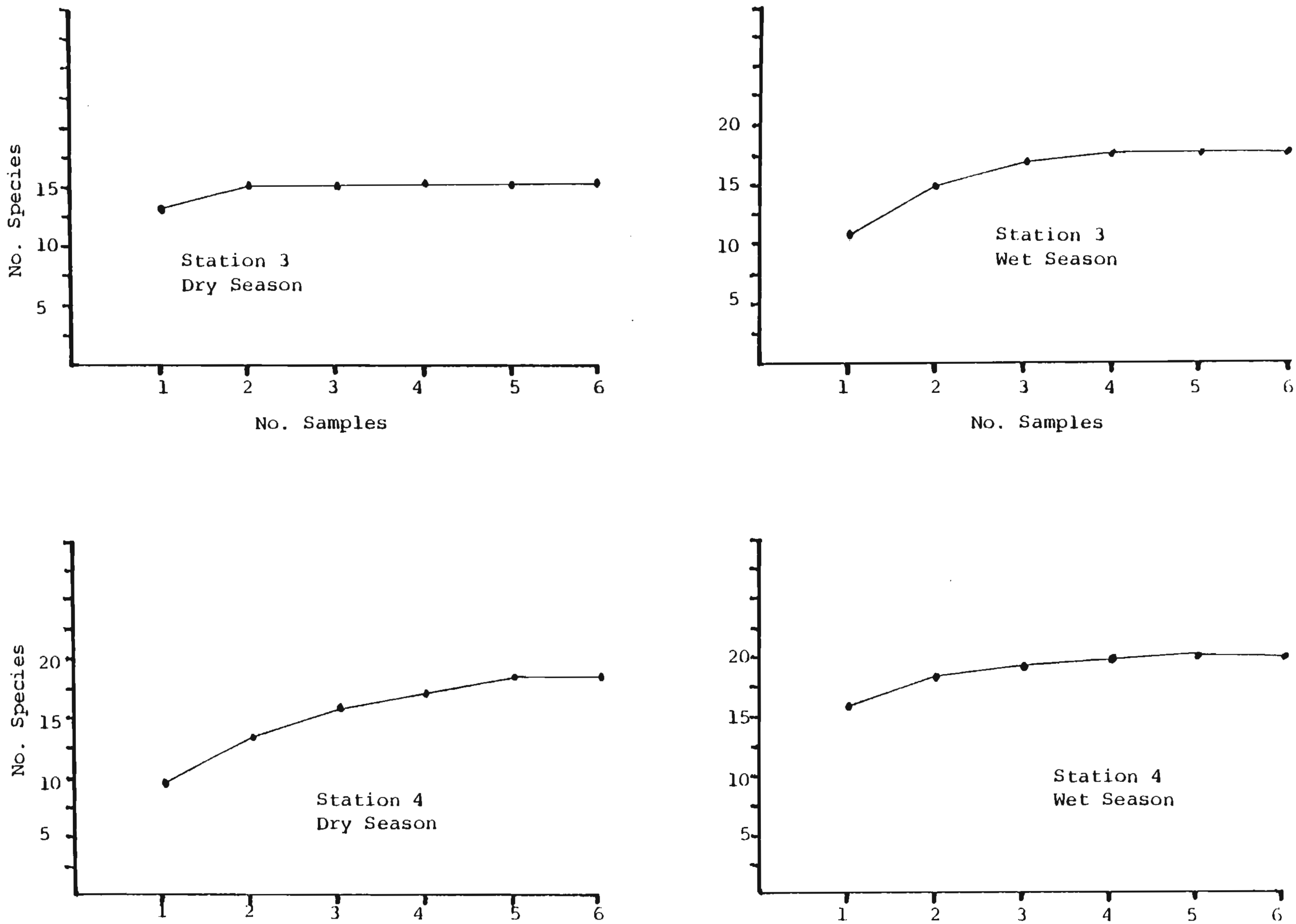


Figure 7. Species saturation curves for wet and dry season samples at Stations 3 & 4 (Sligh Bridge and 22nd Street).



III. ANIMAL BIOASSAYS

A. Introduction

The direct toxicity of urban stormwater runoff to marine or estuarine animals has not been previously reported in the literature. The present bioassay studies were conducted to provide this information with regard to wet season runoff, dry season runoff, river sediments and resuspended particulates.

The choice of an appropriately sensitive, ecologically relevant bioassay organism is a critical step in the design of any toxicity test. The bioasay organisms used in the Mote Marine Laboratory (MML) stormwater bioassays were specifically selected and cultured in the laboratory for these experiments. Three primary species and two secondary species were used in stormwater bioassays (Figure 8). The primary species represent organisms which are widely used in bioassay experiments and are approved for use by EPA/COE (1977). These species include:

1) *Neanthes arenaceodentata* Moore, a polychaete worm obtained from Dr. D.J. Reish, California State University, Long Beach, has been kept in culture at MML for the past two years. Culture procedures follow those of Reish (1980). Worms used in bioassays were immature juveniles measuring at least 16 but not more than 30 setigers (segments). No food was added during short term (96 hour) experiments, but food was added in long term (28 day) chronic experiments.

2) *Mysidopsis bahia* Molenock, mysid crustacenas were obtained from stock cultures maintained by the State of Florida Department of Environmental Regulation, Tallahassee, Florida, and kept in culture at MML for the past two years. Culture procedures follow those of Nimmo et al. (1976). Mysids used in bioassay experiments were immature one quarter to three quarter adult size and were provided with living brine shrimp daily for food in both stormwater and sediment experiments.

3) Cyprinodon variegatus (Lacepede), an estuarine fish, was obtained from Sarasota Bay near MML and kept in culture for the past two years. Culture procedures for maintaining various life stages of these fish were adopted from Standard Methods (1980). Naturally spawned juvenile fish between the age of 12 and 60 days post spawning were used in all bioassay experiments. Fish were not fed during short term experiments but were given living brine shrimp during long term tests.

The secondary species used in bioassay experiments represent seasonally available organisms or animals with a less well defined toxicological background than the primary species and include:

1) Menippe mercenaria, the stone crab, was collected as gravid females from the Gulf of Mexico and allowed to spawn in the laboratory. First through third stage zoea were used in bioassay experiments and were provided with living brine shrimp for food in all experiments.

2) Pseudocyclops sp., a calanoid copepod was isolated from the MML seawater system and cultured in the laboratory. Copepods were not fed during experiments (only short term tests were run) and adults were used in all tests.

B. Methods

Stormwater Bioassays

Stormwater samples used in bioassay experiments were collected by City of Tampa personnel from the Artic Street outfall on July 16 and October 14, 1982 and from the Cass Street outfall on January 21, 1983. These three stormwater samples can be considered as wet season samples. A single rain event sampled on May 5, 1983 from the Artic Street basin was considered to represent dry season runoff. One portion of this sampling, the first flush of runoff, was collected and stored separately for chemical analysis. Stormwater samples represented a composite of numerous subsamples collected throughout the rainfall event and were stored at $4^{o}C$ in linear polyethylene containers following collection. Representative samples of this stormwater were adjusted to an appropriate salinity with Instant Ocean salts prior to experiments. Short term (96 hr) bioassays were static, while long term bioassays were static with periodic replacement of test solutions. Survival rate was the parameter measured in short term experiments, while growth rates (in setigers for *Neanthes* and millimeters for *Cyprinodon*) were measured in long term tests.

Suspended Particulate Phase Bioassays

Equal portions of sediment from the three Hillsborough River collection sites were weighed out and mixed with seawater of the appropriate pH and salinity in a ratio of four parts water to one part sediment by weight. This mixture was stirred continuously for 30 minutes and then allowed to settle undisturbed for one hour. The supernatant remaining after the settling period was siphoned off into the appropriate test container and used as suspended particulate phase (SPP) solution. Test solutions with mysids and fish were aerated to maintain acceptable levels of dissolved oxygen throughout the experiment. Bioassays with worms did not require aeration.

Seawater that was mixed with sediment to produce the SPP was made up with Instant Ocean salts in distilled-deionized water. The pH of this seawater was adjusted to the appropriate value using 10% HCl prior to mixing with sediment. Control treatments were composed of seawater identical in pH and salinity to the water used to make the SPP.

Test conditions for the SPP bioassays included the following combinations: 1) 20 o/oo and pH 8; 2) 15 o/oo and pH 6; 3) 20 o/oo and pH 6; and 4) 15 o/oo and pH 8. Each of these combinations was tested with Neanthes arenaceodentata, Mysidopsis bahia and Cyprinodon variegatus. Survival rate alone was monitored in tests with Mysidopsis, while survival and growth rates were determined for Neanthes and Cyprinodon.

Sediment Bioassays

Whole sediment bioassays were conducted with Neanthes, Mysidopsis and Cyprinodon using a composite sediment sample composed of equal portions from each of the three sampling sites. For Neanthes, an infaunal species, the worms were placed in test chambers containing control sediment from New Pass, Sarasota and allowed to acclimate for two days. Composite test sediment from the Hillsborough River was then added to half the chambers, while an equivalent amount of control sediment was added to the other half. Five replicate chambers with five worms each were exposed to control and experimental treatments for 14 days.

For Mysidopsis, an epifaunal species, test animals were placed inside screened containers which were in turn placed inside larger chambers containing either control sediment or Hillsborough River sediment. Fifteen mysids were used in each of the control and experimental treatments. Exposure lasted for 96 hours.

Cyprinodon tests with whole sediment involved procedures similar to those used with Neanthes. Half the fish were exposed to Hillsborough River sediment on top of control sediment, while the remainder were exposed to control sediment only. Twenty five fish per treatment were used.

Worms, mysids and fish were provided with food during the course of the experiments.

Chemical Analyses

Chemical analyses were performed on each of the five stormwater samples shortly after their arrival at MML. Heavy metal determinations were made on an Instrumentation Laboratory atomic absorption spectrophotometer using standard addition techniques. Analyses were performed on whole, unfiltered stormwater. A total hydrocarbon analysis was performed on the July 1982 sample using a Varian 6000 gas chromatograph with a 30 m capillary column coated with SE30 and run at 100-280 °C. Detection was by flame ionization using splitless injection. (See Section VIII, below.)

C. Results

A total of 78 animal bioassays were completed during the course of this project. Thirty of these bioassays involved stormwater samples; 17 with wet season runoff and 13 with dry season runoff. The remaining 48 bioassays involved single or multiple heavy metals, sediment tests or suspended particulate phase experiments. In all cases, statistical significance was determined using the Students' t Test comparison of mean survival or growth rate between control and experimental treatments or a single classification ANOVA (Sokal & Rohlf, 1973).

Wet Season Runoff Bioassays

Results of initial acute bioassays using July 1982 stormwater are presented in Figures 9-13. No significant differences were observed in 96 hour survival rates for any of the five test species between control treatments and three dilutions of stormwater (10%; 50%; and 100% stormwater). October 1982 stormwater was tested in 96 hour acute bioassays using Neanthes and Cyprinodon as test organisms and showed no significant differences in survival between control and experimental treatments (Figure 15). January 1983 stormwater was tested in 96 hour bioassays using Neanthes and Mysidopsis and showed no significant reduction in survival for stormwater treatments (Figure 16).

Long term chronic bioassays for wet season runoff were undertaken using July stormwater. Neanthes and Cyprinodon were tested in these experiments with survival and growth rates measured in three dilutions of stormwater plus controls. The results of the chronic experiments with Neanthes are presented in Figures 14 and 17. The growth rates between treatments in Figure 14 are significant; however, these differences are due to intraspecific competition and predation rather than stormwater concentration. The same experiment was repeated except that each worm was held in a separate dish (Figure 17) and the results indicate no significant differences between treatments. All subsequent long term bioassays employed separate dishes for each worm.

The results of chronic bioassays with *Cyprinodon* are presented in Figures 18 and 19. The initial 28 day growth experiment (Figure 18) resulted in a significant difference between the 50% stormwater and control treatments. However, the survival rate in 50% and 100% stormwater was lower than controls and this may have influenced the results. The experiment was repeated (Figure 19) using the same procedures and this time survival in all treatments was 100%. In this second experiment, there were no significant differences in growth rates between treatments. As a general procedure, when control survival exceeded 10% the experiment was repeated.

The effects of salinity shock (rapidly lowered salinity) in combination with wet season stormwater exposure were tested in acute 96 hour bioassays using *Mysidopsis* and *Neanthes*. In these experiments, test animals were rapidly transferred from their normal culture salinity (25 o/oo for *Mysidopsis* and 30 o/oo for *Neanthes*) to test solutions of 15 o/oo salinity. Control treatments consisted of standard culture seawater diluted to 15 o/oo with distilled deionized water. Two dilutions of stormwater were tested with *Mysidopsis* (Figure 21) and three dilutions were tested with *Neanthes* (Figure 20). The survival rates for both species after 96 hours showed no significant differences between control and experimental treatments. After 7 days of exposure, *Mysidopsis* had a significantly lower survival rate in 100% stormwater than in controls. However, this type of exposure to stormwater would not be likely to occur under natural conditions in the Hillsborough River.

Dry Season Runoff Bioassays

Dry season runoff, collected on May 4, 1983 from the Artic Street watershed, was tested in acute bioassays with *Neanthes*, *Mysidopsis*, *Cyprinodon*, and *Pseudocyclops*. Chronic bioassays with this stormwater were conducted with *Neanthes* and *Cyprinodon*.

Acute bioassays with dry season runoff were carried out at two salinities (20 o/oo and 15 o/oo) and three stormwater concentrations (10%, 50%, 100%). In tests using *Cyprinodon*, no reduction in survival was evident in 20 o/oo salinity tests. At 15 o/oo, survival was lowered in 100% stormwater; however the reduction in survival was not significant

(Figure 22).

Acute bioassays with Neanthes resulted in no survival reduction at 20 o/oo but produced a significant reduction in 100% stormwater at 15 o/oo salinity (Figures 23 and 24). Similar tests with Mysidopsis produced a progressive reduction in survival with increasing stormwater concentration at both 20 o/oo and 15 o/oo salinitiies; however these reductions were not statistically significant (Figures 25 and 26).

Neanthes and Mysidopsis were tested in acute bioassays with dry season stormwater which had been filtered through a 0.45 u Millipore filter. These tests were conducted at 15 o/oo salinity and results are presented in Figures 27 and 28. Reduced survival was observed in Mysidopsis tests at the highest stormwater concentration but was not significant. Neanthes bioassays resulted in significant reductions in survival at 50% and 100% stormwater concentrations.

Acute bioassays using Pseudocyclops resulted in significantly reduced survival at both 25 o/oo (normal culture salinity) and 15 o/oo salinities in the 100% stormwater concentration.

Chronic bioassays with dry season runoff were undertaken with Neanthes and Cyprinodon in which growth rates were measured in three stormwater concentrations plus controls. Neanthes was tested at 20 o/oo salinity resulting in no significantly reduced growth rate after 28 days exposure and at 15 o/oo salinity resulting in a significantly depressed growth rate in 100% stormwater after 7 days (Figure 29). Cyprinodon was exposed to stormwater at 20 o/oo salinity for 21 days and showed no significant reduction in growth rate. Tests at 15 o/oo salinity were not attempted due to depletion of stormwater supplies.

Figure 9. 96 hour survival rate for <u>Neanthes arenaceodentata</u> exposed to dilutions of July stormwater.
$T = 24^{\circ}C$
$S = 25$ o/oo
$n = 15$/treatment

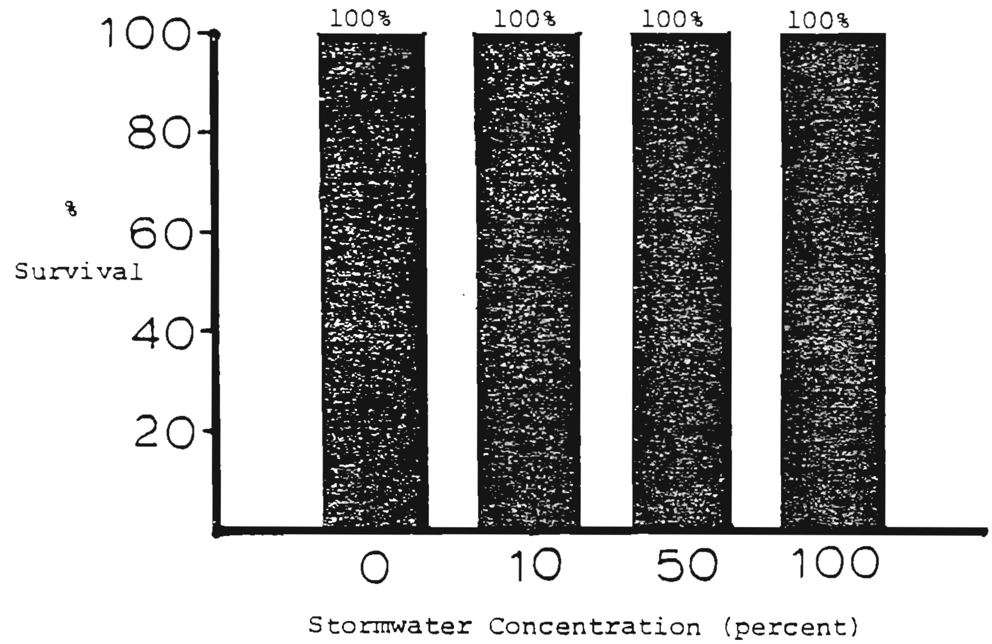


Figure 10. 96 hour survival rate for <u>Cyprinodon variegatus</u> exposed to dilutions of July stormwater.
$T = 24^{\circ}C$
$S = 25$ o/oo
$n = 15$/treatment

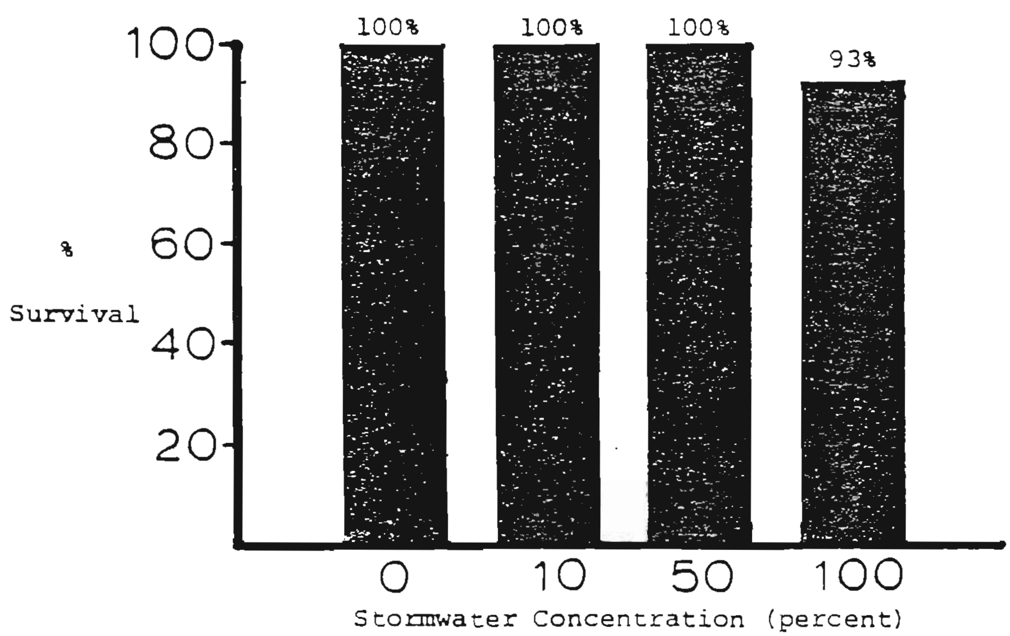


Figure 11. 96 hour survival rate for <u>Mysidopsis bahia</u> exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 15/treatment

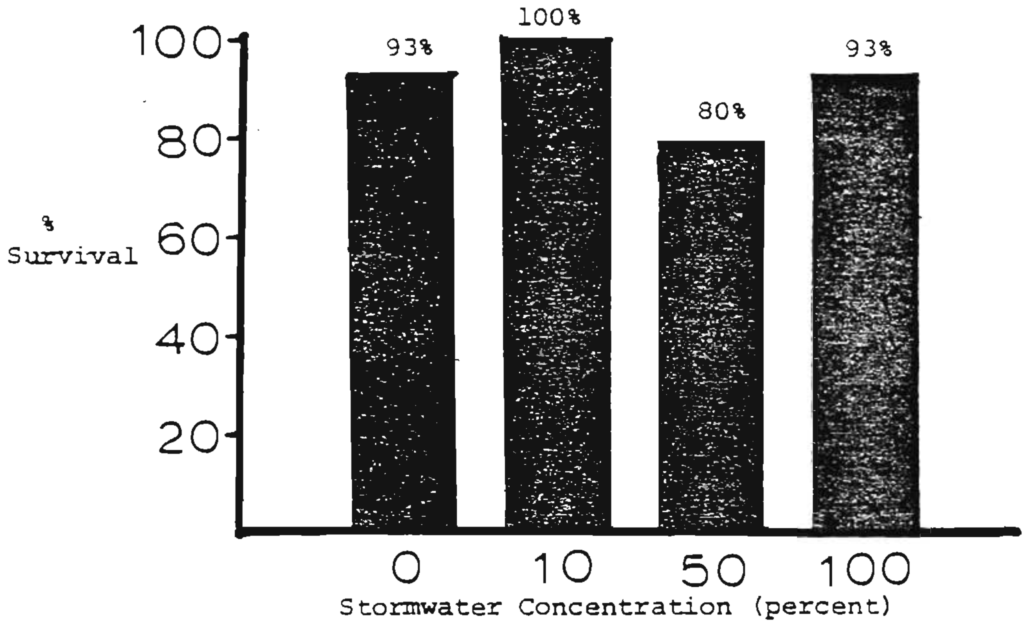


Figure 12. 96 hour survival rate for <u>Pseudocyclops</u> sp. exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 18/treatment

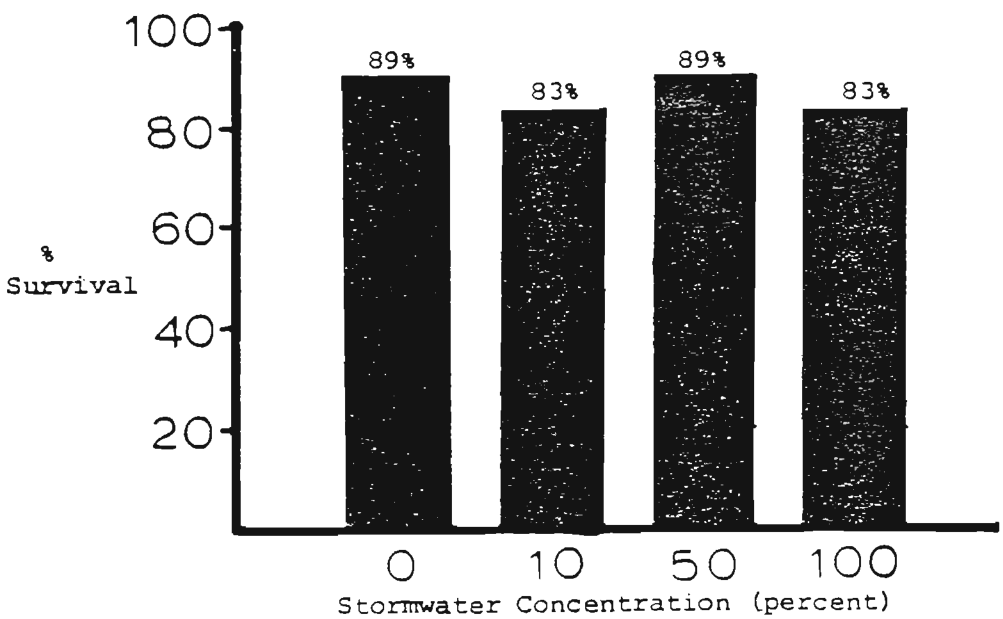


Figure 13. 96 hour survival rate for *Menippe mercenaria* exposed to dilutions of July stormwater.
T = 23°C
S = 30 o/oo
n = 15/treatment

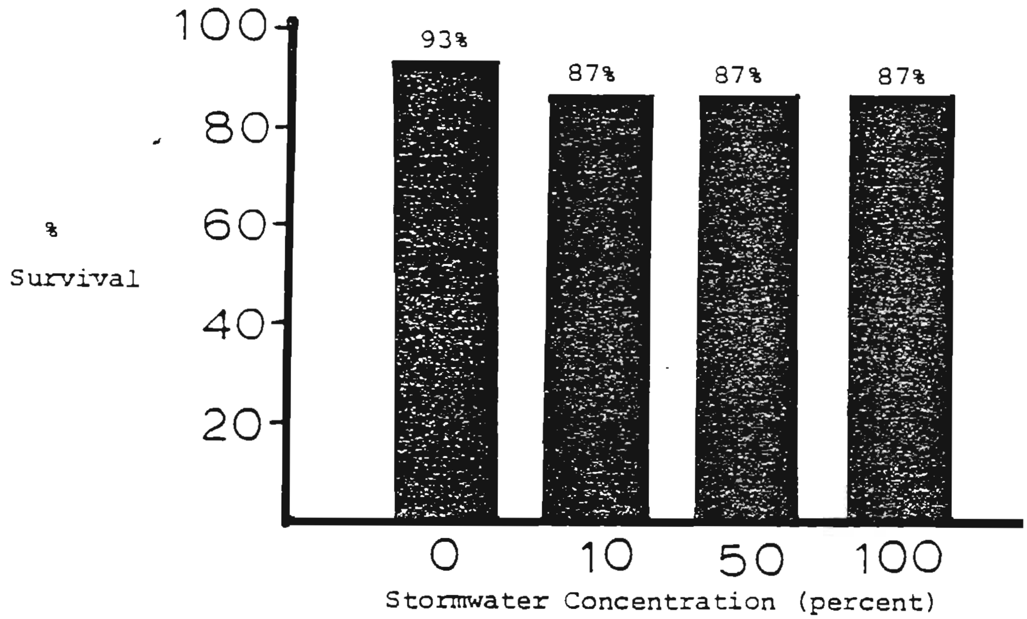


Figure 14. 28 day growth of *Neanthes arenaceodentata* exposed to dilutions of July stormwater.
T = 25°C
S = 25 o/oo
n = 15/treatment (5 worms per dish)

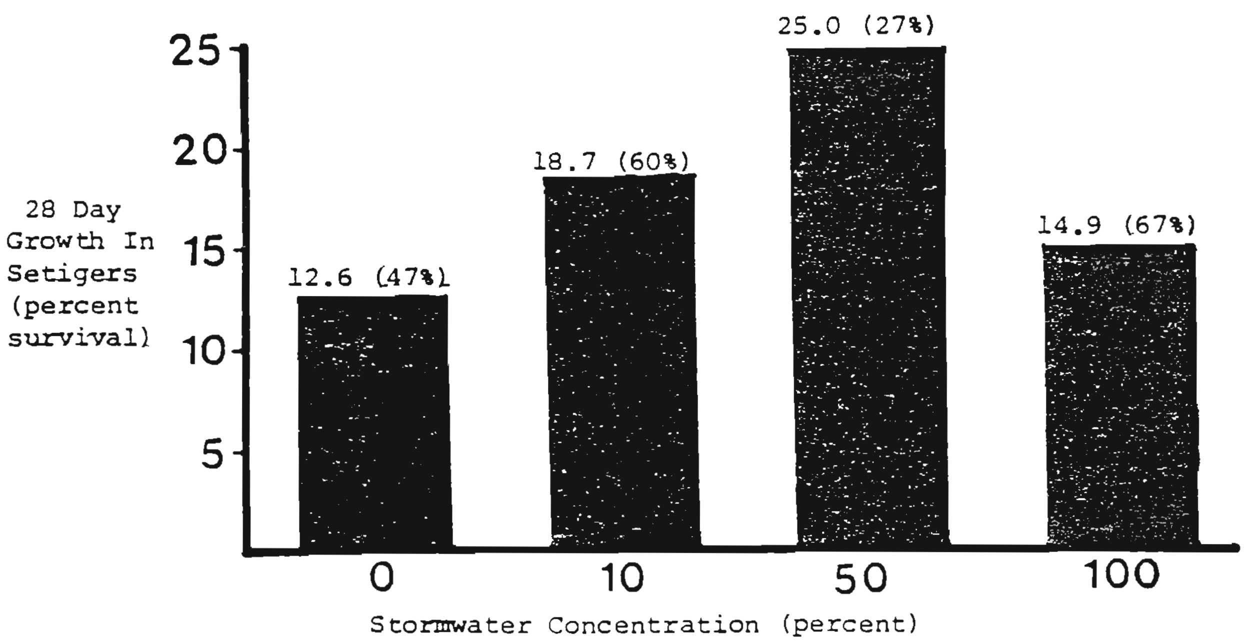


Figure 15. 96 hour survival rates for Neanthes arenaceodentata and Cyprinodon variegatus exposed to October, 1982 stormwater from Artic Street outfall, T= 24 C, S= 25%, n= 15/ treatment

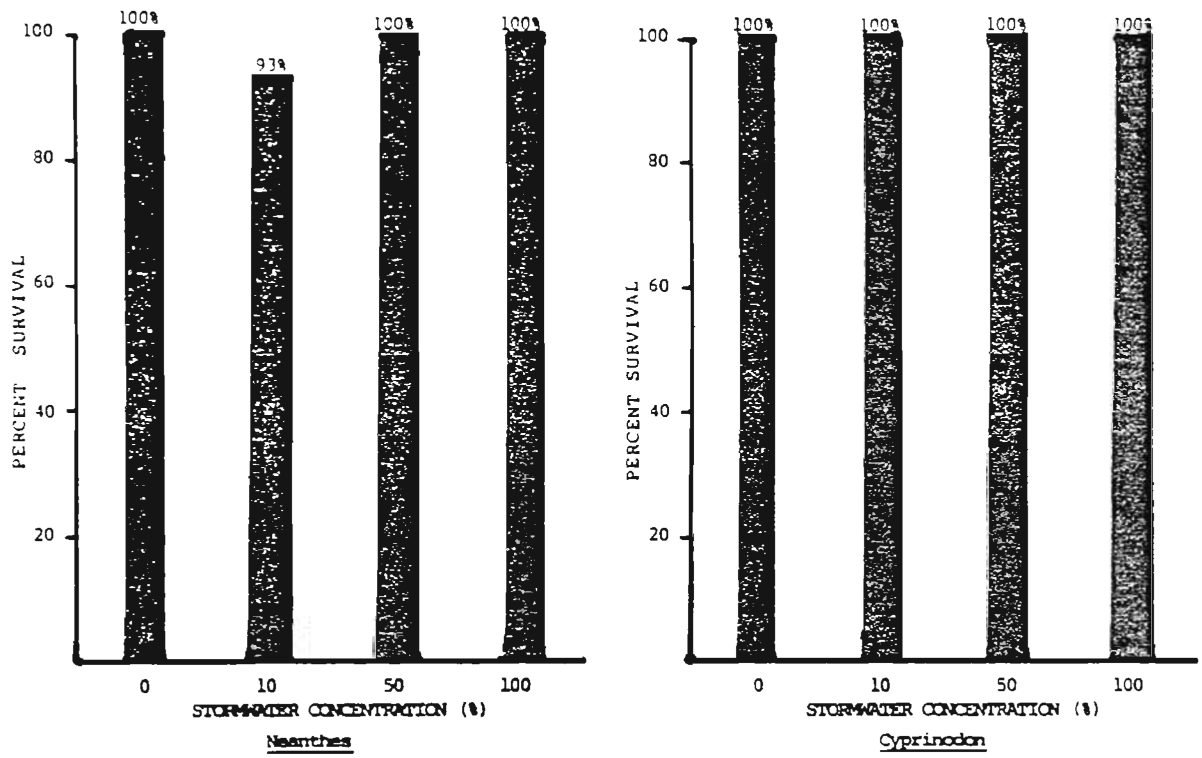


Figure 16. 96 hour survival rates for Neanthes arenaceodentata and Mysidopsis bahia exposed to January, 1983 stormwater from Cass Street outfall, T= 20 C, S= 25% n= 15 or 12/ treatment

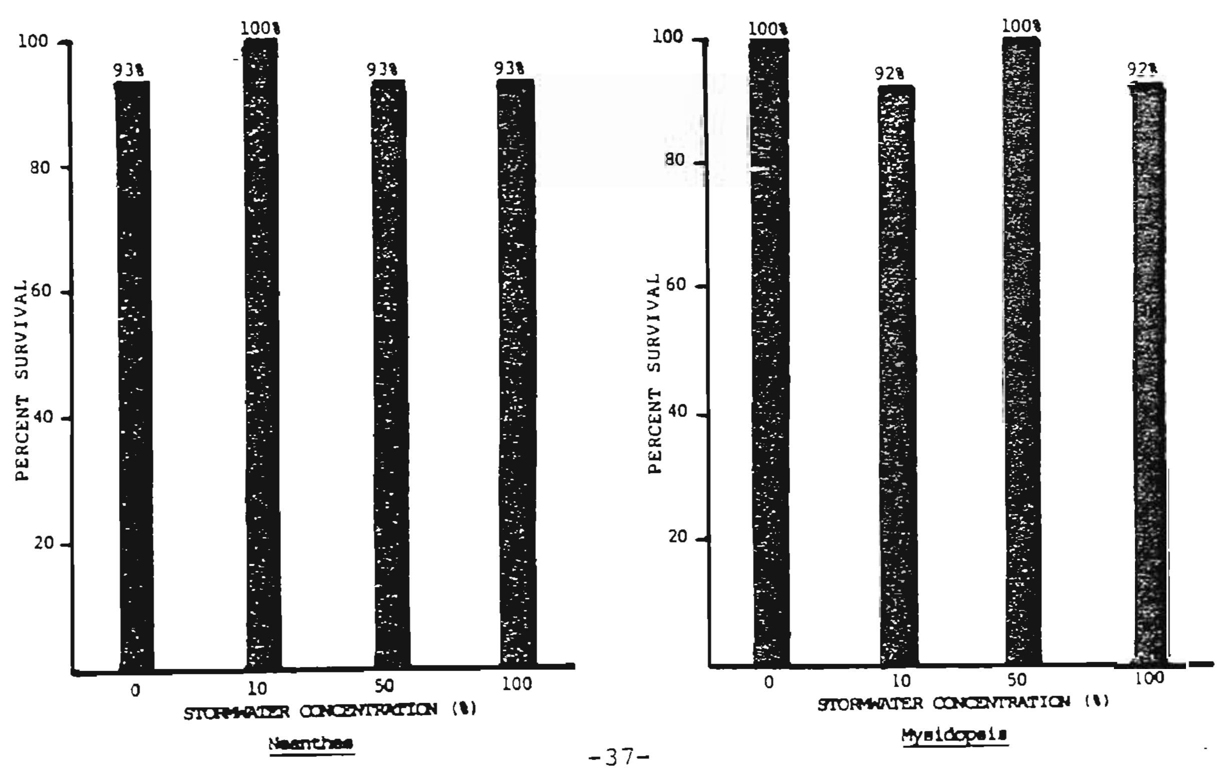


Figure 17. 28 day growth of Neanthes arenaceodentata exposed to dilutions of July stormwater.
T = 23°C
S = 25 o/oo
n = 10/treatment (one worm per dish)

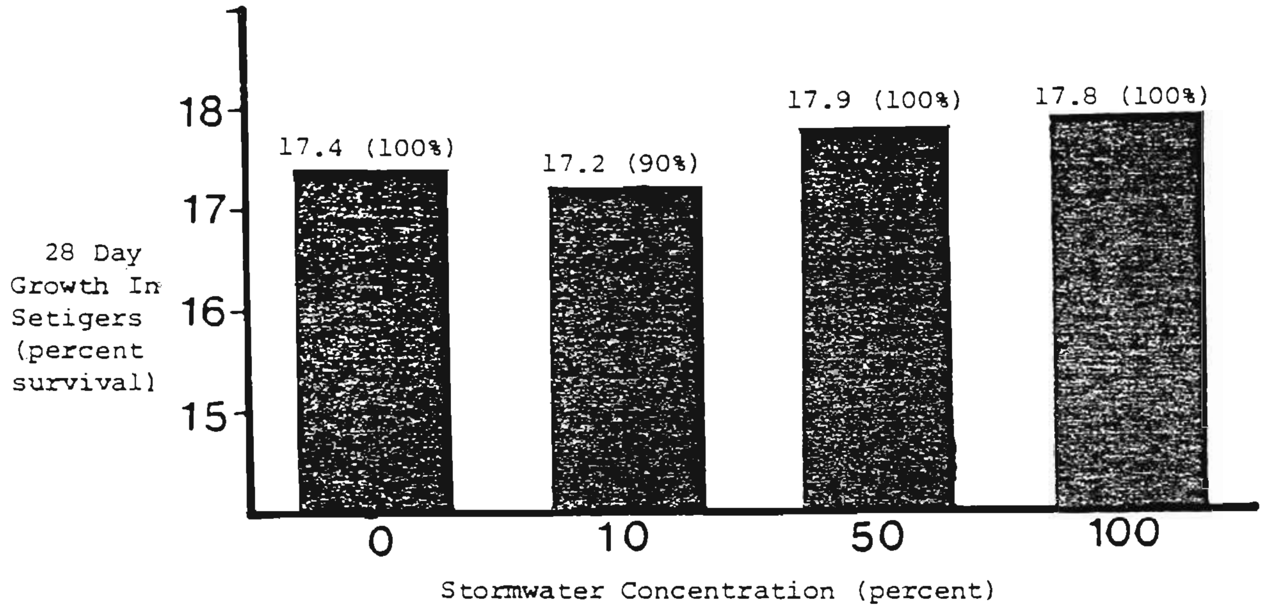
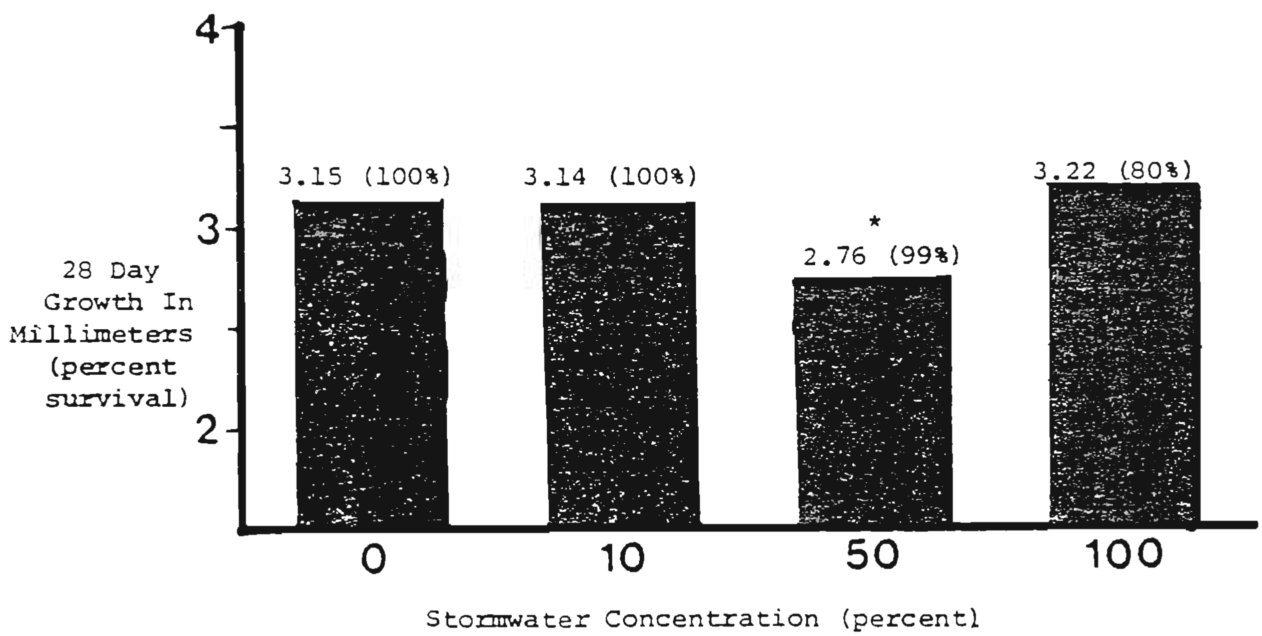


Figure 18. 28 day growth in Cyprinodon variegatus exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 15/treatment



*Significantly different from control.

Figure 19. 28 day growth in *Cyprinodon variegatus* exposed to dilutions of July stormwater.
T = 23°C
S = 25 o/oo
n = 15/treatment

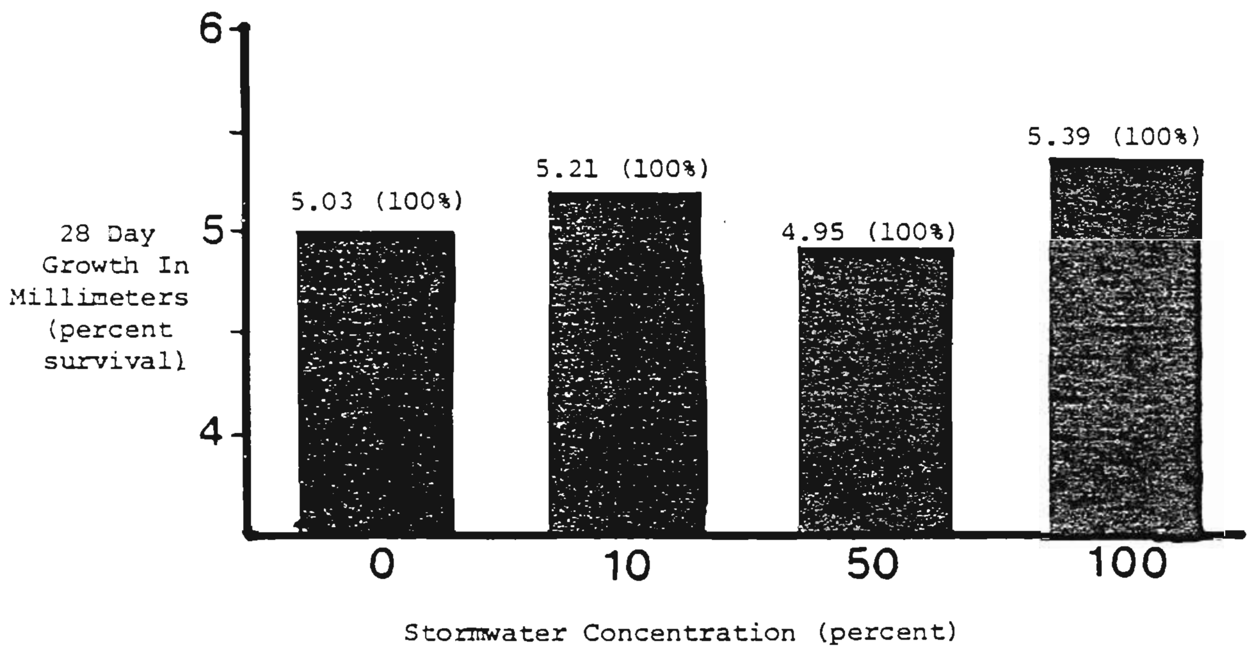


Figure 20. 96 hour survival of Neanthes arenaceodentata exposed to dilutions of July stormwtaer plus reduced salinity (30 o/oo to 15 o/oo). T = 24°C; S = 15 o/oo; n = 15/treatment

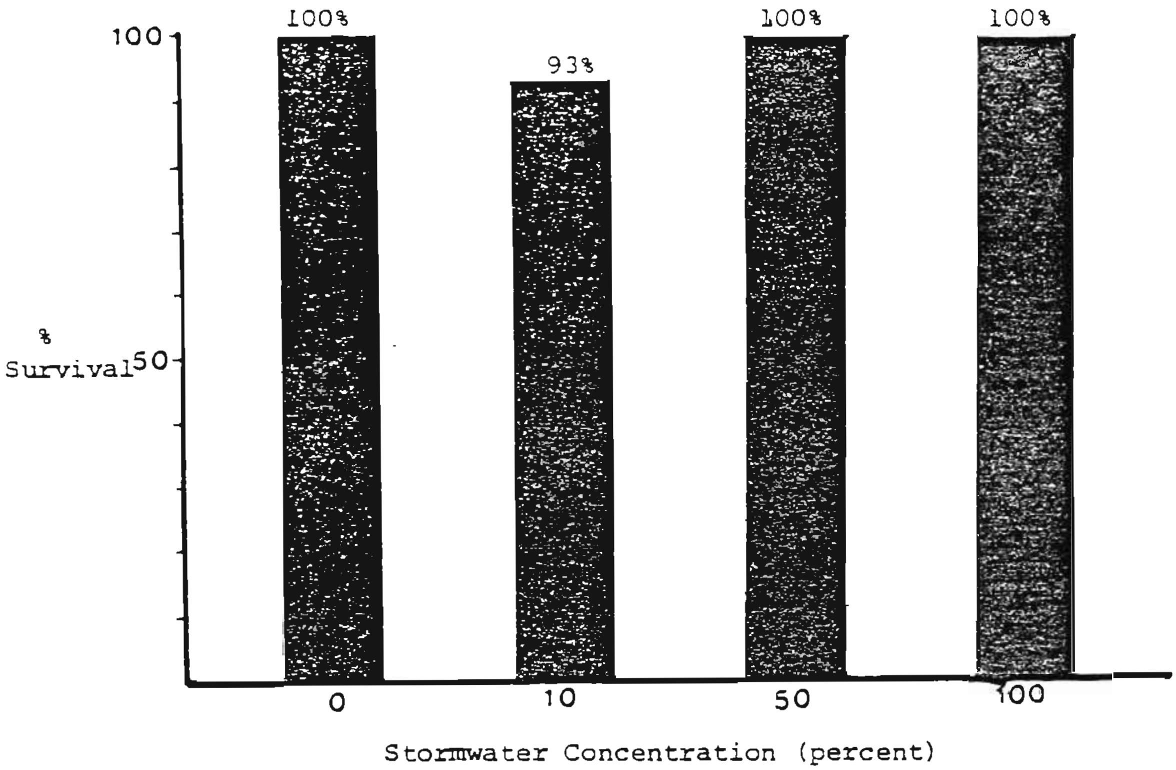
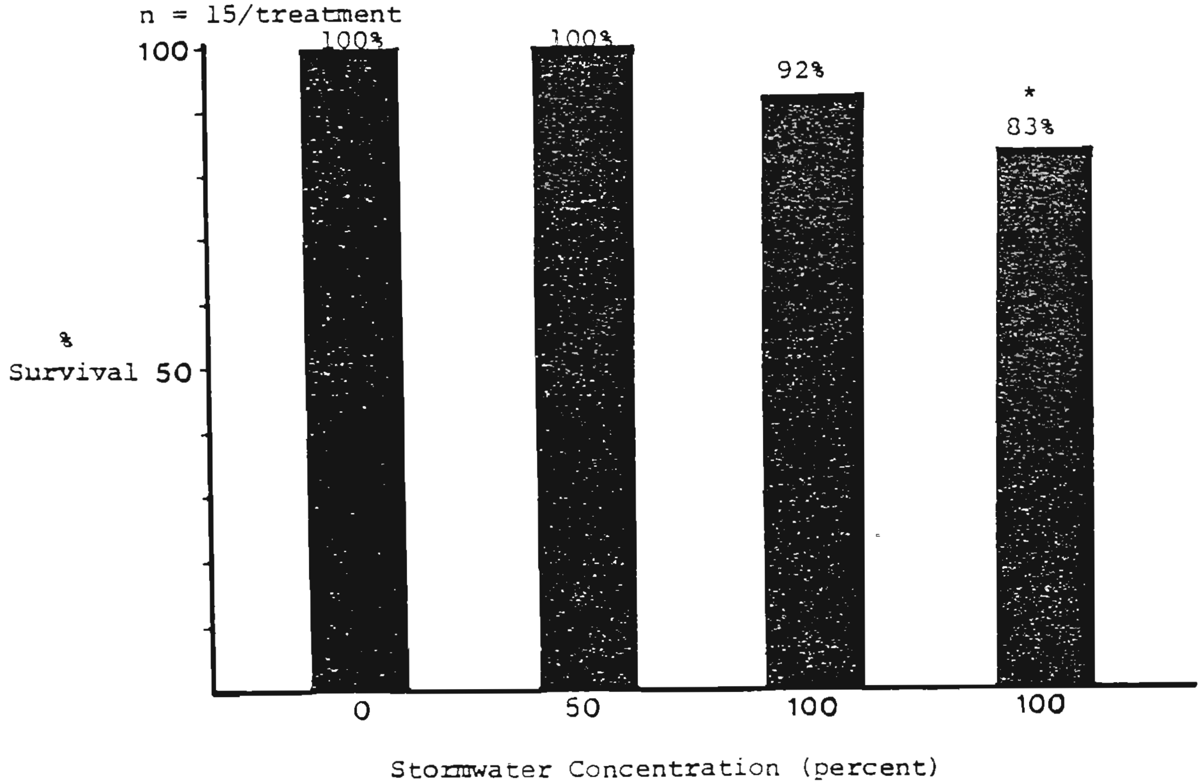


Figure 21. 96 hour and 7 day survival of Mysidopsis bahia exposed to dilutions of July stormwater plus reduced salinity (25 o/oo to 15 o/oo).
T = 23°C
S = 15 o/oo
n = 15/treatment



*This bar represents survival rate in 100% stormwater and reduced salinity after 7 days and is significantly different from controls.

Figure 22. 96 hour survival for <u>Cyprinodon</u> <u>variegatus</u> exposed to May 1983 stormwater at 24°C and 15 o/oo, n - 15/treatment.

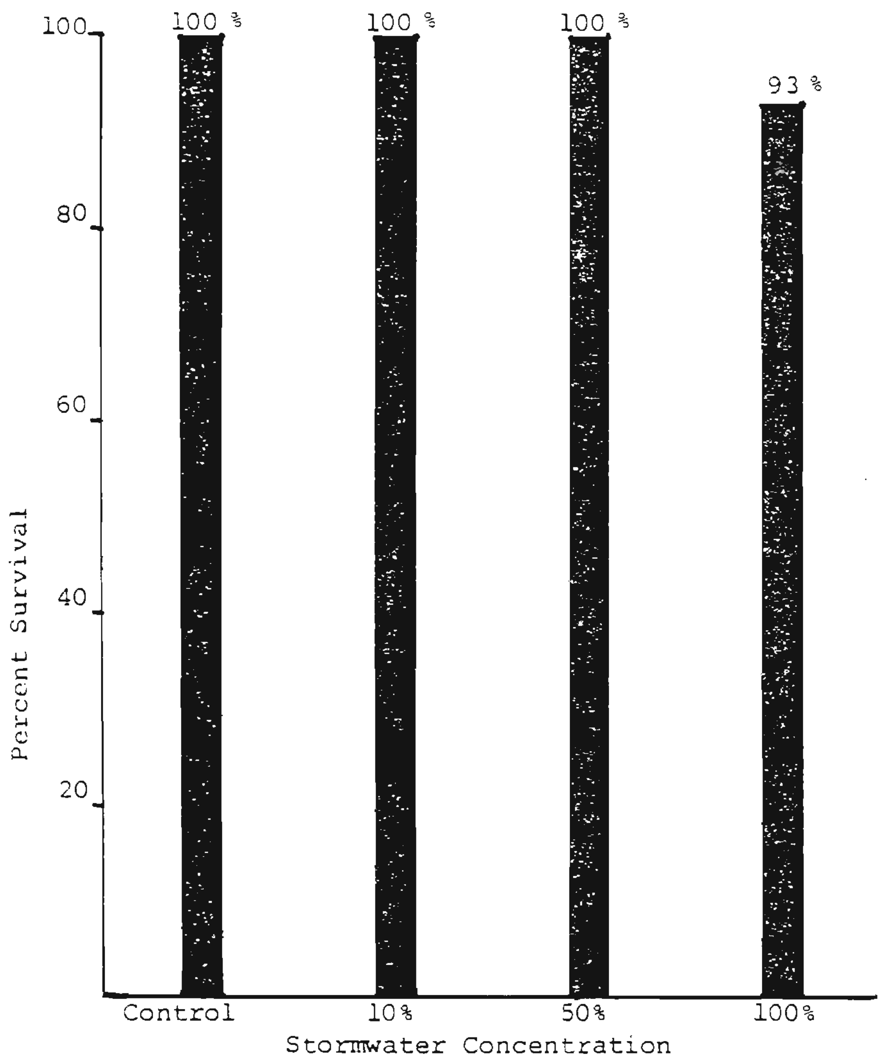


Figure 23.
96 hour survival rate for _Neanthes arenaceodentata_ exposed to May 1983 stormwater at 24°C and 20 o/oo, n = 10/treatment.

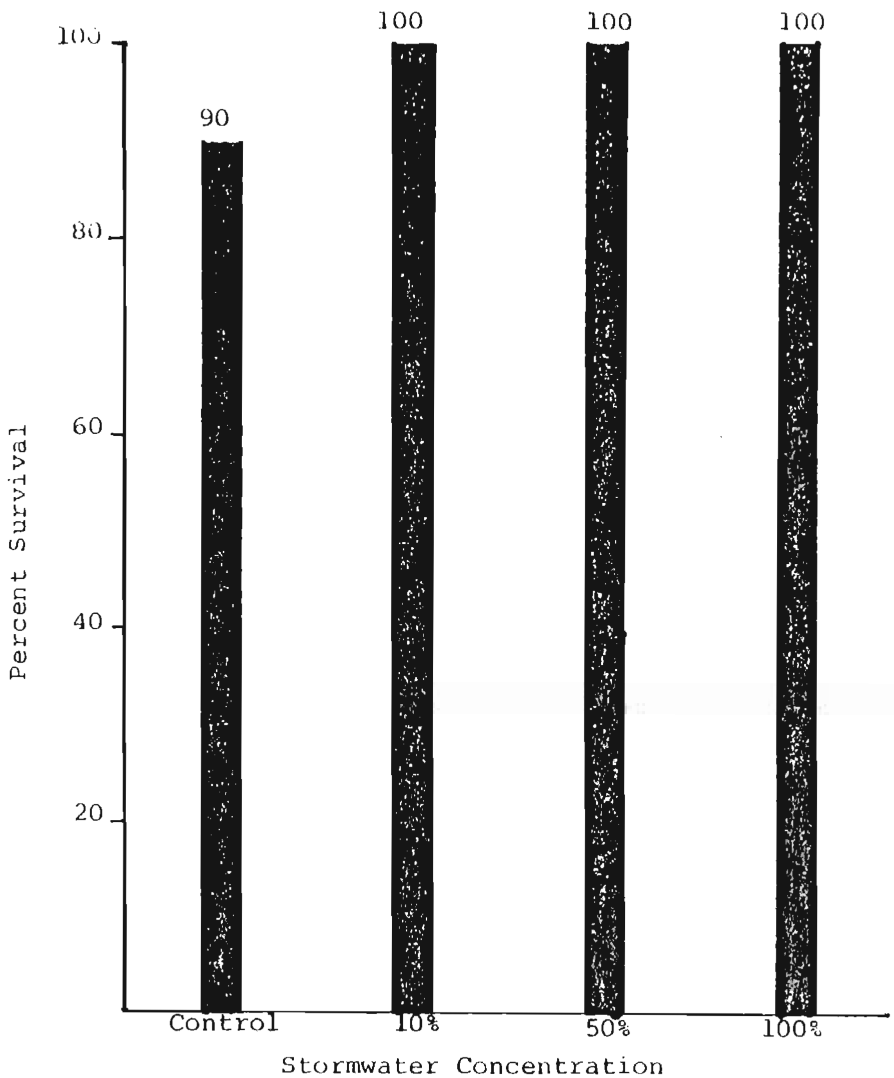
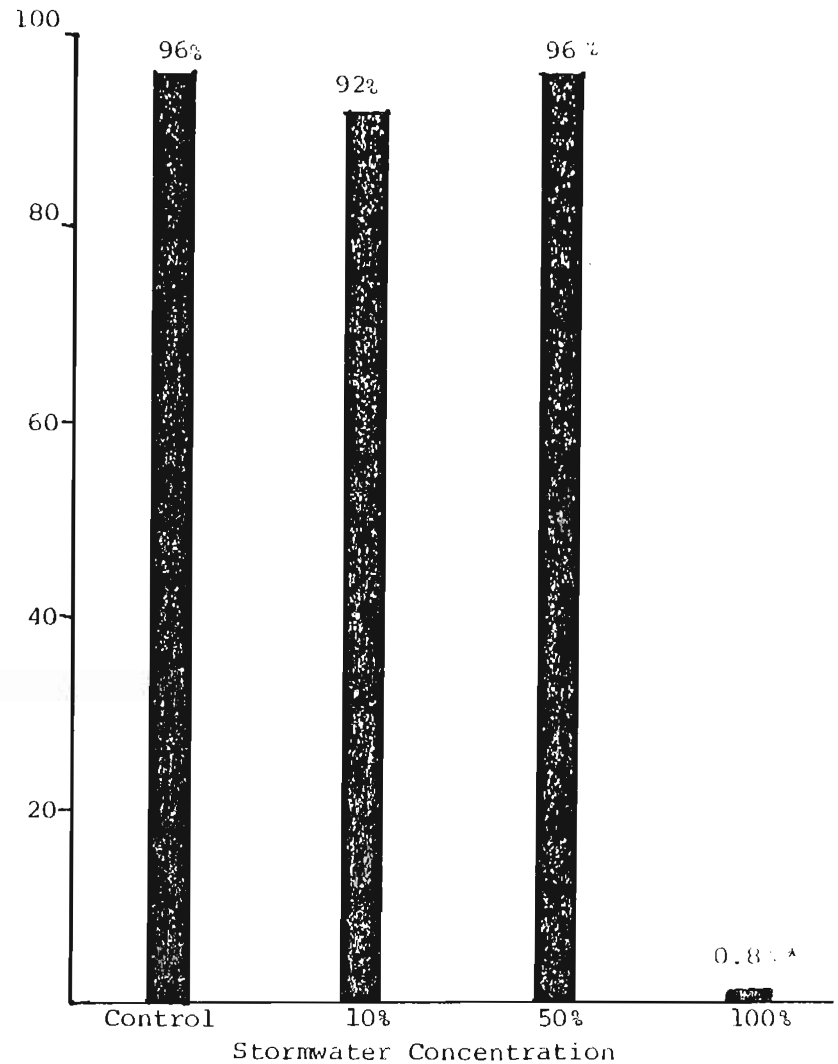


Figure 24.
96 hour survival rate for _Neanthes arenaceodentata_ exposed to May 1983 stormwater at 24°C and 15 o/oo, n = 25/treatment.



* significantly different from control

Figure 25.
96 hour survival rate for Mysidopsis bahia exposed to May 1983 stormwater at 24°C and 20 o/oo, n = 15/treatment.

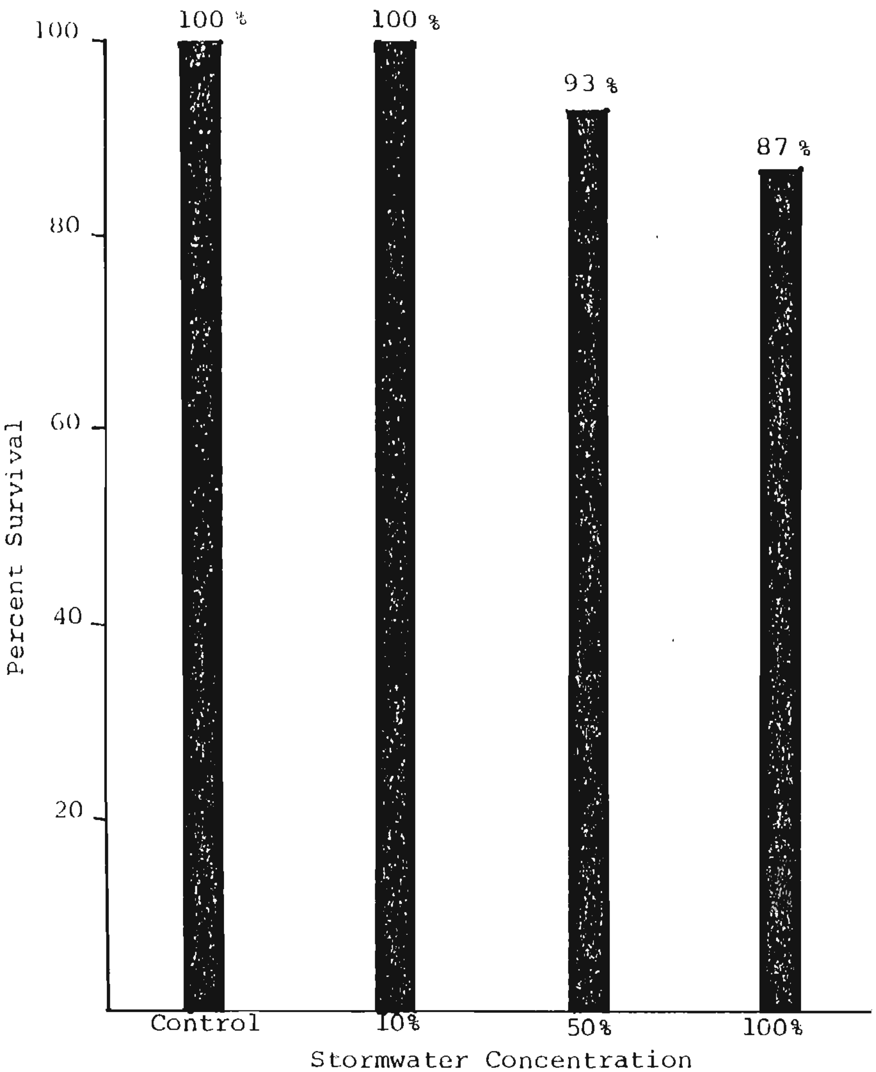


Figure 26.
96 hour survival rate for Mysidopsis bahia exposed to May 1983 stormwater at 24°C and 15 o/oo, n = 15/treatment.

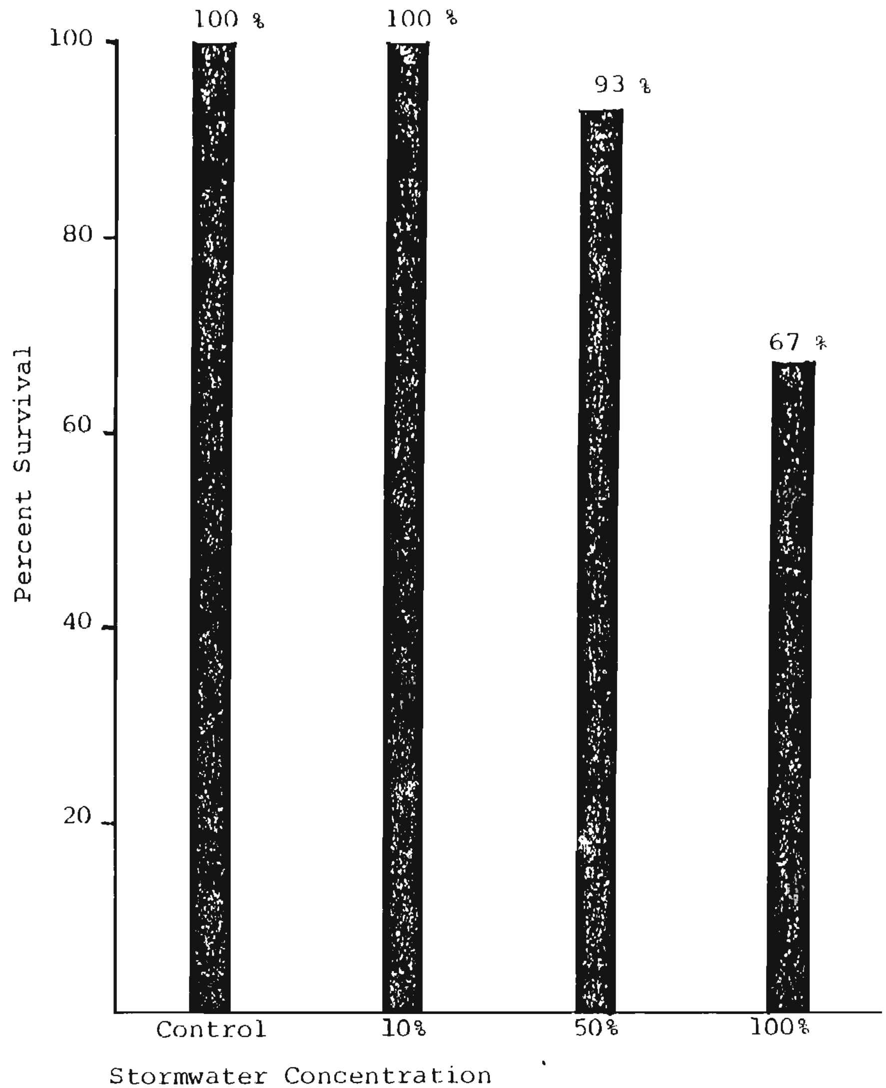


Figure 27.
96 hour survival rate for *Mysidopsis bahia* exposed to filtered May 1983 stormwater at 24°C and 15 o/oo, n = 15/treatment.

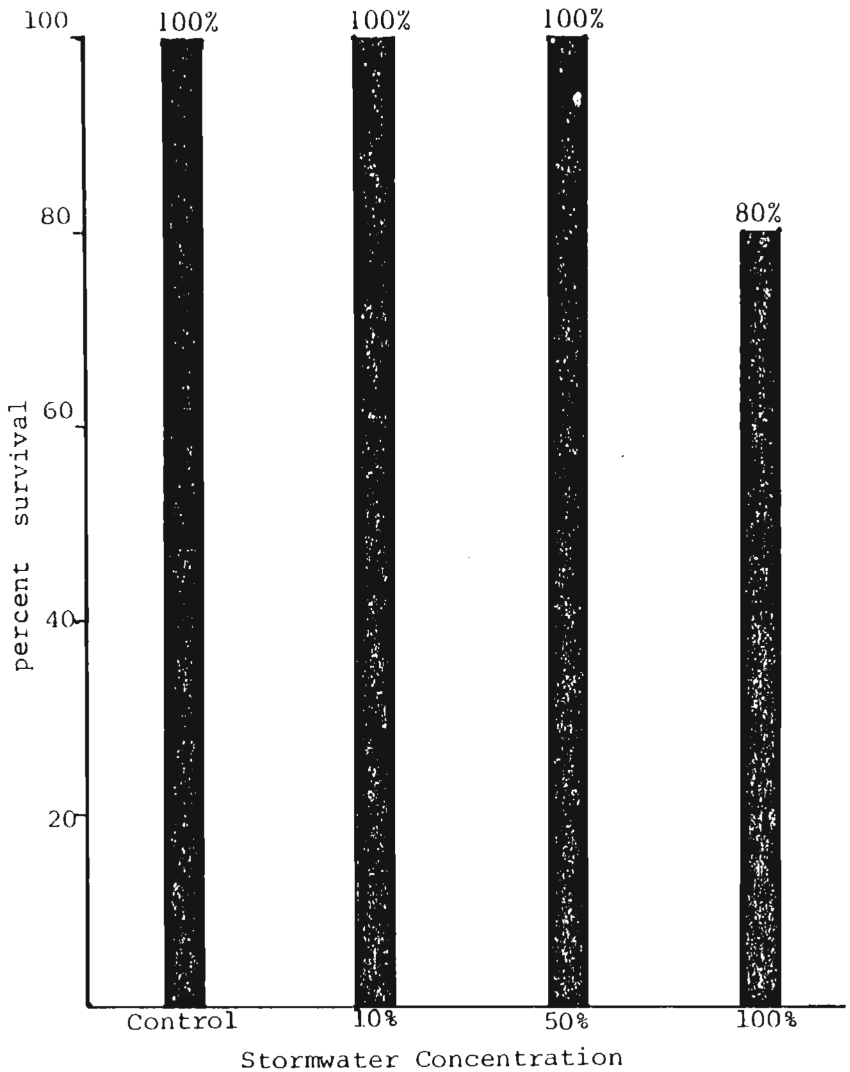


Figure 28.
96 hour survival rate for *Neanthes arenaceodentata* exposed to filtered May 1983 stormwater at 24°C and 15 o/oo, n = 10/treatment.

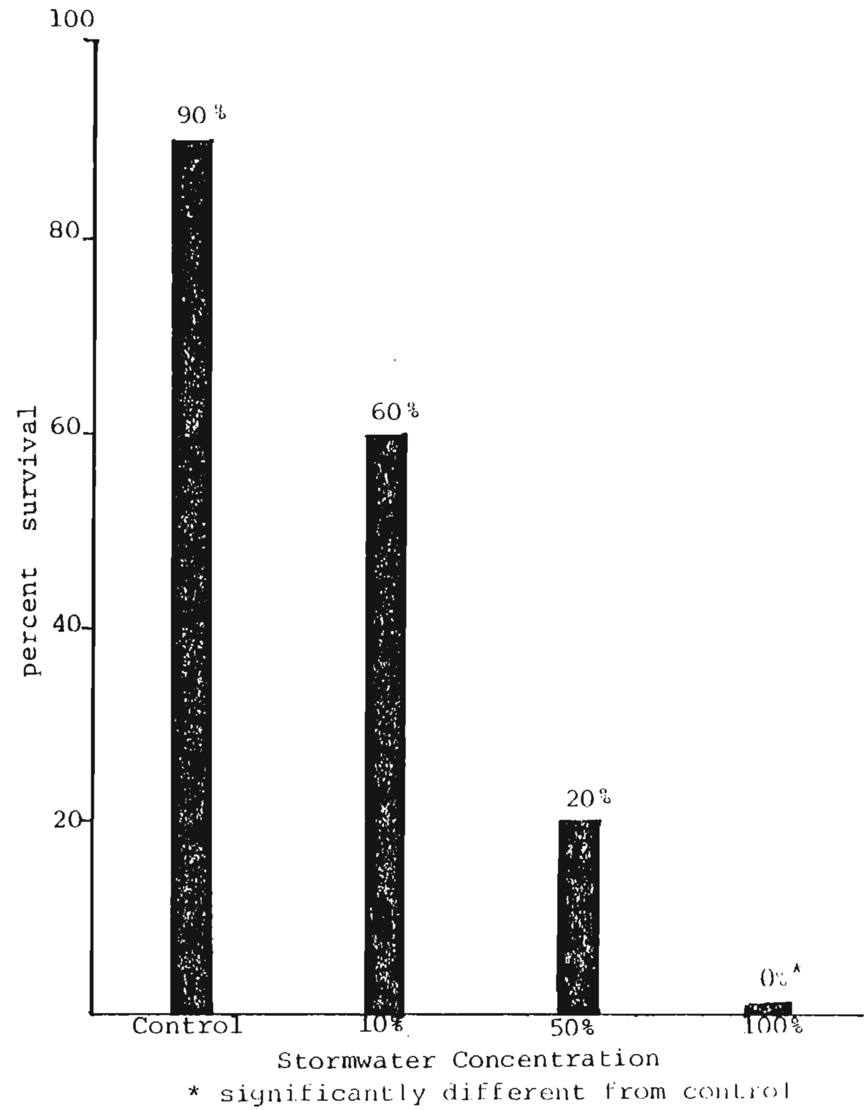
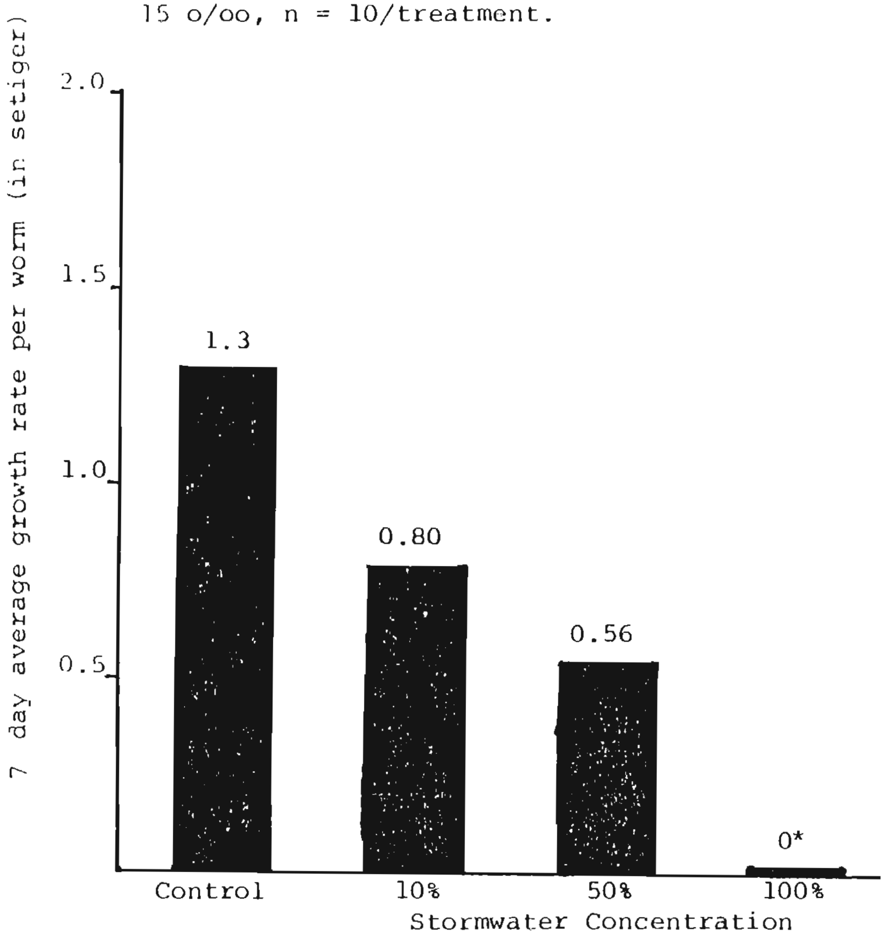
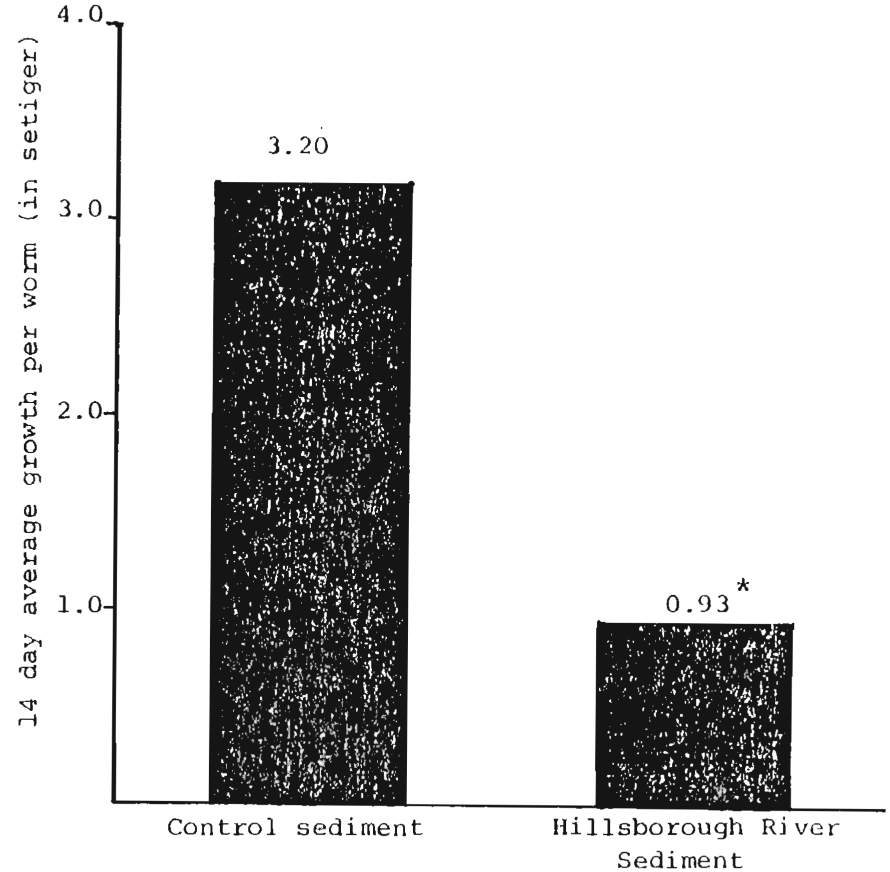


Figure 29.
7 day growth rate for Neanthes arenaceodentata exposed to May 1983 stormwater at 24°C and 15 o/oo, n = 10/treatment.



* significantly different from control

Figure 30.
14 day growth rate for Neanthes arenaceodentata exposed to Hillsborough River sediment and control sediment at 24°C and 25 o/oo, n = 25/treatment.



*significantly different from control

Sediment Bioassays

Toxicity tests with whole composite sediment from the Hillsborough River were conducted using Neanthes, Mysidopsis and Cyprinodon as test organisms. The results of these tests are presented in Tables 6, 7, and 8. For Neanthes, a 14 day exposure to test sediments resulted in a significant reduction in growth rate compared to controls (Figure 30). Mysidopsis bioassays revealed a significant reduction in survival after 96 hours exposure to test sediment. No reduction in growth rate was evident for Cyprinodon following 14 days exposure. All of the above tests were carried out at 25 o/oo salinity and a pH of 7-8.

Suspended Particulate Phase Bioassays

Each of the three primary bioassay species was exposed to four different solutions extracted from Hillsborough River sediments under various conditions of salinity and pH. The results of these suspended particulate phase (SPP) bioassays are presented in Tables 6, 7, and 8.

In tests using Neanthes (Table 6), significant reductions in survival and growth rates were apparent at low salinity (15 o/oo) and pH values of 8 and 6. Tests at higher salinities (20 o/oo) did not produce significant results.

Mysidopsis tests with the SPP are summarized in Table 7. Reduced survival rates were observed in three of the four combinations but proved to be statistically nonsignificant due to high variance between replicates.

Table 8 presents the results of SPP bioassays with Cyprinodon. No significant reductions in growth rates were observed at any of the combinations listed.

D. Conclusions

The conclusions that can be drawn from the above experiments include: 1) July 1982, October 1982 and January 1983 stormwater (all wet season) from the Artic Street drainage basin and Cass Street outfall is not acutely toxic to appropriately sensitive bioassay organisms; 2) this stormwater does not produce a significant reduction in growth rate of these organisms following 28 days exposure; 3) salinity reduction in combination with stormwater exposure does not cause a significant reduction in survival after 96 hours exposure to wet season runoff; 4) dry season stormwater from the Artic Street watershed is acutely toxic to invertebrate species tested, especially at low salinities (15 o/oo); 5) filtered dry season runoff produced a similar toxic response as unfiltered stormwater when tested at 15 o/oo salinity; 6) dry season stormwater produced a significant reduction in growth rate for Neanthes but not for Cyprinodon; 7) Hillsborough River sediments proved to be toxic to two of three species tested; and 8) solutions extracted from river sediments were toxic to some species at low salinities (15 o/oo).

The sensitivity of the three primary bioassay species cultured at MML to various heavy metals in solution is presented in Table 9. Acute sensitivities are expressed as the 96 hour LC_{50}, while chronic sensitivities refer to that concentration of heavy metal which results in a significant reduction in reproductive potential. Most of the 96 hour LC_{50} values in Table 9 were determined at MML using cultured organisms. However, some values were obtained from literature reports. The concentration of heavy metals in the stormwater samples is presented at the bottom of Table 9. The wet season stormwater heavy metal concentrations are considerably lower than the 96 hour LC_{50} values. The dry season runoff concentrations, especially the first flush sample, are considerably higher than the wet season values and exceed the 96 hour LC_{50} values for some species. The river sediment concentrations of heavy metals are extremely high and are undoubtedly responsible for the observed toxic effects. The fact that the dry season runoff and river sediments were not as toxic as might be expected from their chemical composition alone indicates that some portion of the total concentration is present in a chemical form that is not readily available (non toxic) to the test organisms. This situation has been documented with contaminated dredged material.

Table 6. Whole Sediment and Suspended Particulate Phase (SPP) Bioassays with *Neanthes arenaceodentata*.

Toxicant	Test Conditions	Test Parameters	Test Duration	Results[1]
Whole sediment	25 o/oo pH 8	Growth rate & survival	14 days	Significant reduction in growth rate[2]
Composite SPP	20 o/oo pH 8	Growth rate & survival	14 days	No reduction in growth rate
Composite SPP	15 o/oo pH 8	Growth rate & survival	10 days	Significant reduction in growth rate and survival
Composite SPP	20 o/oo pH 6	Growth rate & survival	10 days	No reduction in growth rate
Composite SPP	15 o/oo pH 6	Growth rate & survival	10 days	Significant reduction in growth rate and survival

[1]Results are presented as response of animals relative to control treatment.

[2]Significance refers to $P < 0.05$ using Students' t Test or single classification ANOVA.

Table 7. Whole Sediment and Suspended Particulate Phase (SPP) Bioassays with *Mysidopsis bahia*.

Toxicant	Test Conditions	Test Parameters	Test Duration	Results[1]
Whole sediment	25 o/oo pH 8	Survival	96 hrs	Significant reduction in survival[2]
Composite SPP	20 o/oo pH 8	Survival	96 hrs	Reduced survival but NS
Composite SPP	15 o/oo pH 8	Survival	96 hrs	Reduced survival but NS
Composite SPP	20 o/oo pH 6	Survival	96 hrs	No reduction in survival
Composite SPP	15 o/oo pH 6	Survival	96 hrs	Reduced survival but NS

[1]Results are presented as response of animals relative to control treatment.

[2]Significance refers to $P < 0.05$ using Students' t Test or single classification ANOVA.

NS = not significant.

Table 8. Whole Sediment and Suspended Particulate Phase (SPP) Bioassays with *Cyprinodon variegatus*.

Toxicant	Test Conditions	Test Parameters	Test Duration	Results[1]
Whole sediment	25 o/oo pH 8	Growth rate & survival	14 days	No reduction in growth rate[2]
Composite SPP	20 o/oo pH 8	Growth rate & survival	14 days	No reduction in growth rate
Composite SPP	20 o/oo pH 6	Growth rate & survival	14 days	No reduction in growth rate
Composite SPP	15 o/oo pH 8	Growth rate & survival	14 days	Reduced growth but NS
Composite SPP	15 o/oo pH 6	Growth rate & survival	14 days	No reduction in growth rate

[1]Results are presented as response of animals relative to control treatment.

[2]Significance refers to P <0.05 using Students' t Test or single classification ANOVA.

NS = not significant.

Table 9. Laboratory Toxicity Values for Standard Bioassay Organisms Exposed to Heavy Metals in Solution. and Chemical Composition of Stormwater and Sediment Samples.

SPECIES		Copper µg/l	Cadmium µg/l	Lead µg/l	Mercury µg/l	Zinc µg/l
Neanthes arenaceodentata	Acute 96 hr LC_{50}	350*	3300*	7500	100	670*
	Chronic	--	1000**	3100**	--	320**
Mysidopsis bahia	Acute 96 hr LC_{50}	--	15.5***	--	--	<1000*
Cyprinodon variegatus	Acute 96 hr LC_{50}	13800*	12200*	--	--	7800*
July 1982 stormwater		40	10	280	0.75	130
October 1982 stormwater		5	2	210	--	163
January 1983 stormwater		32	1	130	--	205
May 1983 stormwater ****		38	4	500	--	530
May 1983 first flush		--	30	1600	--	970
May 1983 sediment samples (ug/kg wet wt.)		--	1000	107000	--	69000
Suspended particulate phase (20 o/oo pH 6.0)		--	10	2800	--	2065

*Determined at MML.
**From Reish, et al. 1978
***From Nimmo et al., 1977
**** average suspended particulate load, 214 mg/l

IV. ALGAL ASSAYS

A. Introduction

Urban stormwater runoff has been shown to contain nutrients which may contribute to growth of phytoplankton in receiving water bodies. In some cases, this augmented phytoplankton growth may lead to eutrophic conditions and reduced water quality. Urban runoff pollutants may inhibit phytoplankton growth if present in sufficient quantities. Typically, a balance exists between the nutritive potential and toxic potential of runoff, and this balance can be measured through algal assay experiments. The present algal assays were designed to measure the effects of Artic Street drainage basin runoff upon natural and cultured phytoplankton. Only wet season runoff was tested due to the unavailability of dry season runoff during the operational phase of the algal assay system.

B. Methods

Acid washed, 250 ml cotton stoppered flasks were filled with 112 ml of water containing natural and cultured phytoplankton species, and the experiment initiated on July 19, 1982. The experiment ran for 2 weeks, terminating 2 August 1982.

Water samples were collected on July 19 at the four sites (Station 1 = University of Tampa site; Station 2 = Sligh Avenue Bridge; Station 3 = Buffalo Avenue Bridge; Station 4 = 22nd Street Bridge) along the Hillsborough River. Water temperature ranged from 28.5^{o}C to 32^{o}C at the time of collection.

The natural river water was filtered (0.45 um Millipore filter) to remove all phyto- and zooplankton and a dilution series (100%; 10%; 1%; 0% runoff) was used with the Artic Street runoff collected on July 16 and held in a 4^{o}C cold room. Added to 100 ml of the dilution series was 10 ml of unfiltered natural water from the original sites (Stations 1-4); 1 ml of a culture of *Scenedesmus quadricaudata* and 1 ml of a culture of *Anabaena flos-aquae*. All cultures were maintained on a 12 hour light/dark cycle in a growth chamber at 25^{o}C for the two week period.

C. Results

Table 10 shows the initial (background) biomass levels of each division of natural phytoplankton populations in a sample from each station taken on July 19, 1982. The initial concentration of S. quadricaudata and A. flos-aquae were 1.99 ul/l and 0.25 ul/l, respectively, at the beginning of the experiment. All counts were carried out at 200X using an Olympus inverted light microscope.

Table 11 shows the results of 2 weeks of culture using varying amounts of runoff water and natural water with a phytoplankton supplement. In all cases, the highest total biomass counts occurred at the 10 or 100% runoff dilution levels, suggesting no toxic effects and in fact a possible addition of nutrients. However, the main contributor to the higher biomass levels was S. quadricauda and the Chlorophyceae accounted for more than 70% of all the biomass because of this. These results are presented graphically in Figure 31.

Although the data are not completely consistent, there is a trend for an increase in most classes of algae with the addition of runoff. The major exception to this can be seen for the diatoms (Bacillariophyceae).

D. Conclusions

The wet season runoff obtained from the Artic Street watershed enhanced phytoplankton growth on a short term basis. Furthermore, the green algal component, dominated by the inoculum, Scendesmus quadricauda showed growth in 100% or 0% runoff additions, while the blue-green algae, dominated by the inoculum Anabaena flos-aquae, did not. Final total cell volumes were higher than initial concentrations in all dilutions at all stations, particularly in the higher percent runoff cultures suggesting the runoff water contained nutrients and not bioavailable toxic substances. The effect of runoff in the more estuarine Stations 1 and 2 was to depress the natural populations, and only when in high enough concentration did the inocula of Anabaena and Scenedesmus show growth. Thus, freshwater addition via urban runoff may affect natural phytoplankton populations at estuarine locations in addition to stormwater borne nutrients or pollutants. The effect of dry season runoff with its generally higher pollutant loads may be different than that demonstrated for wet season runoff. Dry season runoff was not tested in algal bioassays due to the unavailability of runoff samples during the course of this study.

Table 10. Initial phytoplankton biomass (μl/l) at four stations.

Control	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
Station A	-	.86	.26	1.12
Station B	-	.694	.41	1.1
Station C	-	2.14	.45	2.59
Station D	-	3.27	.44	3.71

Table 11A. Biomass (μl/l) of phytoplankton at Station 1.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff	2.25	24.29	2.439	28.979
10% Runoff	8.53	2.26	.253	11.043
1% Runoff	5.203	.798	.111	6.112
0% Runoff	5.03	1.75	.655	7.435

Table 11B Biomass (μl/l) of phytoplankton at Station 2.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff	2.509	32.67	.145	35.324
10% Runoff	-	2.97	.374	3.344
1% Runoff	-	.886	1.949	2.835
0% Runoff	-	2.4	1.769	4.169

Table 11C. Biomass (μl/l) of phytoplankton at Station 3.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff*	-	39.55	1.56	41.11
10% Runoff+	-	12.9	1.13	14.03
1% Runoff−	-	8.69	.536	9.226
0% Runoff	-	15.64	.155	15.795

*Various diatoms present but no one species present in large numbers.

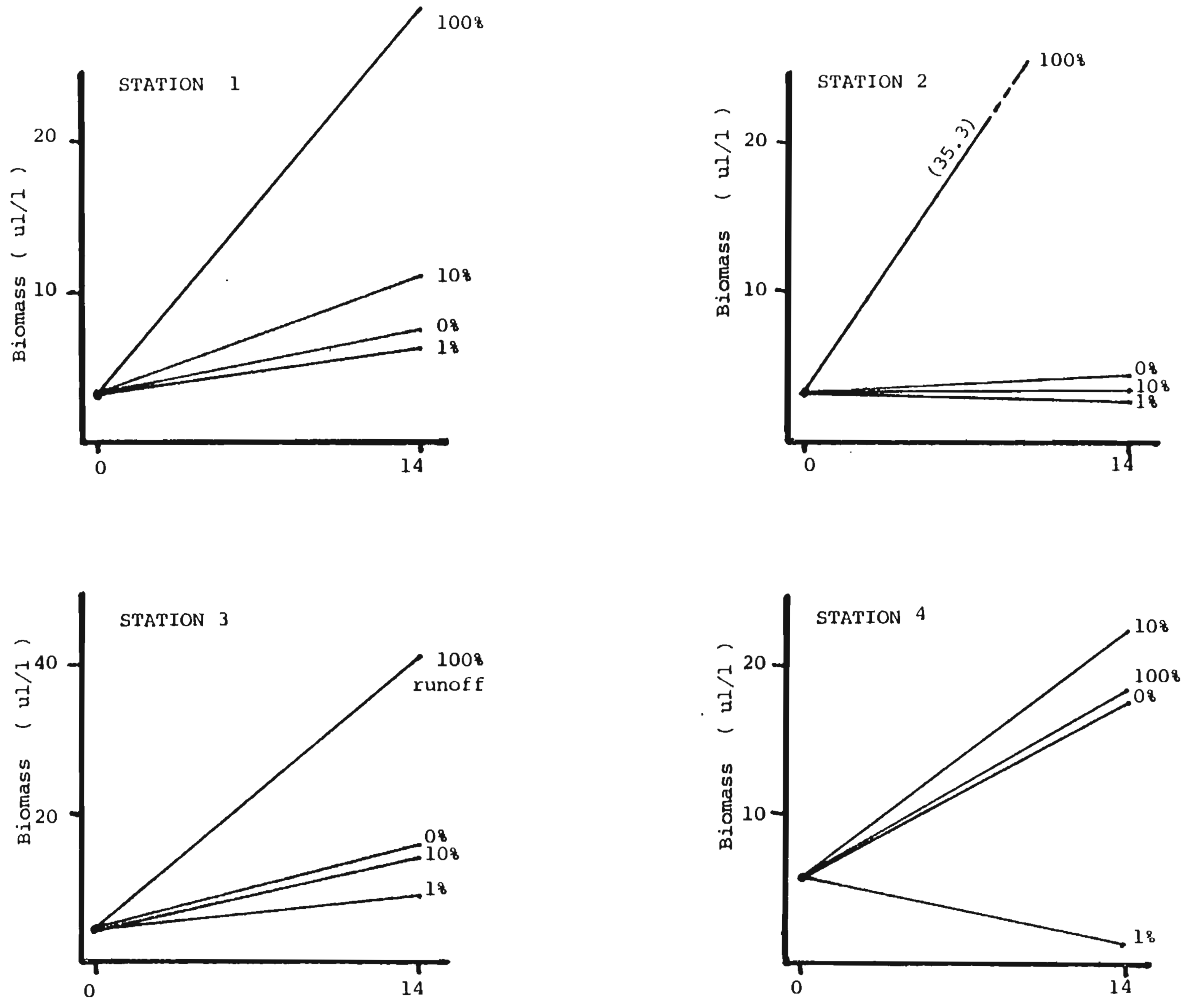
+High concentration of rotifers.

−Many *Anabaena* and *Scenedesmus* not living; various species of diatoms.

Table 11D Biomass (μl/l) of phytoplankton at Station 4.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff	-	17.7	.782	18.482
10% Runoff	-	21.5	.828	22.328
1% Runoff	-	.742	.543	1.285
0% Runoff	-	15.98	1.89	17.87

Figure 31. 14 day algal growth from laboratory experiments using river water from 4 different stations plus July, 1982 stormwater from Artic Street outfall. 100%= 100% runoff, 0% = 100% river water, etc



V. ZOOPLANKTON STUDIES

A. Introduction

Little information exists concerning the composition or dynamics of natural zooplankton populations in the Hillsborough River. The present study was undertaken to document the types and densities of zooplankton in the river and to determine how they are affected by wet and dry season conditions and by urban stormwater runoff.

B. Methods

Zooplankton were sampled at three week intervals from May 7 through August 16, 1982 at four stations on the Hillsborough River (Station 1 = University of Tampa; Station 2 = north of Buffalo Avenue; Station 3 = Sligh Avenue; and Station 4 = 22nd Street). Plankton were sampled with a high speed Miller sampler (Miller, 1961) equipped with a flowmeter and a 74 um Nitex net. An oblique tow was made at each station, beginning approximately 1 m off the bottom and ascending at a rate of 0.5 m every 30 seconds. With this procedure, each tow filtered between 600 and 2,000 liters of water (depending upon depth) and covered a distance of 75-150 m. Samples were preserved in 10% sugar-formalin solution (Haney and Hall, 1973) with rose bengal as a vital stain (Mason and Yevich, 1967).

All sampling was initiated at high tide during daylight hours. Sampling started at Station 1 and progressed upstream. The normal time interval to sample all four stations was approximately 4 hours.

On 25 August 1982, collections were made at Station 1 to assess variations in species compositions and densities over stages of a tide cycle. Sampling was initiated at low tide (1300 hr) and repeated at two hour intervals up through high tide (1900 hr).

In the laboratory, samples were diluted to a known volume and two or three replicate subsamples were counted in a modified rotary chamber (Ward, 1955). Subsample size was considered adequate when 200 individuals were counted and identified. Identification of specimens was to the lowest taxon possible.

C. Results

Zooplankton densities and percentages of marine organisms (calculated two ways because of bias in each method) at four sampling stations on the Hillsborough River during dry and wet seasons are presented in Table 12. Mean zooplankton densities (mean of all four stations) were 6.94 times greater during the dry season than during the wet season. Large differences in densities between sampling stations were found in both seasons, but should not be considered significant because of the low numbers of samples (three in each season). A long term sampling program with frequent samples would be necessary to document between station differences. Mean percentages of marine organisms (for all sampling stations) were between 68.0 and 78.1% for the dry season. The only sampling station to show an appreciable difference was Station 4, which was dominated by freshwater organisms (Table 12). However, during the wet season populations at all stations except Station 1, were predominantly freshwater organisms; percentages ranged from 17.9 to 24.8% marine organisms at the upper three stations. The high percentage of marine organisms at Station 1 was attributable to a large population of clam veligers on August 16.

A list of invertebrate taxa collected in the zooplankton samples from four stations on the Hillsborough River during dry and wet seasons is presented in Table 13. Twenty eight taxa were collected and the following differences between seasons were noted: 1) the number of species of rotifers and cladocerans increased markedly at all stations during the wet season; 2) the presence of copepod species, copepod nauplii and clam veligers remained constant between seasons; and 3) barnacle life stages dissappeared at all sampling stations during the wet season. These data support the finding of a predominance of freshwater species during the wet season. However, it should be noted that the presence of freshwater species in a sample from the lower river does not reflect the physiological or reproductive states of the organisms. Additional studies are necessary to assess tolerances of freshwater organisms to low salinity environments.

Densities of zooplankton at Station 1 over different tide stages on August 25, 1982 are presented in Table 14. There was little variation in total densities or in composition of the zooplankton community from 1300 (low tide) to 1700 hours. Between 1700 and 1900, however, there was a four-fold increase in density. This increase was attributable to increases in densities of copepods, specifically cyclopoid copepods (Table 15). Both cyclopoid species, Mesocyclops edax and Tropocyclops prasinus are freshwater copepods. Thus, the increase at high tide was not attributable to influx from Hillsborough Bay. Instead, it either was due to inflow from upstream or to diurnal migration. Mesocyclops edax is known to be benthic during the daylight hours and to migrate into the water column during the late afternoon and evening hours.

Table 16 shows the densities of major groups of zooplankton at each station on each collection date.

D. Conclusions

This small set of zooplankton samples indicates that densities are high and are comprised principally of marine organisms during the dry season (before opening of the 30th Street Dam). During the wet season densities are low and are comprised principally of freshwater organisms. The differences in densities probably are attributable to water exchange rates (flushing times). During the dry season flushing time is slow and zooplankton populations can reproduce and increase in density as long as food is abundant. However, in the wet season, flushing time is more rapid, zooplankton do not appear to be able to maintain position within the river, and salinity changes may influence survival. Studies of flow rates and movements of plankton populations are necessary to confirm these hypotheses.

During the wet season, pollutant loads in the water column due to urban runoff are probably low enough to have little direct effect upon zooplankton. Flow rates and flushing times probably have more influence on zooplankton composition than runoff pollutants. Dry season runoff, with its higher pollutant loads, may have acute or chronic toxic effects on some zooplankton species especially near major storm drains. The long term effects of pollutant accumulation in river sediments on zooplankton communities remains to be determined. Zooplankton species provide a food source for pelagic species and also contain larval forms that colonize the benthos. These species represent an integral part of the river ecological system.

TABLE 12. Comparison of total densities of zooplankton at four stations on the Hillsborough River at time intervals before and after opening of the 30th Street Dam; dry versus wet seasons. Two estimates of percentage of marine organisms are presented also: the upper estimate is the percentage of total organisms captured during the sample interval, and the lower estimate is the mean of daily percentages.

	Density in No. per Liter & Percent Marine Species at Four Sampling Stations				
Time Interval	Station 4	Station 3	Station 2	Station 1	Mean
Before					
May 7-June 15	70.39	272.83	250.97	70.95	166.28
	37.2%	96.0%	71.2%	74.5%	78.1%
	48.7%	90.5%	71.8%	61.2%	68.0%
After					
July 6-August 16	2.64	1.61	3.03	88.57	23.96
	20.6%	20.3%	24.8%	69.8%	66.2%
	20.3%	17.9%	24.8%	50.9%	28.4%
Total					
May 7-August 16	36.51	137.16	127.00	79.76	95.11
	36.6%	95.6%	70.6%	71.9%	76.6%
	34.5%	54.2%	48.3%	56.1%	48.3%

TABLE 13. List of invertebrate taxa collected in zooplankton samples from the Hillsborough River, Florida May-August 1982. Freshwater taxa are indicated with an asterisk (*), and estuarine and marine taxa with a plus (+). Presence of each taxon at each station during wet and dry seasons also is indicated.

	STATION							
	4		3		2		1	
	D	W	D	W	D	W	D	W
Phylum Rotifera								
Class Monogononta								
Family Brachionidae								
*Brachionus caudatus**								X
*Brachionus havanensis**		X		X		X		X
Brachionus plicatilis+		X					X	X
Euchlanis sp.*	X	X		X				X
*Keratella erlinae**		X		X		X		X
*Kellicottia bostoniensis**								X
Lepadella sp.*		X						
*Platyias quadridentata**		X		X		X		X
Family Lecanidae								
Lecane sp.*		X		X		X		X
*Monostyla bulla**	X	X		X		X		X
Family Asplanchnidae								
Asplanchna sp.*		X				X		
Phylum Annelida								
Class Polychaeta								
Unid. polychaete larvae+	X	X	X	X	X		X	X
Phylum Arthropoda								
Class Crustacea								
Subclass Branchiopoda								
Order Cladocera								
*Diaphanosoma leuchtenbergianum**		X		X		X		X
*Daphnia ambigua**		X				X	X	
*Simocephalus expinosus**		X			X	X	X	X
*Ceriodaphnia lacustris**	X	X	X	X				
*Leydigia quadrangularis**		X		X		X		
*Bosmina longirostris**	X	X		X	X	X	X	X
Subclass Copepoda								
Order Calanoida								
*Diaptomus dorsalis**	X	X	X			X	X	X
Paracalanus spp.+	X	X	X	X	X	X	X	X
Order Cyclopoida								
*Tropocyclops prasinus**	X	X	X	X	X	X	X	X
*Mesocyclops edax**	X	X	X	X	X	X	X	X

Order Harpacticoida								
<u>Euterpina</u> sp.+	X	X	X	X	X	X	X	X
Copepod nauplii*+	X	X	X	X	X	X	X	X
Subclass Cirripedia								
Unid. barnacle nauplii+	X		X		X		X	
Unid. barnacle cypris larvae+	X		X					
Subclass Malacostraca								
Order Decapoda								
<u>Rhithropanopeus harrisii</u> (zoea)+	X		X				X	
Phylum Mollusca								
Class Pelycopoda								
Unid. clam veliger+	X	X	X	X	X	X	X	X
TOTAL NUMBER OF TAXA	15	23	12	17	10	18	14	20

TABLE 14. Changes in the densities of zooplankton at Station 1 at different tide stages on August 25, 1982.

			Density in Number Per Liter					
Time (hrs)	Tide Stage	Total Organisms	Cope-pods	Nauplii	Roti-fers	Clado-cera	Clam veligers	Polychaete larvae
1300	Low	2.43	0.92	1.16	0.07	0.00	0.28	0.00
1500	Low	1.90	1.06	0.56	0.03	0.11	0.14	0.00
1700	Low	2.16	0.38	0.95	0.52	0.11	0.20	0.00
1900	High	9.35	4.76	2.78	0.20	0.13	0.98	0.49

TABLE 15. Copepod densities over a tidal cycle at Station 1 on August 25, 1982.

Time (hrs)	Tide Stage	Cyclopoida Adults	Copepodids	Calanoida	Harpacticoida
		Density in Number Per Liter			
1300	Low	0.20	0.47	0.25	0.00
1500		0.81	0.25	0.00	0.00
1700		0.21	0.06	0.03	0.08
1900	High	3.21*	1.38	0.00	0.17

*60% *Mesocyclops edax* and 40% *Tropocyclops prasinus*.

TABLE 16. Hillsborough River zooplankton data. Stations: 4 = 22nd Street; 3 = Sligh Avenue; 2 = Buffalo Avenue; 1 = University of Tampa. Others include: crab zoea, polychaete larvae, barnacle cyprids. Density = no. organisms per liter.

STATION 4; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	4.200
Cladocera	0.320
Clam veligers	0.220
Adult and copepodid copepods	24.970
Copepod nauplii	91.170
Miscellaneous organisms	0.000
Rotifers	0.000
Total organisms	120.880

STATION 4; DATE: MAY 25, 1982

Organism	Density
Barnacle nauplii	5.2000
Cladocera	0.0000
Clam veligers	10.7000
Adult and copepodid copepods	38.7000
Copepod nauplii	64.2800
Miscellaneous organisms	0.2700
Rotifers	0.0000
Total organisms	74.6800

STATION 4; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	1.9700
Cladocera	0.3700
Clam veligers	2.4600
Adult and copepodid copepods	3.4400
Copepod nauplii	6.6300
Miscellaneous organisms	0.2500
Rotifers	0.4900
Total Organisms	15.6100

STATION 4; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.28000
Clam veligers	0.08000
Adult and copepodid copepods	0.31000
Copepod nauplii	0.71000
Miscellaneous organisms	0.04000
Rotifers	1.28000
Total organisms	2.69000

STATION 4; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.20000
Clam veligers	0.15000
Adult and copepodid copepods	0.58000
Copepod nauplii	0.61000
Miscellaneous organisms	0.03000
Rotifers	0.53000
Total organisms	2.11000

STATION 4; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.12000
Clam veligers	0.06000
Adult and copepodid copepods	0.57000
Copepod nauplii	1.12000
Miscellaneous organisms	0.00000
Rotifers	1.25000
Total organisms	3.11000

STATION 3; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	0.6200
Cladocera	0.0000
Clam veligers	11.5900
Adult and copepodid copepods	0.9500
Copepod nauplii	13.1200

Miscellaneous organisms	0.5000
Rotifers	0.0000
Total organisms	26.7800

STATION 3; DATE: MAY 25, 1982

Organism	Density
Barnacle nauplii	29.330
Cladocera	0.000
Clam veligers	451.350
Adult and copepodid copepods	15.380
Copepod nauplii	229.770
Miscellaneous organisms	4.190
Rotifers	0.000
Total organisms	730.520

STATION 3; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	0.6900
Cladocera	0.5500
Clam veligers	33.2400
Adult and copepodid copepods	10.4400
Copepod nauplii	15.1100
Miscellaneous organisms	0.8200
Rotifers	0.0000
Total organisms	60.8500

STATION 3; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.06000
Clam veligers	0.07000
Adult and copepodid copepods	0.53000
Copepod nauplii	1.08000
Miscellaneous organisms	0.04000
Rotifers	0.40000
Total organisms	2.18000

STATION 3; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.000000

Cladocera	0.130000
Clam veligers	0.000000
Adult and copepodid copepods	0.260000
Copepod nauplii	0.100000
Miscellaneous organisms	0.020000
Rotifers	0.080000
Total organisms	0.580000

STATION 3; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.02000
Cladocera	0.07000
Clam veligers	0.12000
Adult and copepodid copepods	0.55000
Copepod nauplii	0.94000
Miscellaneous organisms	0.00000
Rotifers	0.37000
Total organisms	2.07000

STATION 2; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	2.960
Cladocera	0.350
Clam veligers	2.270
Adult and copepodid copepods	4.020
Copepod nauplii	181.820
Miscellaneous organisms	0.520
Rotifers	0.000
Total organisms	191.940

STATION 2; DATE: MAY 25, 1982

Organism	Density
Barnacle nauplii	0.000
Cladocera	0.000
Clam veligers	4.990
Adult and copepodid copepods	6.240
Copepod nauplii	304.340
Miscellaneous organisms	1.250
Rotifers	0.000
Total organisms	316.820

STATION 2; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	0.930
Cladocera	0.930
Clam veligers	150.150
Adult and copepodid copepods	45.600
Copepod nauplii	44.690
Miscellaneous organisms	1.850
Rotifers	0.000
Total organisms	244.140

STATION 2; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.04000
Clam veligers	0.28000
Adult and copepodid copepods	0.25000
Copepod nauplii	0.76000
Miscellaneous organisms	0.00000
Rotifers	0.59000
Total organisms	1.92000

STATION 2; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.25000
Clam veligers	0.06000
Adult and copepodid copepods	0.36000
Copepod nauplii	1.45000
Miscellaneous organisms	0.00000
Rotifers	0.61000
Total organisms	2.74000

STATION 2; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.16000
Clam veligers	0.50000
Adult and copepodid copepods	1.02000
Copepod nauplii	2.02000

Miscellaneous organisms	0.02000
Rotifers	0.71000
Total organisms	4.42000

STATION 1; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	2.6500
Cladocera	0.1400
Clam veligers	2.7400
Adult and copepodid copepods	5.7500
Copepod nauplii	22.9900
Miscellaneous organisms	0.1800
Rotifers	0.0000
Total organisms	34.4500

STATION 1; DATE: MAY 25, 1983

Organism	Density
Barnacle nauplii	6.230
Cladocera	0.000
Clam veligers	5.590
Adult and copepodid copepods	3.510
Copepod nauplii	120.640
Miscellaneous organisms	0.130
Rotifers	0.000
Total organisms	136.100

STATION 1; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	0.0000
Cladocera	0.5500
Clam veligers	7.9000
Adult and copepodid copepods	18.3300
Copepod nauplii	15.0700
Miscellaneous organisms	0.4400
Rotifers	0.0000
Total organisms	42.2900

STATION 1; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000

Cladocera	0.06000
Clam veligers	0.59000
Adult and copepodid copepods	0.44000
Copepod nauplii	0.13000
Miscellaneous organisms	0.03000
Rotifers	0.14000
Total organisms	1.39000

STATION 1; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.0000
Cladocera	0.4700
Clam veligers	5.1900
Adult and copepodid copepods	34.8100
Copepod nauplii	18.7800
Miscellaneous organisms	0.1000
Rotifers	0.3800
Total organisms	59.7300

STATION 1; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.000
Cladocera	0.000
Clam veligers	153.180
Adult and copepodid copepods	24.140
Copepod nauplii	23.890
Miscellaneous organisms	1.040
Rotifers	2.340
Total organisms	204.600

VI. PHYTOPLANKTON STUDIES

A. Introduction

The goal of this study was to determine the dominant species present and total cell volume of phytoplankton before and after the opening of the dam on the Hillsborough River. These data were used to study the effects of runoff on the phytoplankton populations. Samplings occurred at three week intervals from May 7 through August 16, 1982 at four stations and two sites at each station.

B. Methods

The following procedures were followed:

a) All samplings were taken at high tide during daylight hours.

b) Samplings began at Station 1 and progressed upstream, normal sampling time for all four stations was 4 hours.

c) Samplings were made with a van Dorn water bottle and were taken in the first meter of water.

d) Stations were at the University of Tampa (Station 1), the Buffalo Avenue Bridge (Station 2), the Sligh Avenue Bridge (Station 3), and the 22nd Street Bridge, about 1/4 mile from the dam (Station 4).

On August 25, a tide-state variation sampling was made at Station 1 at the University of Tampa site with collections taken every 2 hours from low tide (noon) to high tide (1900 hrs).

C. Results

Total densities, density of the dominant algal group, and chlorophyll 'a' levels are given for the 8 substations in Tables 17-20, for the dates May 7 through August 16. Note that three dates precede the dam opening (May 7 and 25; June 15) and three dates follow the dam opening (July 6, 30; August 16).

It is evident that total biomass was highest at all four stations before the opening of the dam (May 7, 25; June 15). In nearly all cases biomass was highest in substations in the river center. Diatoms were the dominant group of phytoplankton found, generally accounting for over half of the total biomass. Chlorophyll 'a' levels were highest just before the dam opened and highest at the University of Tampa site. Species composition changed from freshwater forms to marine forms, progressing from

Station 4 to Station 1.

Total density, density of the dominant algal group and chlorophyll 'a' levels are given in Table 21 for Station 1 (University of Tampa site) for August 25 in which the effects of a tidal change were followed.

It is evident that diatoms dominated at low tide and green algae dominated at high tide. A confounding factor was the effect of an incoming tide on the outflow of the river. It may be that the surface phytoplankton, which were more freshwater in nature, were held back during the period of high tide causing a biomass increase. Chlorophyll 'a' levels also changed, showing an increase with the green algae.

D. Conclusions

In general, the level of cell volume was high, approaching a eutrophic lake condition before the opening of the dam and lower afterward being similar to a lake of lower trophic status. The effect of salinity is another confounding factor and the changes in species composition both due to tidal and site location make comparisons difficult.

As with zooplankton populations, phytoplankton composition and density appears to be largely affected by river flow rates, with higher densities present during low river flow periods and lower densities during high flow periods. The net effect of urban runoff is likely to be stimulatory to natural populations of phytoplankton, although this may be tempered by changes in salinity or pollutant concentrations in certain locations.

Table 17 Total densities, density of dominant algal group, and chlorophyll a level at Station 1 (University of Tampa site) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	7.67	5.78 (Diatoms)	26.7
	B	12.67	11.91 (Diatoms)	23.2
25 May	A	26.89	24.58 (Diatoms)	32.1
	B	6.20	3.88 (Diatoms)	21.4
15 June	A	17.64	10.20 (Dinoflag.)	49.0
	B	17.90	14.36 (Diatoms)	51.5
6 July	A	5.22	4.21 (Dinoflag.)	4.3
	B	1.78	1.32 (Diatoms)	4.3
30 July	A	4.85	4.65 (Diatoms)	6.5
	B	--	—	10.1
16 Aug.	A	2.45	1.20 (Dinoflag.)	12.7
	B	2.71	1.02 (Chrysophy.)	14.7

[1]Biomass expressed as ul/l.

[2]Chlorophyll a expressed as ug/l.

A Near storm drain
B Center of river

Table 18 Total densities, density of dominant algal group, and chlorophyll a levels at Station 2 (Buffalo Avenue) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	27.61	13.36 (Dinoflag.)	33.7
	B	18.24	12.85 (Dinoflag.)	--
25 May	A	6.45	2.45 (Diatoms)	26.1
	B	7.02	3.80 (Diatoms)	11.4
15 June	A	0.94	0.37 (Cryptophy.)	7.4
	B	1.10	0.64 (Cryptophy.)	7.6
6 July	A	1.24	0.84 (Cryptophy.)	50.8 (detritus)
	B	2.62	1.06 (Cryptophy.)	32.1
30 July	A	0.83	0.48 (Diatoms)	14.1
	B	3.74	2.25 (Diatoms)	17.3
16 Aug.	A	3.95	2.37 (Diatoms)	19.0
	B	2.61	1.12 (Dinoflag.)	29.7

[1]Biomass expressed as ul/l.

[2]Chlorophyll a expressed as ug/l.

A Center of river
B Near cattails on east side

Table 19 Total densities, density of dominant algal group, and chlorophyll a levels at Station 3 (Sligh Ave. bridge) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	14.95	8.12 (Cryptophy.)	29.9
	B	5.53	1.96 (Cryptophy.)	3.7
25 May	A	4.67	2.06 (Diatoms)	18.81
	B	15.24	12.34 (Dinoflag.)	24.73
15 June	A	0.53	0.23 (Diatoms)	20.97
	B	0.95	0.54 (Cryptophy.)	--
6 July	A	2.46	1.18 (Cryptophy.)	27.3
	B	2.83	1.25 (Dinoflag.)	28.3
30 July	A	6.77	5.73 (Diatoms)	27.3
	B	2.34	2.01 (Diatoms)	28.3
16 Aug.	A	1.02	0.37 (Dinoflag.)	19.2
	B	0.85	0.38 (Cryptophy.)	18.7

[1] Biomass expressed at ul/l.

[2] Chlorophyll a expressed at ug/l.

A Center of river
B West bank, north of bridge

Table 20 Total densities, density of dominant algal group, and chlorophyll a levels at Station 4 (22nd Street bridge, ¼ mile from dam) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	7.78	6.90 (Chrysophy.)	17.6
	B	1.35	0.60 (Diatoms)	10.8
25 May	A	3.58	3.03 (Diatoms)	2.0
	B	0.86	0.76 (unknown)	7.4
15 June	A	2.30	1.24 (Chlorophy.)	9.9
	B	3.07	1.60 (Chlorophy.)	6.5
6 July	A	1.30	0.61 (Diatoms)	24.1
	B	3.47	3.06 (Diatoms)	15.0
30 July	A	2.54	2.36 (Diatoms)	14.8
	B	5.29	4.43 (Diatoms)	15.6
16 Aug.	A	3.04	1.45 (Diatoms)	18.7
	B	1.68	1.46 (Diatoms)	22.5

[1] Biomass expressed at ul/l.

[2] Chlorophyll a expressed at ug/l.

A Center of river
B Near east bank

Table 21 Tidal change effect on total phytoplankton density, density of dominant group of phytoplankton and chlorophyll a levels at Station 1 (Hillsborough River at University of Tampa site) on 25 August, 1982).

Time	Substation	Total Density[1]	Density of Dominant Group[1]	Chlorophyll a[2]
12:45 PM	A	3.46	1.70 (Diatoms)	10.0
	B	6.15	3.60 (Diatoms)	20.1
2:45 PM	A	2.45	1.71 (Diatoms)	22.7
	B	2.24	1.54 (Diatoms)	43.7
4:45 PM	A	2.94	1.78 (Chlorophyl.)	34.3
	B	1.14	0.33 (Cryptophy.)	33.3
6:45 PM	A	4.92	2.15 (Chlorophy.)	33.0
	B	1.93	0.82 (Dinoflag.)	25.8

[1] Biomass expressed as ul/l.

[2] Chlorophyll a levels expressed at ug/l.

A Near storm drain
B Center of river

VII. LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY

A. Introduction

This section describes the findings and recommendations from the Hillsborough River receiving waters biological study, Task V, conducted by Mote Marine Laboratory (MML) and Mangrove Systems, Inc. (MSI) for the City of Tampa. Task V has these objectives:

- o To identify existing shoreline conditions, including public shores and stormwater outfalls;
- o To identify opportunities for increasing shoreline vegetation and modifying existing stormwater outfalls on public shores for the purpose of improving water or habitat quality in the lower Hillsborough River.

Described herein are the findings on shoreline types and use, based upon two boat trips along the river shores from Davis Island to the reservoir, and two land-based tours.

B. Results

Shoreline Categories

Shorelines of the Lower Hillsborough River were classified by the structures or vegetation thereupon. Nonexclusive categories used in this study are listed below.

1. Bulkheads

A bulkhead is a wall or embankment constructed to protect the shore from erosion. Bulkheads are typically made of concrete slabs poured in place or elsewhere; or bricks, blocks, sandbags or other materials bound with a cement matrix. Bulkheads on the lower river are made of poured slabs, concrete block, sandbags, wood, or steel.

2. Riprap

Riprap is a loose assemblage of broken stones erected on shors to protect against erosion. Riprap is usually distinguished from fill by involving graded banks, roundstone or roughly uniform size, and their stable arrangement. Materials used for riprap on the lower river include stones (mostly limestones), blocks and slabs of cement, or composites.

3. Fill

Fill is earth dredged from the river or dumped onto shorelines to increase upland property or retard erosion. Occasionally, fill material will contain logs, large blocks, rubbish, or other incompatible objects. The fill may be vegetated or not.

4. Native Shores

These are banks of the river judged by their aspect, elevation, and relation to other features to be not greatly different than their historic condition. Vegetation on native shores may be residential landscape, exotic, or native. Examples of each are given below.

Residential Landscape:	Willow, hollies, palm, bamboo, fig, citrus.
Exotic Vegetation:	Australian pine, punk tree (cajeput), Brazilian pepper, Eucalyptus.
Native Vegetation:	Cypress, leatherfern, cattail, black needlerush, oak, palm.

5. Related Features

Observations were also made on the erosion of hardened and other shores, limits of salt and freshwater indicators, and novel uses of the river.

Shoreline Condition

1. Overview

Approximately 54 percent of the lower river shorelines have been hardened. The shores hardened by bulkhead constitute ca. 47 percent; riprap, 8 percent. About 13 percent of the river's shores are filled but unhardened and 34 percent are native. (Note: A total of 102% for these figures is due to their nonexclusive nature.) Most bulkhead was of poured slab construction (6.3 mi). Concrete block bulkhead accounted for 1.5 mi total. Wood and cemented sandbag bulkhead each totaled 0.4 mi; all but 2 segments of wood walls are of recent construction. Another half mile of bulkhead (total) is constructed of miscellaneous material. Riprap of all kinds accounted for 1.3 mi, and a total of 2.5 shoreline miles have been filled. A summary of shoreline composition for the east and west banks is presented in Tables 22 and 23.

Table 22.

LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY - EAST BANK.
Numbers represent inches of shoreline from a map of scale: 1 inch = 400 feet.

SEGMENT	SEGMENT LENGTH	BH SLAB+ CAP	BH CB+ MORTAR	BH SANDBAGS +MORTAR	BH WOOD	BH STEEL	BH OTHER	RR STONE OR SLAB	RR MIXED	RR TOTAL	FILL LARGE RUBBLE	FILL DIRT	FILL TOTAL	NATURAL SHORE VEGETATION (NATIVE)	NATURAL SHORE VEGETATION (EXOTIC)	TOTAL NATURAL SHORE
PLATT/KENNEDY	7.0	7.0														
KENNEDY/CASS	5.5	5.5														
CASS - I-275	12.0	12.0														
I-275 - N. BOULEVARD	14.0	8.0			3.5	2.5										
N. BOULECARD - COLUMBUS	17.5	3.0	1.0					1.0	1.5			6.0		(IJ) 4.5(IT)		
COLUMBUS - TURTLE CR.	7.5	2.0	1.0					3.0			1.5	6.0		1.0(T)		
TURTLE CR - BUFFALO	25.0	5.5(3.0F)						6.0						6.0(IJ/IT)		
BUFFALO - D.F.11-8	16.5	4.5(4.0F)		1.5				8.0			1.0			3.0(.ST)	1.0	
D.F.11-8 - HILLSBORO	16.5	5.0						0.5						7.5(3.OT)	1.0	
HILLSBORO - HENRY	16.5	7.0(1.5F)	3.5								3.0			0.5	6.0	
HENRY - SLIGH	29.0	18.0(.5F)						3.5			2.0	3.0			3.0	
SLIGH - KIRBY	14.0	9.0(1.5F)			1.0		(4.0STONE)				. .			.	.	1.0
KIRBY - I-75	18.5	2.5(2.0F)	1.0(F)		1.0						1.0			5(.5 E)	5.0(AP)	
I-75 - NEBRASKA	5.0		2.0(1F)	3.0												
NEBRASKA - CRENSHAW	17.5	4.0(1F)		2.5(2F)				1.0					2.0	9.0		
CRENSHAW - ROWLETTE	27.0	2.5	1.0(F)	1.0	2.0							2.5		12.5		
ROWLETTE - DAM	12.5													12.5		
	261.5	95.5	9.5	8.0	7.5	2.5		23.0	1.5		8.5	17.5	2.0	61.5	16.0	
		(36.5%)	(3.6%)	(3.0%)	(2.8%)	(0.9%)		(8.7%)	(0.5%)		(3.2%)	(6.6%)	(0.7%)	(23.5%)	(6.1%)	

TOTAL HARDENED SHORE - 57.9%

2,900 FT BULKHEAD IS FAILING
800 FT CONCRETE BLOCK WALL FAILING
100 FT ERODING

MOST TIDAL JUNCUS AND TYPHA 1,000' ABOVE N. BLVD
1ST CYPRESS TREE 1,200 FT BELOW BUFFALO

Table 23.
LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY - WEST BANK.
Numbers represent inches of shoreline from a map of scale; 1 inch = 400 feet.

SEGMENT	SEGMENT LENGTH	BH SLAB+ CAP	BH CB+ MORTAR	BH SANDBAGS +MORTAR	BH WOOD	BH STEEL	BH OTHER	RR STONE OR SLAB	RR MIXED	RR TOTAL	FILL LARGE RUBBLE	FILL DIRT	FILL TOTAL	NATURAL SHORE VEGETATION (NATIVE)	NATURAL SHORE VEGETATION (EXOTIC)	TOTAL NATURAL SHORE
PLATT/KENNEDY	6.5	6.0	0.5(F)													
KENNEDY/CASS	6.5	6.5														
CASS - I-275	12.5	12.5														
I-275 - N. BOULEVARD	16.0	16.0														
N. BOULEVARD - COLUMBUS	21.0	4.0	5.0				14.0				6.5				6.5(BP)	
COLUMBUS - TURTLE CR.	7.0					1.0								6.0(2.5T)		
TURTLE CR. - BUFFALO	27.0	12.0(1.0F)	5.0		1.0	3.0		2.5							1.0(BP)	
BUFFALO - D.P.11-8	18.5	7.0												7.5(2.0J, 5.5T)		
D.P.11-8 - HILLSBOROUGH	14.5	3.5												8.0(.5J, 7.5T)	2.0(BP)	
HILLSBORO - HENRY	16.0				2.0							8.0(2.0E)		4.5(3.5T, 1.0C)		
HENRY - SLIGH	30.0	2.5	7.5(1.0F)	1.0				3.0	2.0(1.0SB)			2.0		4.5	5.5	
SLIGH - KIRBY	14.0		2.0								1.0	11.0			11.0	
KIRBY - I-75	20.0	0.5						3.0			1.0			5.5(3T)	6.0	
I-75 - NEBRASKA	4.5							4.5			4.5					
NEBRASKA - CRENSHAW	18.0		6.0						3.0(SB)		1.0 TRASH			8.5(1.0C)		
CRENSHAW - ROWLETTE	25.0	1.0	5.0(2.0F)	0.5	1.0					1.5				15.0		
ROWLETTE - DAM	11.0												3.0 (ASPHALT)	9.0(4.0E)		
	268.0	71.5	31.0	1.5	4.0	4.0	117.0	13.0	5.0	19.5	14.0	21.0	38.0	68.5	32.0	100.5
		(26.6%)	(11.5%)	(0.5%)	(1.4%)	(1.4%)	(43.6%)	(4.8%)	(1.8%)	(7.2%)	(5.2%)	(7.8%)	(14.1%)	(25.5%)	(11.9%)	(37.5%)

TOTAL HARDENED SHORE - 50.9%
200 FT BULKHEAD IS FAILING
700 FT CONCRETE BLOCK WALL FAILING
1,200 FT ERODING SHORELINE

MOST TIDAL TYPHA 800 FT ABOVE COLUMBUS DRIVE
MOST TIDAL JUNCUS 50 FT ABOVE BUFFALO AVENUE
MOST UPLAND JUNCUS 1400 FT BELOW HILLSBOROUGH AVENUE; TYPHA TO DAM

F = failing; T = *Typha*; BP = Brazilian pepper; J = *Juncus*; C = cypress; E = eroding; SB = sandbag; 1 MILE = 5,280 FT

2. Trends Across the River

The east (and south) bank of the lower river has approximately 7 percent more hardened shores than the other bank. The east bank has more failing walls, totaling 2,900 ft of bulkhead and 800 ft of concrete block compared to 200 ft of bulkhead and 700 ft of block on the west bank. By proportion to the total length of these walls on both banks, twice as much concrete block wall is failing than slab types, illustrating the relative inadequacy of concrete block as wall material. More of the west bank is actively eroding (1,260ft compared to 100 ft on the other shore). This fact is attributed to the shorter length of protected shoreline and to the general southwesterly course of the river.

3. Trends Down River

Contrary to our expectations based upon the total bulkheading of the river in downtown Tampa, no trends in the amount or kind of hardened shores were otherwise evident when data were analyzed along the length of the river. Bulkhead, riprap, fill and native shores occur in varying proportions from N. Boulevard upstream to Rowlett Park.

4. Vegetation

Five species indicative of long term salinity regimes were encountered on the banks of the lower river.

a)	Southern bald cypress	<u>Taxodium</u> <u>distichum</u>
b)	Cattail	<u>Typha</u> sp.
c)	Leatherfern	<u>Acrostichum</u> <u>danaeaefolium</u>
d)	Black rush	<u>Juncus</u> <u>roemerianus</u>
e)	Cordgrass	<u>Spartina</u> spp.

The species are listed in order of their approximate tolerance to saltwater, cypress being completely intolerant.

No clear pattern of zonation is evident among these plants along the length of the lower river due probably to logging, shoreline modifications, and the highly variable salinity regime of the river. For example, the most downstream cattails and rush occur together, approximately 1,000 ft above the N. Boulevard Bridge. Cattails grow on banks upriver to the dam, whereas the uppermost rushes were found 1,400 ft below Hillsborough Avenue.

Five small patches of rush were found altogether. Ten patches of cattails, some up to 1,500 linear ft in size, were also noted. Cypress were solitary and disjunct. The cypress found 1,200 ft below Buffalo Avenue were the most downriver of that form. Exotic vegetation occurs on the river banks in three types: as (i) pure stands of either pine or pepper; (ii) mixed species growing as fringes adjacent to native or ornamental vegetation; or (iii) as small isolated stands. All together, approximately 9,600 ft of river bank was vegetated by Australian pine or Brazilian pepper. Of that length, about one third occurred below the Sligh Avenue Bridge and could therefore be eligible for restoration as native estuarine shoreline.

Other Observations

1. Construction of various types was in progress or recently completed on the river, including seawall and riprap installations, creek "improvements", and sanitary sewerage (Figure 38). During the interval between trips, one stand of cattail fronting an apartment house was destroyed.

2. Public shores on the river are in varied condition but include segments worthy of immediate improvement. Examples include the irregular filling at Lowry Park (Figure 39), dumping of waste asphalt at Rowlette Park, and severe erosion at the Eddie Lopez tract.

3. Freshwater sources to the river were evident even though most were observed during the dry season. Minor springs were found on either shore of the river above Hillsborough Avenue, and all four creeks were flowing, albeit at low levels.

4. Vacating of rights-of-ways, mostly streets, ending at the river was noticed in several places (Figure 42). Continuation of this process may preclude use of these public lands for "pocket parks", stormwater basins, or habitat patches. At the very least DPW Stormwater Management Division should review all petitions to vacate for consistency with the stormwater control plan.

Recommendations

Our recommendations are predicated upon the following observations and opinions.

1. The lower Hillsborough River is generally free of point sources but affected in various ways by stormwater, tidal incursions, and reservoir discharge.

2. The salinity wedge ranges from Columbus Drive (where a natural sill occurs) at high flows to Sligh Avenue (where the river becomes incised) at low flow.

3. Sligh Avenue is also the upriver limit during low flows of the 5 o/oo isohale at the surface (e.g., intertidal) zone.

4. No clear patterns of natural salinity zonation in shoreline vegetation are present due to historical (e.g., logging, filling or other man-induced habitat changes) and natural causes (e.g., responses to damming, rising sea level, freeze effects, etc.).

5. Several benefits would result from the restoration/creation of plant communities on the shorelines of the lower river.

First, we recommend that the City of Tampa recognize the river section between Sligh Avenue and North Boulevard as the preferred area for immediate shoreline improvements. This suggestion stems from the topographic and hydrographic character of the river (Figure 32) and the complexity of repair efforts of river segments above or below the described segment. Topographic character refers to the wide, level, historically inundated flood plain, while hydrographic character refers to the zone of salinity transition in surface waters and areas where shores are level enough to intercept runoff. The segment above Sligh Avenue contains shorelines in need of repair or restoration for aesthetic or structural reasons (e.g., irregular fill at Lowry Park; erosion at Eddie Lopez tract; or waste asphalt at Rowlette Park), but the segment's steep and intensively used shorelines will require more extensive planning for repair and may be more costly. Eventually all these areas should be restored.

Second, we recommend that a 3 phase plan of shoreline improvement be developed for the target segment, as follows:

a) creation/restoration of vegetated shorelines on public lands;

b) removal of exotic plant species from natural and filled shorelines;

c) replacement of riprap shorelines by native vegetation.

Each is developed in turn.

Creation/Restoration of Vegetated Shorelines on Public Lands

Emphasis in this phase should be placed on 3 elements:

- o aesthetic improvement of public vistas;
- o redesign of creek mouths for habitat value;
- o creative use of drainage easements, rights-of-ways, and other public land.

Specific areas suggested for improvement include:

Creeks at N. Boulevard (near Circle Drive), Rome and Albany, Hillsborough Avenue (upstream, on either bank near flowing wells) (Figures 33, 34, & 35).

Vistas from N. Boulevard Bridge (shoreline along both banks above bridge), Columbus Drive Bridge (west bank up to Fremont), and Buffalo Avenue Bridge (between River Club and Park Lane extension) (Figure 2).

Removal of Exotic Plant Species from Natural and Filled Shorelines

The majority of unhardened shoreline on both banks occurs in the "estuarine" segment between N. Boulevard and Sligh Avenue. Some of these shores were created by filling but have not been stabilized. Regrading combined with exotic species control and replanting would establish useful habitat and reduce the adverse ecological impacts of exotic species, primarily the displacement of native vegetation which had greater habitat and erosion control value. Similar successful efforts have been accomplished along the Palm River (Courser and Lewis, 1980).

Enhancement of Riprap Shorelines with Native Vegetation

Riprap is an effective form of shoreline stabilization that can be used to promote the establishment or maintenance of shoreline vegetation. A program is needed to plant those riprap shorelines already of suitable design, reconfigure other, existing riprap shores, or build new ones as part of a planting program. Particular emphasis could be placed on street end drainageways, box culvert discharges, and other small scale shoreline features.

Third, we suggest that the City of Tampa involve citizens and shoreline owners in waterfront improvement in at least four ways.

o Produce and distribute a "Homeowner's Guide to Shoreline Management", comparable to that enclosed in the Appendix;

o Develop an incentive program for shoreline redevelopment along privately owned waterfront, such as tax relief; blue or green belt zoning; no-interest loans for shoreline restoration; or awards for civic improvements (Figures 41 & 43).

o Sponsor annual wildlife census projects in the lower river emphasizing avifauna and fishes.

o Coordinate city-county planning efforts closely, particularly in reference to linking actions recommended here, to the Planning Commission's "Hillsborough River Study" program (see Appendix).

Fourth, we strongly recommend that the City have a formal role in the permit review and approval process affecting dredging, filling or shoreline construction in the Hillsborough River, beyond that currently exercised through planning, review, or code enforcement programs. This authority is necessary as all submerged sovereignty lands are titled in the Tampa Port Authority, which has regulatory authority over uses of and activities in the river, but is not bound to consider the plans or programs of the City of Tampa with regard to drainage or shoreline management.

C. Conclusion

It is probably true that most great cities of the world are located on rivers and have made optimal public use of their waterfronts. During the expansion and development of the City of Tampa, no consistent vision has emerged for the public use and best management of the Hillsborough River. Now that Tampa is on the threshhold of becoming a city of international consequence, the chance to secure the urbanized river as a public resource may be irrevocably lost.

A unified plan for shoreline restoration and habitat creation in the Hillsborough River would, in summary,

- o improve the aesthetic value of scenic vistas, resulting in favorable public attitudes toward river management;
- o increase and improve habitat for wildlife, especially avifauna and fish;
- o contribute to water quality enhancement at creek mouths and, to a lesser extent, throughout the lower river by assimilating nutrients and sequestering some contaminants, such as metals.

Figure 32. This photograph illustrates the low relief and wide floodplain of the Hillsborough River between Sligh Ave. and North Boulevard. This scene looks downriver from the east bank toward Buffalo Avenue. A retirement center on the west bank appears in the distance.

Figure 33. A scenic view from the Hillsborough Avenue bridge looking upstream to the west bank. The hammock of dense vegetation has grown around a relict spring, now capped but still flowing by seepage. Public lands between the road and river could be improved by exotic species control, regrading and planting of marsh vegetation.

Figure 34. A creek near the North Boulevard bridge has intact banks and some native flora. Brazilian peppers are crowding the shoreline vegetation and the creekbed is strewn with debris. This creek can be improved by reshaping and planting the banks. A control placed upstream would retard discharge and scouring, and reduce sediment loading.

Figure 35. A view from across the river, looking west to the mouth of a creek near Albany and Rome. The creek proper has been encroached upon by filling but the creek mouth and river bank to the south (left in photograph) are sites worthy of study for reshaping and planting. Ideally, the creekmouth rehabilitation would be coupled with improvements upstream to the intersection of Columbus Drive and Howard Avenue.

Figure 36. An example of public drainage at Ola Park. This ditch is an excellent candidate for the creation of a ponded and planted stormwater basin, as a demonstration project. Adjacent public land is ample. This shallow drainage system can be contrasted to the ravine-type gully depicted in Figure 37.

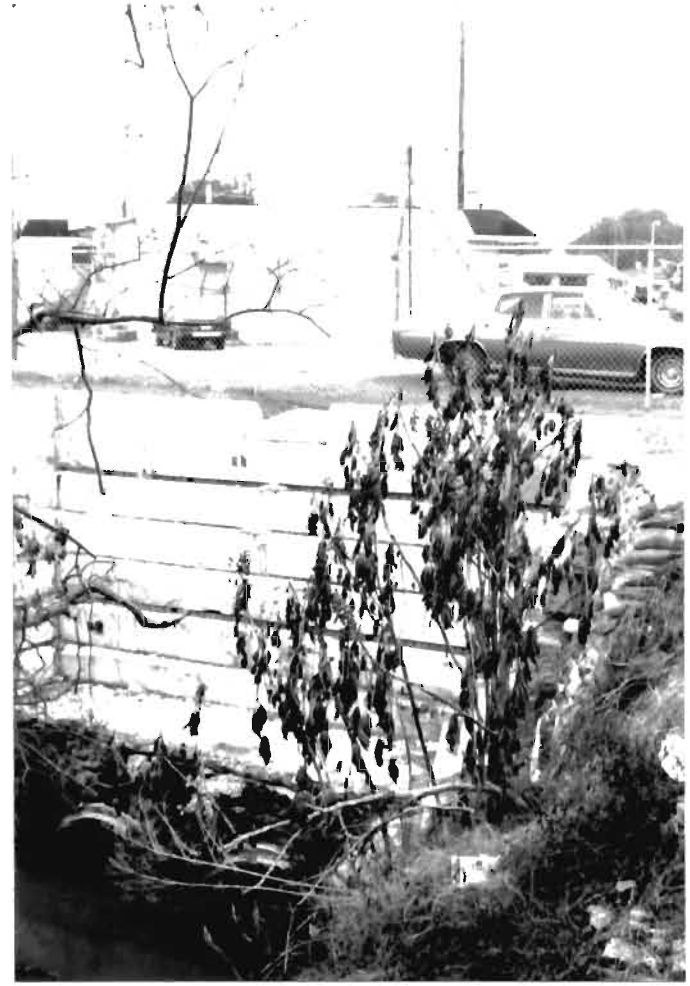


Figure 37. An example of public works "improvement". This drainageway at the northeast corner of Columbus Drive and Howard Avenue has been so enlarged that the once productive tidal creek habitat of downstream areas to the river have been destroyed, all during a period of 30 years.

Figure 38. A sanitary sewers project conducted at this site involved crossing the river with submerged and buried pipe. The opposite shore was not graded or planted, and is presently eroding and offers negligible habitat value. Minimum standards for city, county or other public projects affecting the river and its shores could prevent such cases and contribute to water quality and habitat improvements.

Figure 39. The west shore north of Sligh Avenue at Lowry Park is a disgrace. Piles of rubble and construction wastes have been dumped along the entire park boundary facing the river. This shoreline could be made into productive habitat and serve aesthetic and recreational needs with reshaping and planting. Minor creeks on the park could be drained through vegetated banks.

Figure 40. Storm drains leading to the river can be long, such as this one near Rowlette Park, and cover large areas where meandering, vegetated creeks could be made. Hardened ditches offer no assimilation of particulates and can worsen sediment loads where erosion occurs at failure points.

Figure 41. This photograph illustrates an example of riverfront management for stormwater. A pond once fed by artesian springs now receives direct and indirect runoff. It is controlled by a spillway near the river (behind treeline) and is attractively planted. Local residents report no odor or noxious problems.

Figure 42. The end of this road abuts the river. The sign states that it may be vacated as a public way. This action will preclude using the land as a catchment for stormwater, "pocket park", or habitat patch. Note the runoff draining from the street into the river. With vacating, not only will the potential for improvement be lost, but drainage will probably be "improved" by installing a culvert.

Figure 43. A private, recreational bathing area at a small springhead on the banks of the river. This pond also receives runoff. The ponded water flows to the river over a spillway. This structure is of historical interest but may also offer potential as an aesthetically acceptable catchment for sites like the one depicted in the top photograph.

VIII. HYDROCARBON STUDIES

A. Introduction

The results of the Nationwide Urban Runoff Program (NURP) studies conducted in Tampa indicate that sediment accumulation in the lower Hillsborough River represents a serious and persistent threat to water quality and the endemic biological community. Toxicity tests conducted with Hillsborough River sediments have revealed both acute and chronic toxicity of sediments to appropriately sensitive bioassay organisms. Chemical analyses of sediments have indicated high concentrations of heavy metals and petroleum hydrocarbons. Water quality studies have determined that oxygen demand in accumulated sediments can depress dissolved oxygen concentrations in overlying water.

The evidence appears conclusive that these sediments act as a sink for pollutants and for oxygen demanding material. In order to improve water quality in the river, these sediments must be successfully managed. Before this can be accomplished, the origin of the accumulated sediments needs to be determined. Potential sources of sediment include particulate matter entering the lower river via stormwater runoff, erosion of river beds and banks below the dam during periods of heavy flow and sediment transport upriver from Hillsborough Bay during tidal cycles. The relative contribution of these potential sources of sediment can be determined through detailed sediment transport studies or through the use of tracer substances carried with the particulate matter. To get an initial idea of the relative contribution of upstream and downstream transport to the sediment accumulation problem, we have used petroleum hydrocarbon analysis of sediment and suspended particulate matter as a tracer to identify the origin of accumulated sediment in the river. The specific results of this research are intended to provide the following:

a) A characteristic hydrocarbon "fingerprint" for sediments and suspended particulate matter in the Hillsborough Reservoir, lower Hillsborough River and Hillsborough Bay.

b) An analysis of the probable origin of hydrocarbons found in samples based upon previous analyses and literature reports.

c) A comparison of sample hydrocarbons with known stormwater runoff hydrocarbons as determined from previous analyses of Artic Street drainage basin runoff.

d) A comparison of hydrocarbon composition in suspended particulate matter with that of accumulated bottom sediments in the reservoir, river and bay.

e) An estimate of the relative contribution of the bay and the river to the accumulation of sediment in the river mouth based upon hydrocarbon quantity and composition in samples analyzed.

f) An estimate of the spatial influence of the bay upon the lower river based upon hydrocarbon tracers determined to originate from the bay and move upstream with tidal currents.

The rationale for this type of approach is that most petroleum hydrocarbons in freshwater or saltwater are found in association with particulate matter as adsorbed complexes. The types of petroleum hydrocarbons present in urban runoff are suspected to be different from those present in Hillsborough Bay. Therefore, qualitative and quantitative analysis of hydrocarbons will reveal the source of the pollutants as well as the source of the particulate matter since the hydrocarbons are adsorbed onto the particles.

B. Methods

Sediment samples were collected from eight sampling stations located in the Hillsborough River, three in Hillsborough Bay, and one in the Hillsborough Reservoir above the dam (Figure 5). Five of the river stations, two of the bay stations and the reservoir station were also sampled for suspended particulate matter.

1. Field Sampling

Suspended particulates were collected with water samples in 3.8 liter glass bottles. The bottles were sealed with teflon-lined caps and stored on ice for transport to the laboratory.

Sediment was collected from the upper 5 cm (surface sediment) with a petite Ponar sampler to provide information relative to recent petroleum input. A composite of three samples was collected at each site, transferred to clean glass jars and stored on ice for transport to the laboratory.

Stormwater runoff was collected during a rain event from the Artic Street basin watershed. A sample of the first flush (the first gallon of runoff) was collected along with a composite sample consisting of aliquots (1 gal. each) collected throughout the total event. The samples were placed in precleaned plastic jugs and were kept at $4^{o}C$ until analyzed.

2. Laboratory Analysis

a) Preparation-Extraction

1. Sediment

Sediment subsamples from each site were thawed and thoroughly mixed in a clean glass tray. Excess water was evaporated at room temperature and the composite sample homogenized again by mixing. Aliquots of wet sediment were collected randomly throughout the sample to provide approximately 25-35 grams (g) wet weight. The sediment was placed in a Soxhlet extraction apparatus with internal standard hydrocarbons added (5-α -androstane for the aliphatic hydrocarbon fraction, and o-terphenyl for the aromatic fraction). An aliquot of methyl stearate was also added to verify complete saponification.

Extraction and saponification were performed simultaneously by Soxhlet extraction using a benzene/KOH-methanol solvent system according to the procedures of Pierce et al. (1983); Boehm (1981); and Farrington and Tripp (1975). The extracts were washed with 1% aqueous NaCl solution and the lipid material recovered in the benzene layer. Benzene was replaced with hexane as the solvent and the hydrocarbons recovered as the saturated (f_1) fraction and unsaturated (f_2) fraction by elution through a column of silica gel and alumina. Sulfur was removed by passing the eluants through copper filings.

2. Suspended Particulates

Particulate matter was collected from 1 liter of seawater sample by filtration through a Gelman A/E glass fiber filter with a nominal pore size of 0.3 um. Each filter pad was then placed in a micro-soxhlet extraction apparatus and processed as described above for sediment samples.

3. Stormwater Runoff

All samples were brought to room temperature and were mixed thoroughly to ensure homogeneity. One liter of sample was transferred to a 2 liter separatory funnel and the pH of the sample was adjusted to 1 with concentrated HCl. The sample was then extracted 3X with 50 ml of dichloromethane (CH_2Cl_2) each time. The addition of 20% sodium chloride solution and centrifugation was utilized when emulsions occurred. The combined CH_2Cl_2 extract was reduced using a flash rotary evaporatory and the CH_2Cl_2 was gradually replaced by the addition of hexane. The sample was separated into f_1 and f_2 fractions as described for sediment samples.

b) Hydrocarbon Analysis

All samples were analyzed in duplicate to verify analytical precision and sample homogenity. Reagent blanks and standard hydrocarbon samples were run with each sample set for quality assurance.

Gas chromatographic (GC) analysis of each column chromatography elution fraction was carried out with a Varian Vista 6000 gas chromatography system coupled with a Vista 401 chromatography data system. The instrument is equipped with dual flame ionization detectors (FID) and linear temperature programming. The column used was a 30 m x 0.25 mm I.D. glass capillary coated with SE-30 (Supelco, Inc.). The system was operated in the splitless injection mode for low concentrations. The carrier gas was N_2 with N_2 make up gas at the detector. Data are reported as hard copy chromatograms with qualitative and quantitative printout as well as storage on floppy discs. The 401 data system was interfaced with an Apple II Plus computer with dual disc drive for further manipulation and storage of data. The instrument was temperature programmed to recover n-alkanes from n-C_{12} through n-C_{32}. The column is capable of resolving n-C_{17} from pristane and the FID sensitivity is in the range of 1×10^{-10} g/sec (approximately 1 to 10 ng/g sample).

3. Data Analysis - Interpretation

The detection of hydrocarbons in the marine environment is complicated by the fact that the analyst must distinguish among recently biosynthesized (biogenic) hydrocarbons, hydrocarbons from fossil fuel combustion and forest fires (pyrogenic) and petroleum (petrogenic) hydrocarbons. The type of petroleum also must be discernible to ascertain the pollution source.

Much consideration has been given to the development of classification schemes to aid in hydrocarbon source identification. The basis for the most widely accepted identification scheme is separation of the hydrocarbons into aliphatic (saturated) and aromatic/olefinic (unsaturated) fractions. Analysis of these fractions by capillary GC-FID and gas chromatography-mass spectroscopy (GS-MS) provides the qualitative and quantitative information necessary to establish source classification criteria (Farrington and Meyers, 1975; Boehm and Fiest, 1980; Boehm et al., 1981; Pierce et al., 1981).

A major distinction between biogenic and petrogenic hydrocarbons is that biogenic hydrocarbons exhibit discrete sets of n-alkanes and alkenes, whereas petroleum contains the homologous series of n-alkanes, branched and cyclic alkanes and substituted polynuclear aromatic hydrocarbons. A predominance of specific compounds such as pristane (2, 6, 10, 14-tetramethylpentadecane), pentadecane (n-C_{15}), and heptadecane (n-C_{17}) are indicative of marine biogenic sources, while pristane in the presence of the isoprenoid, phytane and a homologous series of n-alkanes, indicates petroleum hydrocarbons (Ehrhardt and Blumer, 1972; Blumer et al., 1971; Farrington, 1980). Hydrocarbons of terrigenous flora exhibit a high odd/even carbon preference index (CPI) in the n-C_{23} through n-C_{31} n-alkane region (Boehm and Quinn, 1978; Farrington and Tripp, 1977; Bieri et al., 1978; Atlas et al., 1981).

Petrogenic hydrocarbons are characterized by an unresolved complex mixture (UCM) of hydrocarbons in the aliphatic fraction, which is comprised primarily of branched and cyclic saturated hydrocarbons too numerous to be resolved by gas chromatographic techniques.

Petroleum that has been recently introduced into the marine environment is indicated by a smooth alkane distribution (CPI = 1) over an UCM (Pierce et al., 1975; Farrington, 1980). Crude oil GC patterns are characteristic of geographical origin, but generally exhibit a wide boiling range of n-alkanes and UCM, sometimes with a bimodal UCM distribution. Refined petroleum distillates favor low boiling components, whereas residual oils show a predominance of the higher boiling compounds (Butler et al., 1973; Thompson and Eglinton, 1978; Traxler and Pierce, 1974).

Our approach to hydrocarbon data analysis and interpretation is to provide a GC-FID "fingerprint" chromatogram for the f_1 (saturated) and f_2 (unsaturated) fractions of each sample. Armed with this information, we can analyze trends in hydrocarbon quality and quantity from the bay to the dam for surface sediments and suspended particulate matter. Comparisons of upstream stations and bay stations with river mouth stations may indicate the source of hydrocarbons and sediments which have accumulated near the mouth of the river.

C. Results

The hydrocarbon content of stormwater runoff (July 1982 and May 1983) and Hillsborough River sediment (May 1983) was dominated by petroleum indicative of crankcase oil-like material. A summary of key parameters for hydrocarbon characterization for Hillsborough River sediment and stormwater runoff collected in May 1983 is given in Table 24. To enhance interpretation of sample hydrocarbon content from high resolution gas chromatographic (GC) analysis, chromatograms from representative petroleum contaminants (Kuwait crude oil, crankcase oil, #2 fuel oil) are given in Figure 44. Key parameters for hydrocarbon characterization of Kuwait crude oil are listed in Table 25.

It was observed that the first flush of stormwater has approximately 3 times the hydrocarbon content as that of the composite sample. This is consistent with other studies (Hoffman et al., 1982; Hunter et al., 1979) which observed higher concentrations of suspended solids, with adsorbed hydrocarbons, associated with the first flush. It should be noted that the hydrocarbon content of the stormwater runoff is probably lower than might normally be expected. This is because the initial collection procedure (sample storage in plastic jugs) was not designed for hydrocarbon analysis. Laboratory experiments have shown that hydrocarbons adsorb to plastics, effectively reducing the observed concentration in the contained water samples. Representative chromatograms from the analysis of hydrocarbons in stormwater samples are shown in Figure 45. The GC traces of the stormwater samples are similar to that of crankcase oil (Figure 44)

Table 24. Hydrocarbon Characterization of Hillsborough River Sediment and Stormwater (Artic St.) Runoff Collected May 1983.

SAMPLE	TOTAL (μg/g)		RATIOS[1]				KEY HYDROCARBONS (ng/g)[2]				N-ALKANES	
	f_1	f_2	Resol/ Unres.	Prist/ Phyt.	C_{17}/ Prist.	C_{18}/ Phyt.	1500	1700	2085	2900	Homol. Ser.	CPI
SEDIMENT												
Buffalo Ave.	258.96	N.C.[3]	0.06	0.80	1.38	0.38	135.49	202.65	193.64	--[4]	C_{17-26}	1.92
I-275	535.54	N.C.	0.03	0.85	0.81	0.87	145.15	146.88	324.30	--	C_{17-24}	1.28
Sligh Ave.	297.17	N.C.	0.07	0.79	1.42	0.90	159.95	183.72	154.86	3469.18	C_{17-30}	1.84
STORMWATER RUNOFF												
1st Flush	1947.2[5]	N.C.	0.10	--	--	--	--	--	--	31.0[3]	--	--
	2127.0	N.C.	0.10	--	--	--	--	--	--	31.4	--	--
1-Hour Composite	605.2	N.C.	0.03	--	--	--	--	--	--	3.7	--	--
	631.1	N.C.	0.02	--	--	--	--	--	--	5.3	--	--
July 1982 composite	607.5	N.C.	0.07	0.60	1.19	0.74	--	250.0	--	1520.0	--	--

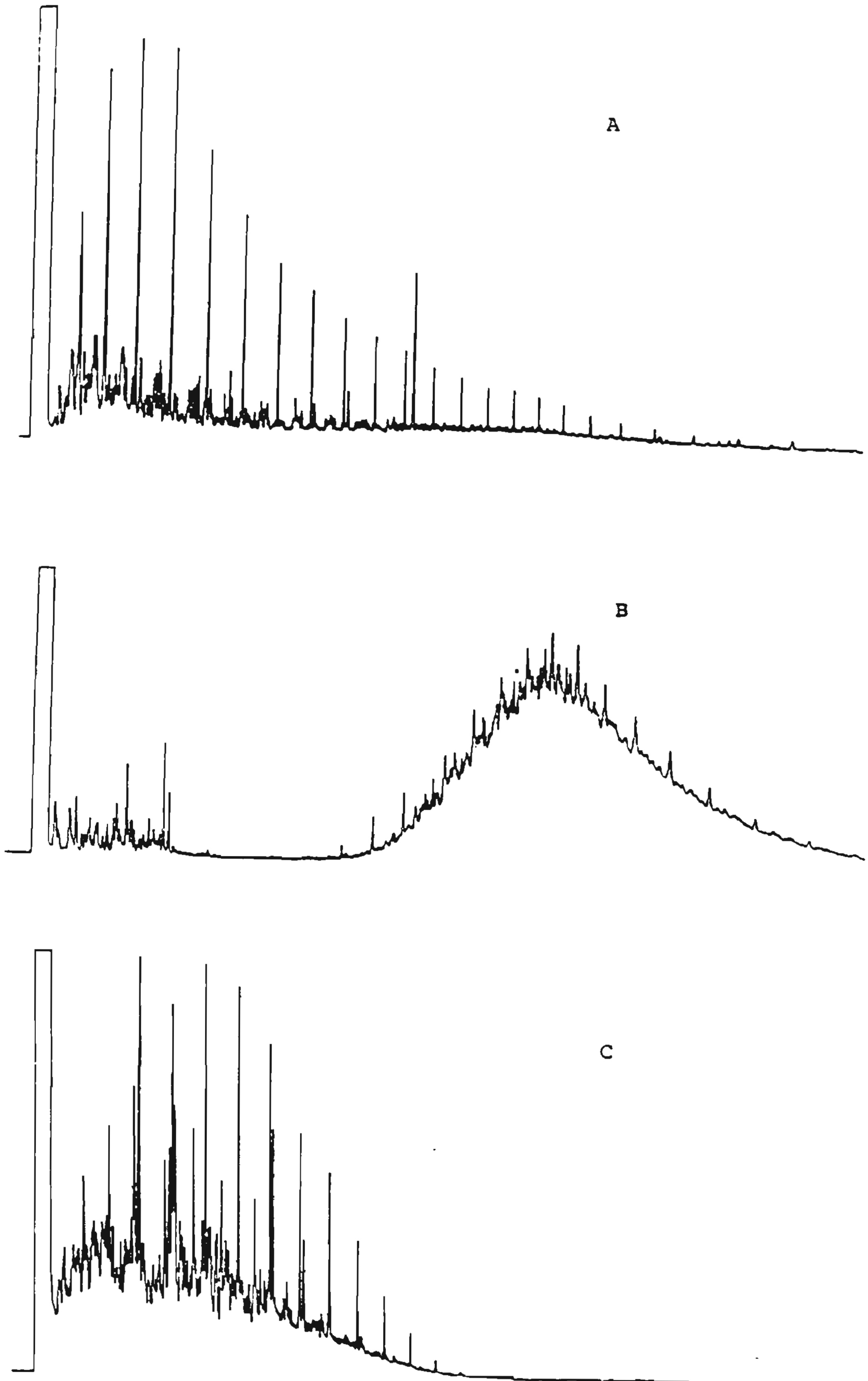
[1]Resol = Resolved components as determined from the GC-FID fingerprint
Unres = Unresolved components as determined from the GC-FID fingerprint
Prist = Pristane; Phyt = Phytane

[2]Expressed as Kovats Indices where 1500 represents n-C_{15}, 1700 represents n-C_{17}, etc. (Kovats and Keulemans, 1964).

[3]N.C. = not calculated.

[4]Not identified.

[5]μg/l.



Temp. Prog. 100-280°C @ 8°/min, SE-30, 30 m X 0.25 m

Figure 44. Reference Petroleum Contaminants: A, Kuwait crude oil; B, crankcase oil; C, #2 fuel oil.

Table 25. Hydrocarbon Characterization: Kuwait Crude Reference Oil and Recovery From Triplicate Spiked Water Samples (10 ℓ each A, B, & C).

SAMPLE	TOTAL (μg/g)		RATIOS[1]				KEY HYDROCARBONS (μg/g)[2]				N-ALKANES	
	f_1	f_2	Resol/ Unres.	Prist/ Phyt.	C_{17}/ Prist.	C_{18}/ Phyt.	1500	1700	2085	2900	Homol. Ser.	CPI
Kuwait Crude	2294.7	N.C.[3]	0.4	0.6	5.6	3.0	51.8	36.6	--	--	C_{13-24}	0.9
A	2702.1	N.C.	0.4	0.7	4.9	2.9	64.5	50.3	--	--	C_{13-24}	1.1
B	3089.0	N.C.	0.3	0.7	4.8	2.9	55.4	46.3	--	--	C_{13-24}	1.0
C	2678.5	N.C.	0.3	0.7	5.0	2.8	54.8	44.7	--	--	C_{13-24}	1.1
$\bar{x}$	2823.2		0.3	0.7	4.9	2.9	58.2	47.1				1.1
±S	± 230.5		±0.05	±0.0	±0.1	±0.06	± 2.9	± 2.9				±0.06

[1]See Table 24.
[2]See Table 24; [3]Not calculated
[4]Mean and standard deviation of triplicate extractions (A, B, & C).

analyzed in this laboratory and others (Hoffman et al., 1982). The "fingerprint" pattern of crankcase oil and of the runoff consists of a large UCM with the boiling range from ca. n-C_{16-32} along with very few resolved components. This similar "fingerprint" pattern was also observed in Hillsborough River sediment collected May 1983 (Figure 46). It should be noted that representative chromatograms are shown to illustrate similarity in hydrocarbon patterns and are not quantitative. All hydrocarbon concentrations are calculated with respect to internal standards added prior to sample processing. Key parameters for hydrocarbon characterization of Hillsborough River sediment collected near Buffalo Avenue, I-275 overpass, and Sligh Avenue are given in Table 24. The hydrocarbon content of the sediment consisted primarily of crankcase oil-like material. Characteristic biogenic hydrocarbons were also observed, but these were less abundant than the petroleum component.

A broader study was carried out in December 1983 to more accurately characterize the hydrocarbons associated with suspended particulated matter and sediments from Hillsborough Reservoir, Hillsborough River and Hillsborough Bay. The hydrocarbon content of sediment collected throughout the entire study area (Figure 25) was dominated by petroleum indicative of crankcase oil-like material. The characteristic biogenic hydrocarbons were again observed, especially farther upriver and in the reservoir, but were less abundant than the petroleum component. Representative chromatograms from the analysis of hydrocarbons in sediment sample from the reservoir, river and bay are shown in Figure 47a-f. A summary of key parameters for hydrocarbon characterization for all sediment samples is given in Table 26. These results show an increase of sediment petroleum content going from the reservoir (Station 4-2: 25 ug/g) at the uppermost region of the study area downriver to a maximum at Station 1-2 (485 ug/g), near the I-275 bridge. The concentration then diminished on to the mouth of the river and out into Hillsborough Bay (Station 0-1: 76 ug/g). This is consistent with the hydrocarbon concentrations observed in the sediments collected in May 1983 with the highest concentration reported near the I-275 overpass (535 ug/g).

Water samples were collected simultaneously with sediment samples. No petroleum contamination was observed in any of the samples, as indicated by the representative chromatogram of the water sample along with the chromatogram of a procedural blank (Figure 48).

The hydrocarbon content of sediment collected throughout the entire study area and from stormwater runoff collected from the Artic Street watershed was dominated by petroleum indicative of crankcase oil-like material. Characteristic biogenic hydrocarbons were also observed in the sediments, but these were less abundant than the petroleum component.

The reason for a buildup of petrogenic hydrocarbons in sediment near I-275 could be a combination of several factors including: 1) chronic influx from commercial marine activities along this section of the river; 2) high loadings of petroleum contaminated stormwater from intensive use automobile traffic areas; 3) specific hydrology and sedimentology characteristics of the river at this point. Adequate interpretation of this phenomenon requires a more intensive investigation providing additional samples over time and space within this area.

The fact that the type of petroleum found in sediment (crankcase oil) very closely resembles that found in stormwater runoff strongly implicates stormwater runoff as the primary source for sediment contamination. This is supported by the observation that the hydrocarbon content of stormwater particulate matter was about ten times greater than that in sediment, indicating dilution of stormwater particulates with non-contaminated sediment and degradation-weathering of the oil after sedimentation.

Water samples (December, 1983) were collected simultaneously with sediment samples. Near surface and near bottom water was collected on the rising tide to observe the presence of petroleum contaminated particulate transport moving upriver from resuspended bay sediment. These water samples were collected during a dry period when no storm runoff was entering the river to observe petroleum input from non-storm related sources. No petroleum contamination was observed in the surface (freshwater) or in the bottom (saltwater) samples.

D. Conclusions

a) A characteristic hydrocarbon "fingerprint" for sediments and particulate matter in the Hillsborough Reservoir, lower Hillsborough River and Hillsborough Bay was provided.

b) An analysis of the probable origin of hydrocarbons found in samples indicated that crankcase-like oil was a primary contributor to sediment hydrocarbon contamination.

c) A comparison of sample hydrocarbons with known stormwater runoff hydrocarbons as determined from previous analyses of Artic Street drainage basin runoff showed that the major source of crankcase-like petrochemicals found in sediment was the stormwater runoff.

d) A comparison of hydrocarbon composition in suspended particulate matter with that of accumulated bottom sediments in the reservoir, river and bay, during a non-storm period and rising tide, indicated that most contaminated sediment transport was downriver. No upriver transport of resuspended bay sediment was observed. Additional studies should be performed over various tidal cycles and storm events.

e) An estimate of the relative contribution of the bay and the river to the accumulation of sediment in the river mouth, based on hydrocarbon quantity and composition indicates that most of the hydrocarbon contaminated sediment originated upstream.

f) No special influence of the bay upon the lower river was observed relative to hydrocarbon tracers. Additional investigations are required incorporating sediment cores, sediment grain size analysis and hydrocarbon characterization at more closely spaced stations near the river mouth to adequately evaluate this problem.

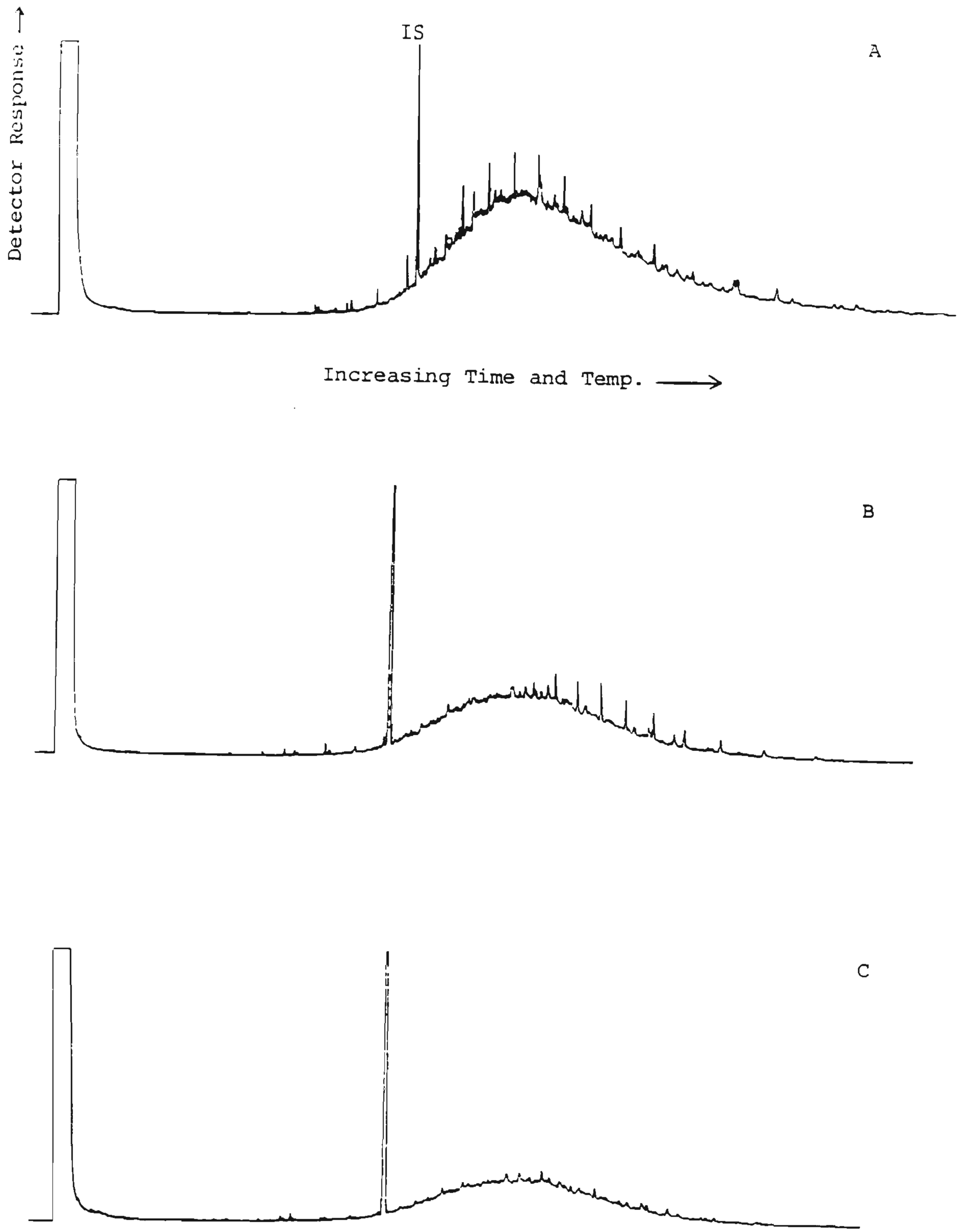


Figure 45. GC-FID analysis of Stormwater runoff. A, aliphatic (f_1) fraction of July 1982 composite sample; B, aliphatic (f_1) fraction of May 1983 - 1st flush; C, aliphatic (f_1) fraction of May 1983 1-hour composite. IS= Internal Standard

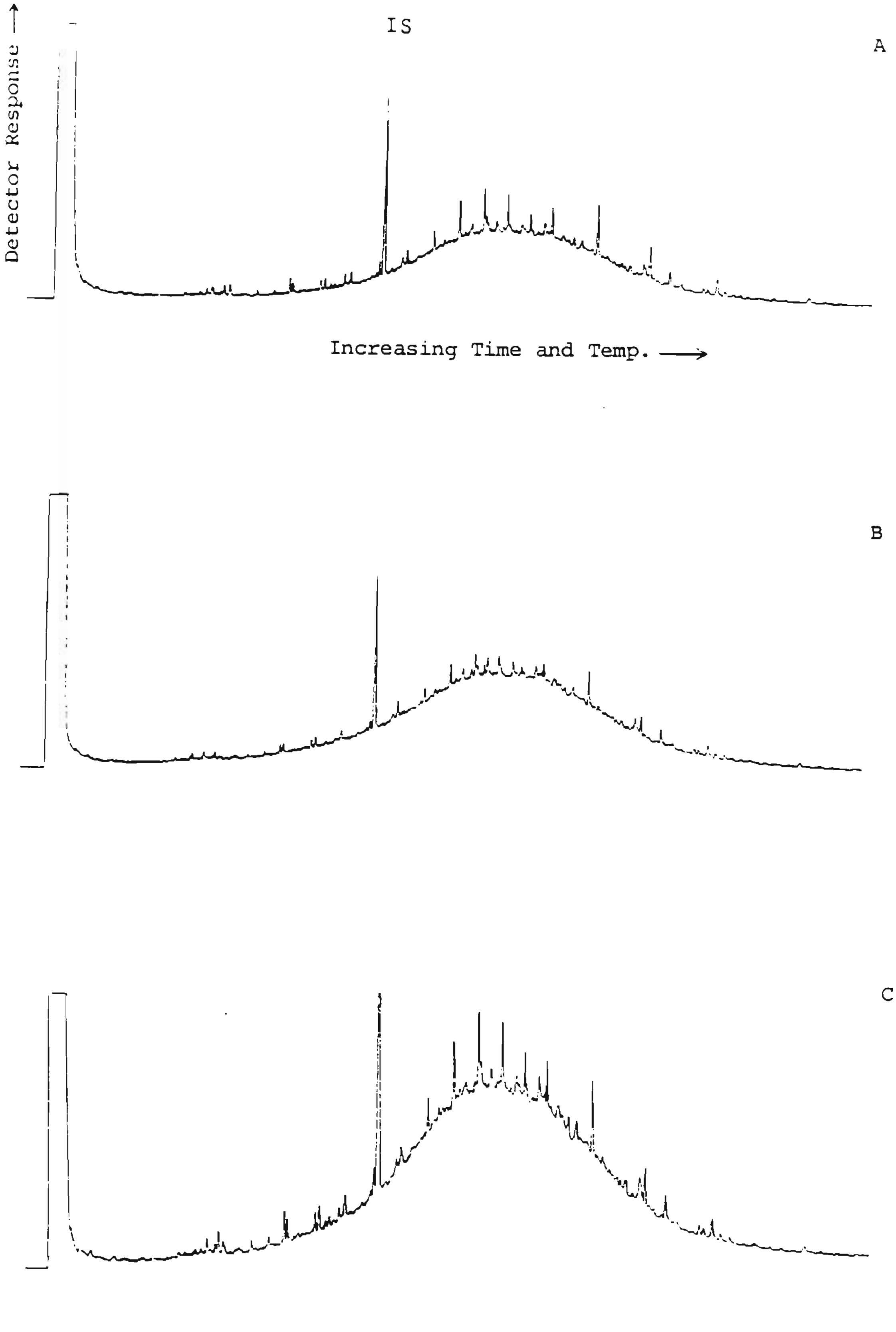


Figure 46. GC-FID analysis of Hillsborough River sediment. A, Sligh Ave.; B, I-275; C, Buffalo Ave.

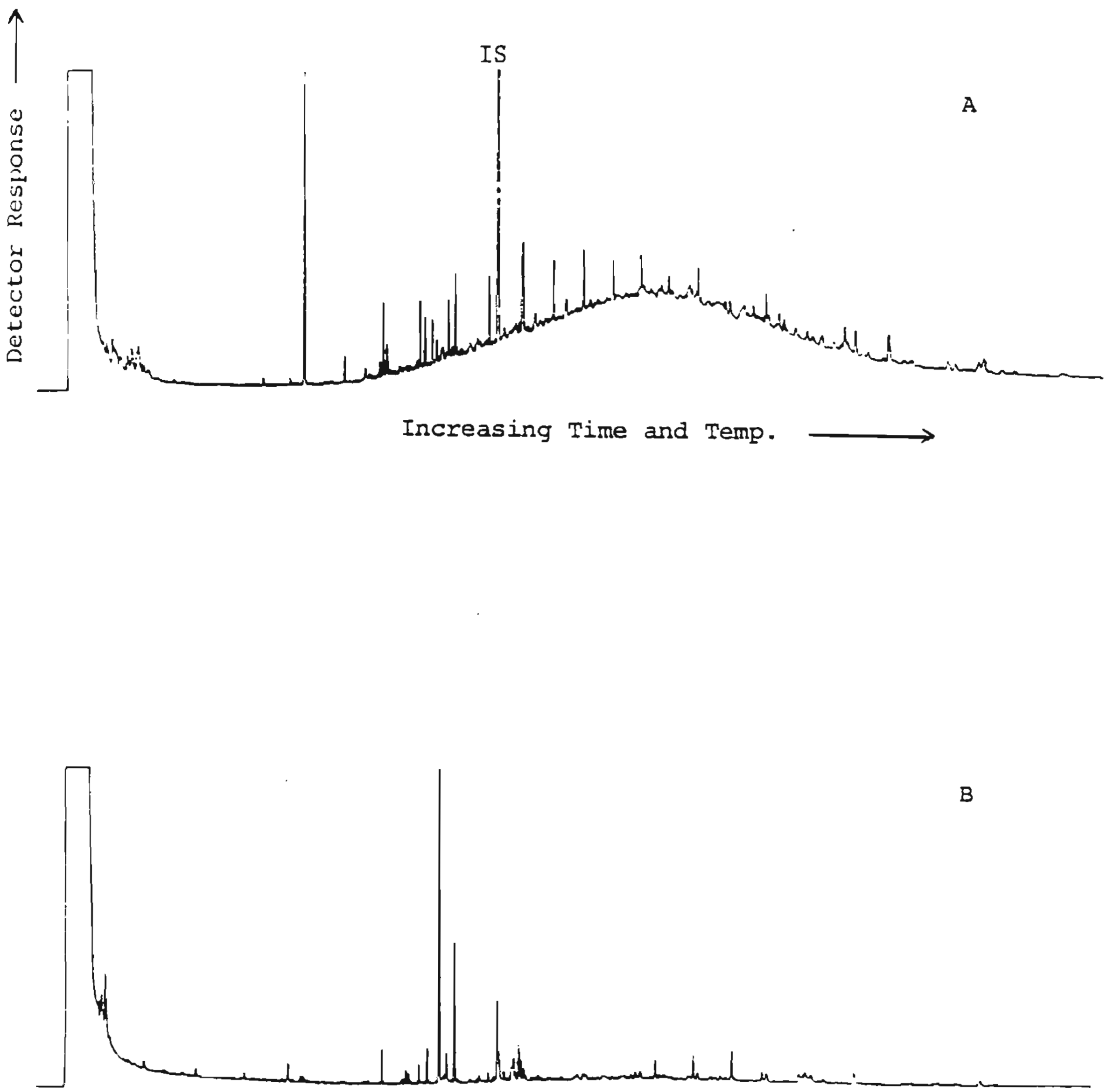


Figure 47a. GC-FID analysis of sediment sample O-1 (Hillsborough Bay). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

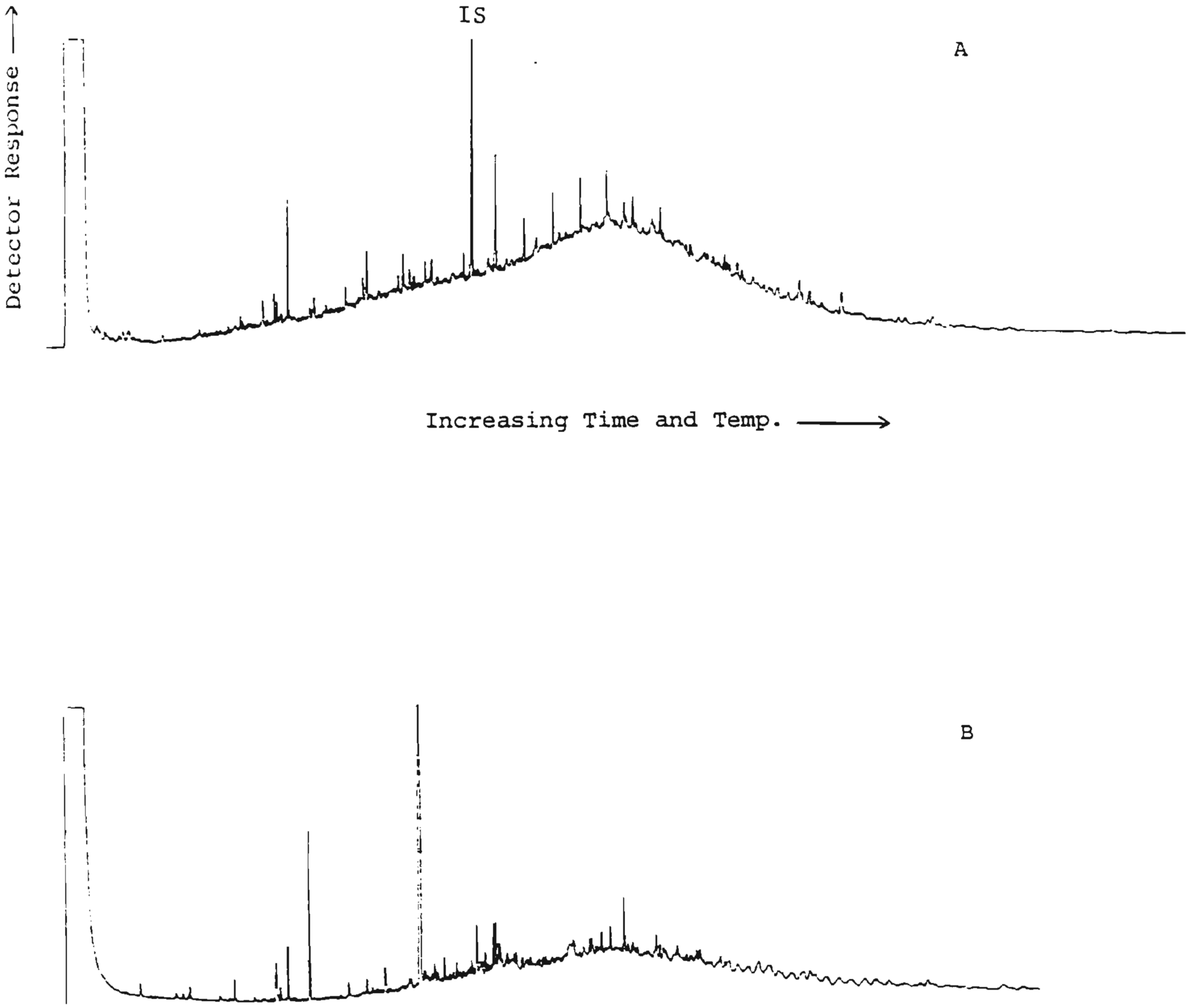


Figure 47b . GC-FID analysis of sediment sample 0-3 (Hillsborough Bay). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

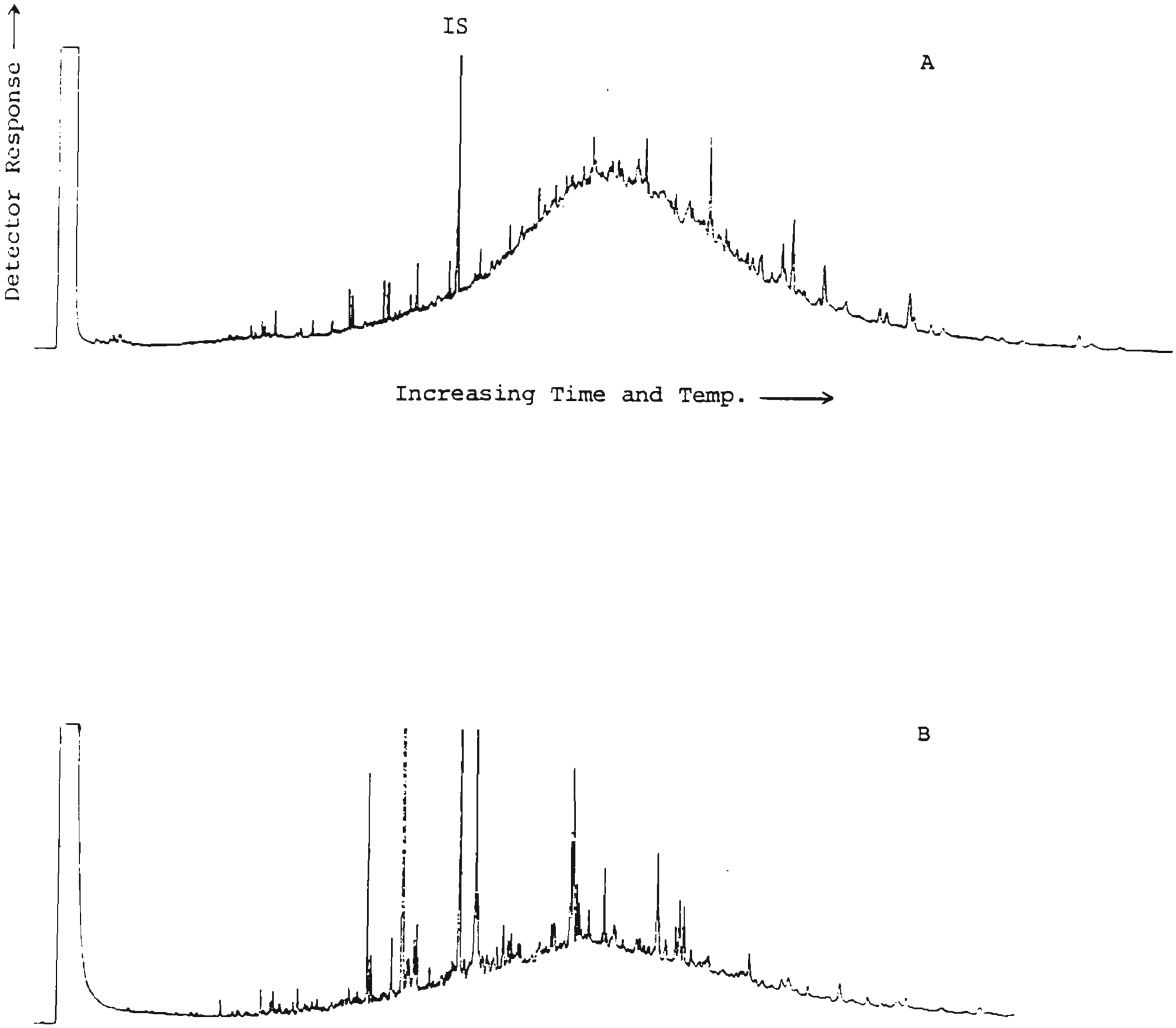


Figure 47c. GC-FID analysis of sediment sample 0-4 (River mouth).
A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

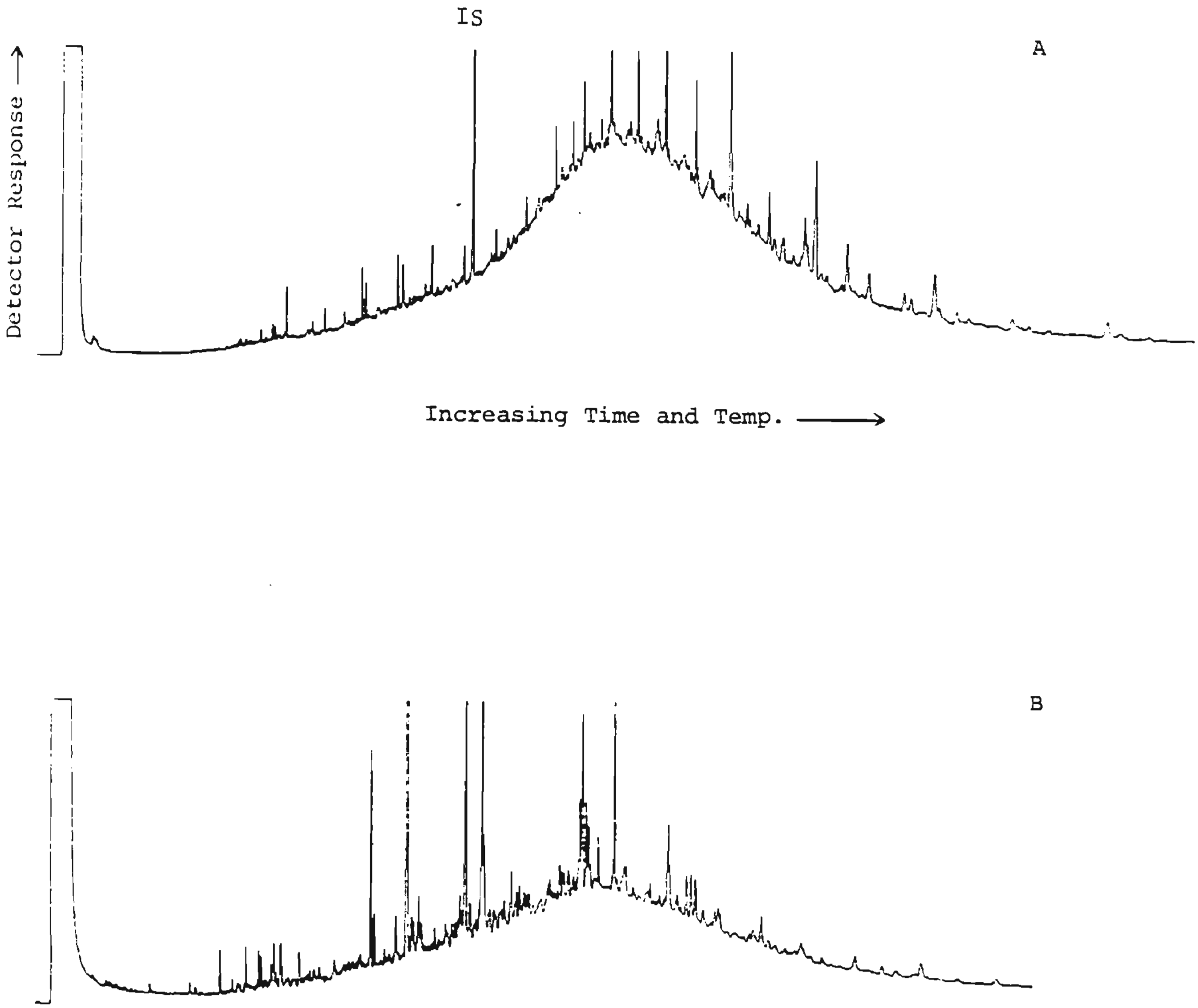


Figure 47d. GC-FID analysis of sediment sample 1-2 (I-275 station). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

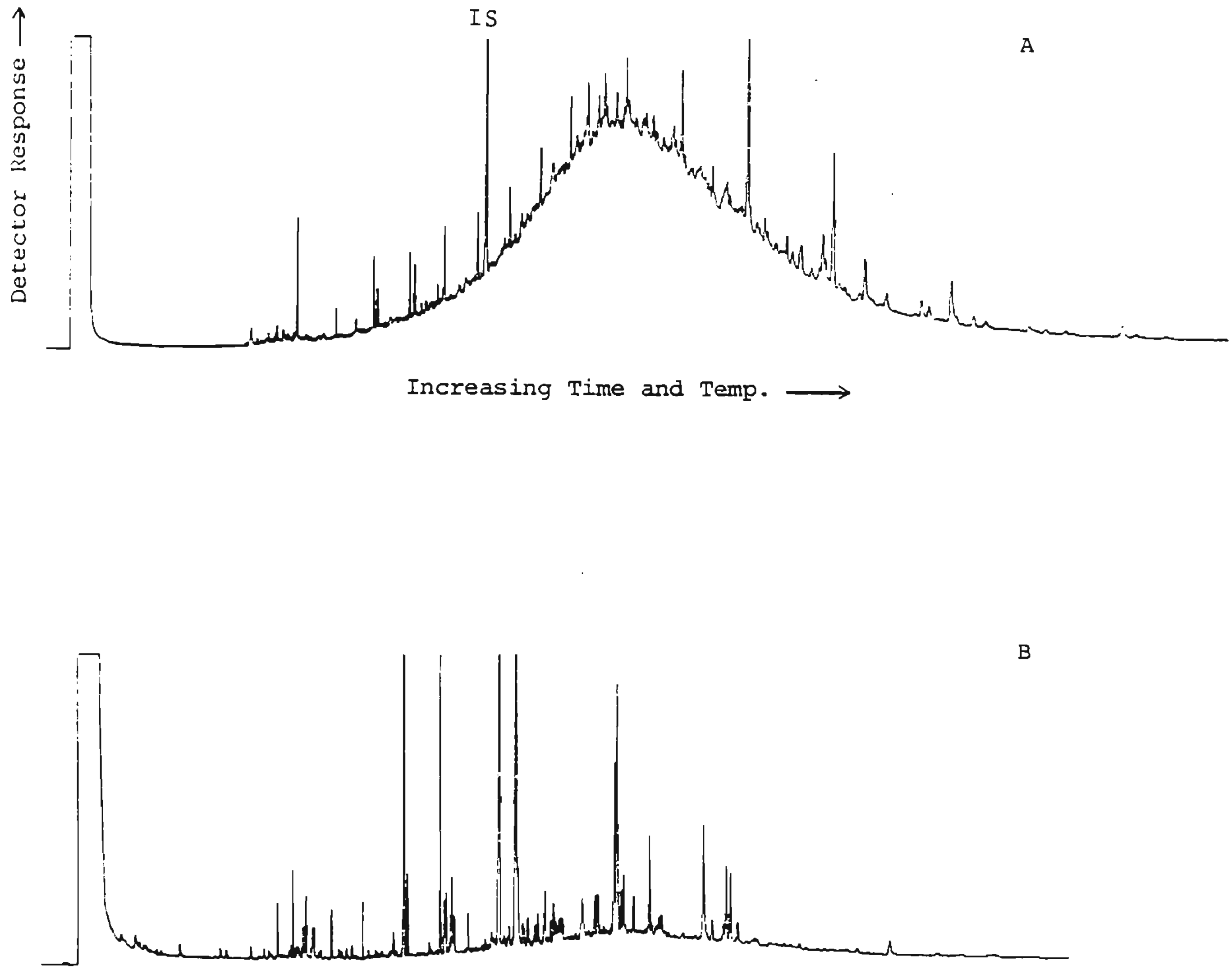


Figure 47e. GC-FID analysis of sediment sample 2-2 (Hillsborough Avenue). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

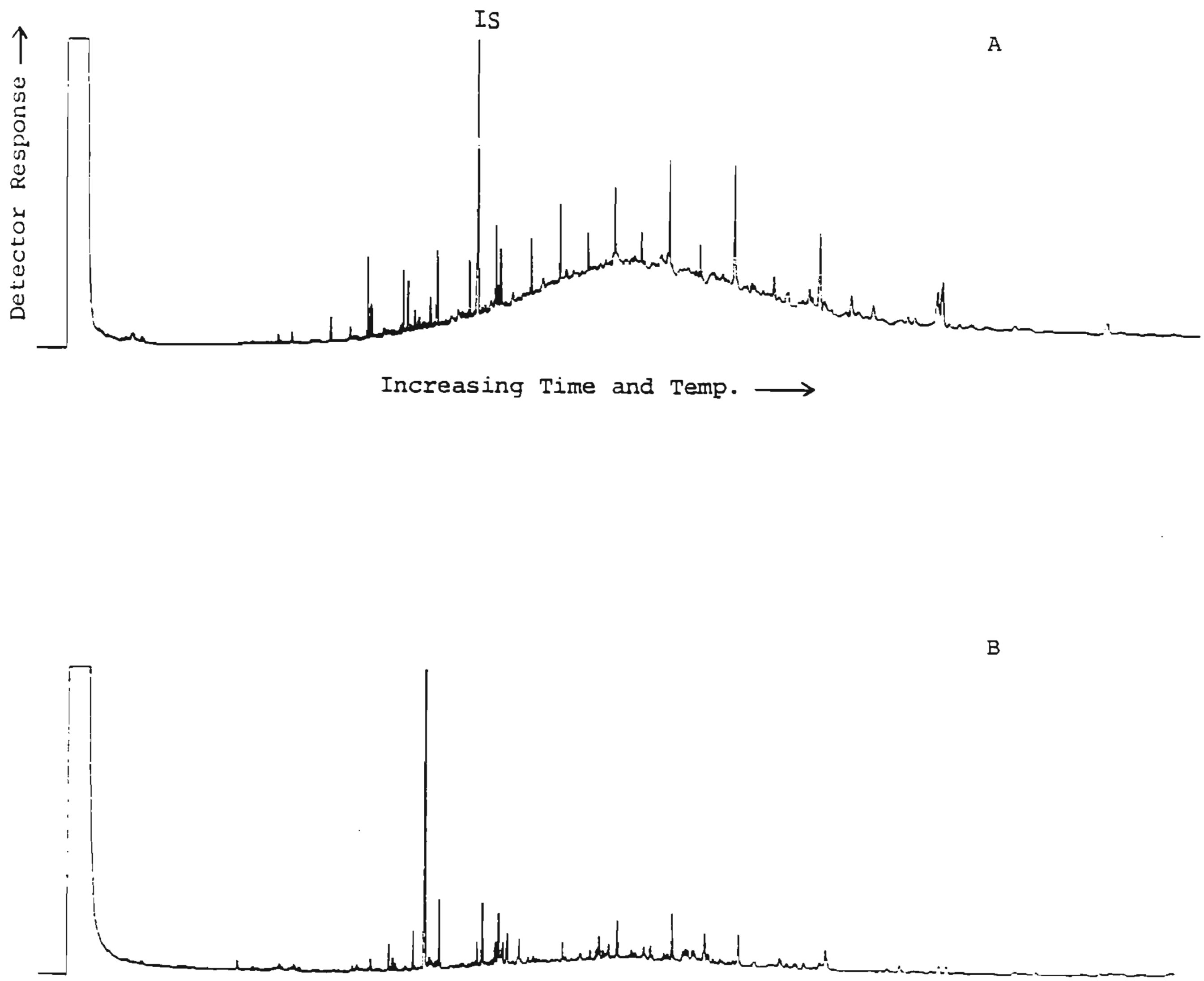


Figure 47f. GC-FID analysis of sediment sample 4-2 (Hillsborough Reservoir). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

Table 26. Hillsborough River Sediment Hydrocarbon Characterization.

SAMPLE	TOTAL (μg/g) f_1	f_2	THC[1] $f_1 + f_2$	$\bar{x}$	RATIOS[2] Resol/ Unres.	Prist/ Phyt.	C_{17}/ Prist.	C_{18}/ Phyt.	KEY HYDROCARBONS (ng/g)[3] 1500	1700	2100	2900	N-ALKANES Homol. Ser.	CPI
0-1A[4]	64.24	10.50	74.74	76.62	0.09	0.34	2.03	1.37	--	63.32	414.21	110.80	C_{17-32}	1.36
0-1B	59.70	18.81	78.51		0.10	0.66	2.05	1.37	--	138.30	330.26	100.00	C_{17-32}	1.63
0-3A	187.52	18.85	206.37	228.70	0.06	0.98	0.47	0.50	465.84	112.85	669.71	118.45	C_{14-31}	2.06
0-3B	228.74	22.29	251.03		0.07	1.14	0.84	1.13	716.50	374.44	503.92	150.52	C_{14-31}	1.73
0-4A	309.62	55.78	365.40	379.54	0.10	1.01	0.98	1.11	179.08	243.36	197.84	1527.72	C_{15-32}	1.52
0-4B	331.48	62.20	393.68		0.06	0.75	1.12	1.07	143.24	230.84	224.64	1332.08	C_{15-32}	2.10
1-1A	246.13	44.47	290.60	283.96	0.07	0.95	1.53	1.48	354.71	285.41	162.77	885.66	C_{14-29}	1.81
1-1B	220.84	56.49	277.33		0.06	0.94	1.28	0.84	383.97	146.63	141.10	774.77	C_{14-29}	2.59
1-2A	387.28	90.73	478.01	484.94	0.08	0.84	1.24	1.32	312.24	278.42	197.07	2369.03	C_{15-32}	1.54
1-2B	405.48	86.38	491.86		0.06	0.84	1.30	1.34	265.60	307.69	279.94	1551.76	C_{15-32}	1.98
1-3A	135.49	20.18	155.67	151.69	0.07	0.77	1.62	1.21	266.54	128.55	127.26	442.21	C_{15-32}	2.00
1-3B	118.78	28.93	147.71		0.07	0.92	1.57	1.06	249.70	97.73	120.80	473.96	C_{15-32}	1.50
2-1A	196.72	63.31	260.03	254.84	0.06	0.80	1.57	1.24	99.71	168.20	153.51	714.46	C_{15-32}	2.00
2-1B	188.75	60.90	249.65		0.07	0.74	1.70	1.37	94.92	226.41	211.20	802.50	C_{15-32}	1.96
2-2A	200.38	89.78	290.16	296.89	0.08	0.69	1.74	1.29	365.96	216.54	225.16	1651.15	C_{14-31}	3.19
2-2B	220.65	82.97	303.62		0.07	0.78	1.71	1.00	483.17	159.47	170.47	1498.02	C_{13-30}	2.31
3-1A	150.18	30.46	180.64	183.88	0.05	0.74	1.40	1.36	96.97	84.91	135.60	455.43	C_{14-31}	1.45
3-1B	149.60	37.53	187.13		0.06	0.65	1.40	1.12	78.50	71.81	180.00	211.81	C_{13-30}	1.31

[1] Total Hydrocarbon Concentration
[2,3] See Table 24.
[4] A and B are duplicate samples

Table 26. Continued. Hillsborough River Sediments.

SAMPLE	TOTAL (µg/g) f_1	TOTAL (µg/g) f_2	THC[1] $f_1 + f_2$	$\bar{x}$	RATIOS[2] Resol/ Unres.	RATIOS[2] Prist/ Phyt.	RATIOS[2] C_{17}/ Prist.	RATIOS[2] C_{18}/ Phyt.	KEY HYDROCARBONS (ng/g)[3] 1500	KEY HYDROCARBONS (ng/g)[3] 1700	KEY HYDROCARBONS (ng/g)[3] 2100	KEY HYDROCARBONS (ng/g)[3] 2900	N-ALKANES Homol. Ser.	N-ALKANES CPI
3-2A	145.16	30.05	175.21	177.65	0.08	1.02	1.21	1.14	124.92	198.90	155.36	929.10	C_{15-32}	2.34
3-2B	136.86	43.23	180.09		0.07	0.79	1.59	0.95	93.96	135.37	156.14	712.06	C_{15-32}	1.28
4-1A	172.92	44.66	217.58	224.12	0.07	0.94	1.14	0.95	71.29	280.48	290.37	1866.60	C_{15-32}	2.71
4-1B	192.53	38.14	230.67		0.08	0.92	0.97	0.55	44.40	211.09	176.61	1425.27	C_{15-32}	2.32
4-2A	161.63	21.96	183.59	170.70	0.10	0.65	2.00	0.91	39.88	227.15	321.23	1173.32	C_{15-32}	3.10
4-2B	128.28	29.52	157.60		0.12	0.64	2.14	1.15	44.40	351.27	278.02	1185.77	C_{15-32}	2.89

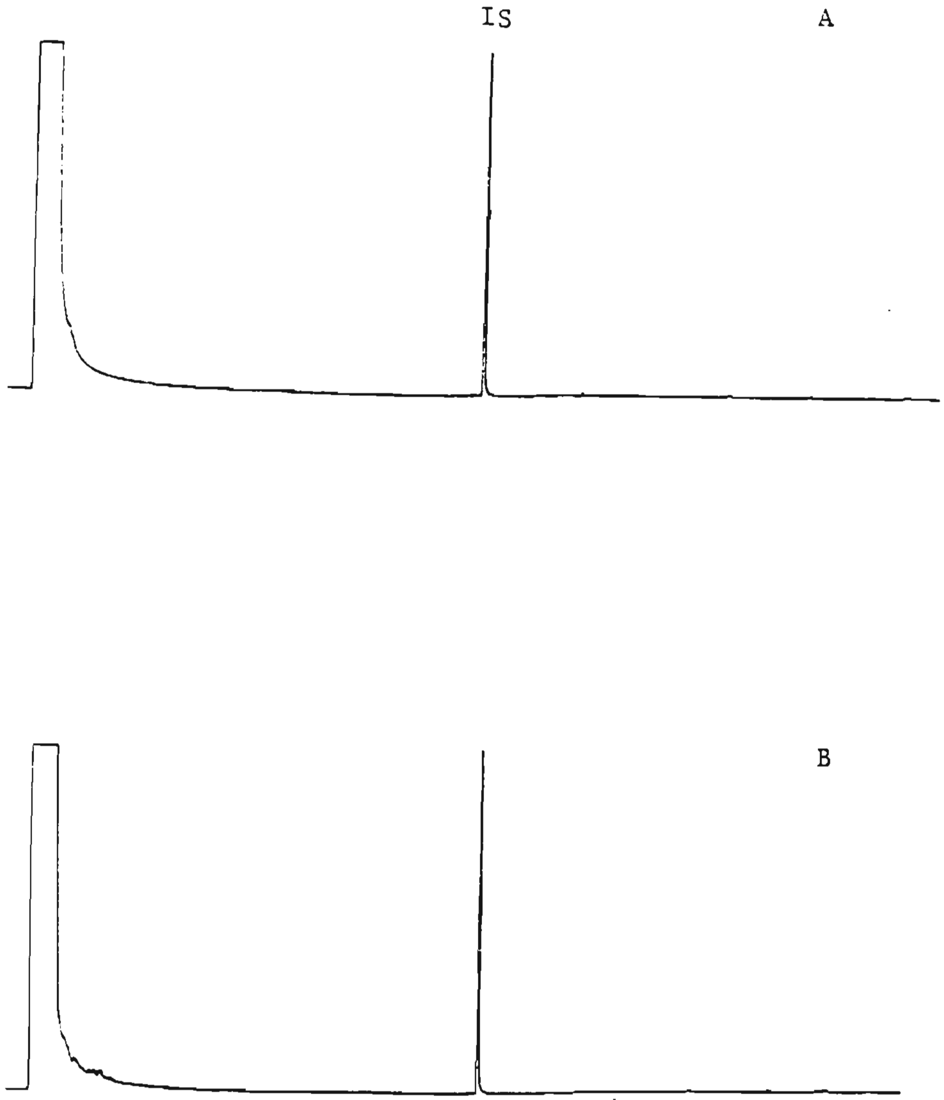


Figure 48. GC-FID analysis of f_1 fraction: A, Procedural blank; B, Station 2-1 (bottom) suspended particulate sample.

IX. CONCLUSIONS AND RECOMMENDATIONS

The scientific information presented in this report represents a significant step toward a better understanding of the pollution potential of urban stormwater runoff and the dynamics of the Hillsborough River system. To the best of our knowledge, this study represents a unique approach to the biological and chemical characterization of the relationship between stormwater runoff and pollution problems in an urban receiving water body. Our ultimate goal in this research has been to integrate a multidisciplinary project including field biological studies, laboratory biological studies and chemical analyses of runoff and river sediments into a comprehensive assessment of the short term and long term degradative potential of urban stormwater runoff in Tampa.

In summing up the major conclusions of this research, the following generalizations can be made: 1) the benthic animals in the Hillsborough River are largely affected by seasonal changes in salinity and flow rate associated with rainfall; 2) a higher proportion of benthic pollution indicator species are present downriver as compared to upriver; 3) wet season runoff contains relatively low levels of toxic chemicals and does not appear to be toxic to estuarine animals; 4) dry season runoff contains significantly higher concentrations of toxic chemicals and can be acutely toxic to estuarine animals; 5) wet season runoff has a stimulatory effect upon phytoplankton growth and may represent a significant source of nutrients; 6) Hillsborough River sediments contain high concentrations of potentially toxic chemicals can be acutely toxic to estuarine animals; 7) major pollutants such as petroleum hydrocarbons in river sediments can be traced to urban runoff as their primary source; 8) based upon hydrocarbon analyses of sediments and suspended particulate matter, Hillsborough Bay has little effect upon pollution loads in the lower river sediments during periods of low river flow; 9) planktonic animals and plants in the river are dominated by river flow rates and salinity changes and are most likely little affected directly by runoff pollutants; and 10) numerous possibilities exist for shoreline improvements along the river to increase stability, decrease the impact of stormwater runoff, and increase aesthetic values.

A. Benthic Studies

Benthic macroinvertebrates have been used in several studies to document or assess the impact of non-point source pollution. Generally, benthic samples in published studies were collected at regular intervals for one or more years in order to account for seasonal variations. Pratt and Coler (1979) documented a progressive disruption in the macrobenthic community in a river system as it flowed through increasingly urbanized areas. These authors attributed this disruption to increasing urban runoff with the most acute effects seen during low river flow periods. In addition, they suggest that the most significant problems occur in the stream bed where pollutants and particulates may accumulate.

Pitt and Bozeman (1980) studied the chemical and biological characteristics of a river system as it flowed from an unurbanized area through an urbanized section affected by stormwater runoff. They reported that the urbanized section had a lower diveristy of aquatic organisms, increased abundance of pollution indicator species and generally higher levels of toxic chemicals and nutrients.

Benthic invertebrate populations in the Lynnhaven River system (Virginia) were sampled by Dauer et al. (1979) in a study of the effects of non-point sources of pollution. Comparisons of species composition and abundance among three creeks within the river system showed little correlation with quantity of non-point discharge; however, all three creeks contained several pollution indicator species within the benthic community.

Tomlinson et al. (1980) sampled benthic invertebrate populations and measured water and sediment chemistry in the vicinity of two storm drain outfalls in Lake Washington. Their data indicate a general enhancement of oligochaetes and depletion of chironomids in the vicinity of the outfalls. These and other alterations in benthic community composition were attributed to discharge toxicity, substrate alterations and/or smothering by particulates.

In the present research, benthic infaunal communities were found to vary in composition and density of organisms along the Hillsborough River in general accordance with the salinity regime. Highest densities occurred at the more estuarine stations during the dry season. The Hillsborough

River benthos appear to represent a system that seasonally oscillates between an estuarine salinity gradient and an essentially freshwater habitat. The persistence of estuarine species at some stations during the wet season is likely attributable to the capacity of the sediment to buffer the effect of overlying low salinity water for infaunal organisms and to the periodic intrusion of higher salinity water from Hillsborough Bay. It is unlikely that stormwater runoff has much of an acute effect upon benthic communities other than those associated with changing salinities. The long term effect of urban runoff upon benthic communities, however, may be substantial, especially at downstream stations, and is manifested in the accumulation of stormwater borne particulate matter with its associated pollutants. The accumulation of this particulate matter in river sediments may affect benthic organisms through direct toxicity (discussed below under Animal Bioassays) or through reduced dissolved oxygen levels. Many of the benthic species identified at river stations are also present in Hillsborough Bay where annual defaunation due to low dissolved oxygen levels have been well documented (Santos and Simon, 1980a; Santos and Simon, 1980b; Santos and Bloom, 1980). Reducing the rate of input of runoff particulate matter and/or removal of accumulated sediment in the lower river would lead to improved water quality and likely a reduction in the presence of pollution indicator species. Periodic sampling of benthic invertebrates, especially at downstream stations during the dry season, could provide a good indication of the success of mitigative procedures.

B. Animal Bioassays

Urban stormwater runoff is a very heterogeneous effluent. Both quantity and quality of runoff can be highly variable. Even the same drainage basin may produce very different effluents, depending upon the intensity of the rain event and the number of antecedent dry days. To compound matters further, the quality of runoff from a single outfall often varies temporally during the course of a storm event. For these reasons, a single drainage basin was selected to provide stormwater for toxicity testing. This drainage basin, the Artic Street basin, is described in the Introduction section of this report and was selected because of its balanced land use characteristics. The stormwater runoff from the Artic

Street basin was presumed to represent more or less "average" runoff for the greater Tampa Bay region.

Chemical analyses of stormwater runoff used in bioassay experiments (Tables 9 and 27) revealed heavy metal and hydrocarbon concentrations that could be potentially toxic to estuarine animals. The results of bioassay experiments using runoff samples, however, revealed an unexpectedly low toxicity relative to the concentration of pollutants revealed by chemical analysis. This lower than expected toxicity pattern was also evident in tests with whole sediment and suspended particulate matter. The reasons for these discrepancies are likely related to the fact that most potentially toxic chemicals in stormwater runoff are bound to particulate matter and that contact of runoff with saltwater causes precipitation of pollutants due to reduced solubilities.

Li (1975) reported that many pesticides, especially the least water soluble ones, adhered to particulate matter in stormwater runoff and were transported to receiving waters. Hunter et al. (1979) found that on the average 86% of the petroleum hydrocarbons in urban runoff were associated with particulate matter. Heavy metals often form relatively insoluble complexes, particularly in seawater, and tend to become adsorbed onto suspended particles (Renfro, 1973; Etcheber and Jouanneau, 1980).

Giovannelli and Murdoch (1983) reported that in most cases dissolved concentrations of lead, zinc and copper from the Artic Street drainage basin accounted for 50% or less of the total concentrations of these metals. Major reduction in solubility of these metals are known to occur at salinities above 15 ppt (Callahan et al., 1979) and thus the soluble fraction reported above could be significantly reduced upon mixing with estuarine water. Lum et al. (1982) tested a method of sequential chemical extraction of urban particulate matter for determination of soluble or exchangable forms of heavy metals relative to total heavy metal content. They concluded that a high proportion of heavy metals such as cadmium, copper, lead, and zinc, among other elements, were present in urban particulate matter in readily bioavailable form. These determinations were made under specific laboratory conditions and may not be representative of the bioavailability of these pollutants in seawater solutions.

Considerable research has been conducted with contaminated sediments as part of the U.S. Army Corps of Engineers Dredged Material Research Program. Some of these studies conclude that most pollutants associated with harbor sediments (which probably resulted from runoff particulates) are not present in readily bioavailable form and thus do not pose a problem in ocean water (Neff et al., 1978). Olsen (1980) reviewed the Corps' dredged material literature and concluded that site specific, physical, chemical and biological factors are all important in determining the bioavailability of sediment associated pollutants.

In an estuarine system like the Hillsborough River, several factors interact simultaneously to determine the form and effect of sediment associated pollutants. These factors include salinity, temperature, dissolved oxygen levels, pH and microbial activity. As these factors change and interact, sediment associated pollutants may be released into the water in toxic forms or alternatively precipitated as bound complexes.

Based upon the results of this study, urban stormwater runoff does not appear to pose a significant acute toxicological problem to animal life in the lower Hillsborough River. Rapid dilution of runoff and mixing with estuarine water would both reduce the toxicity of runoff under field conditions. The only conditions under which urban runoff might be acutely toxic within the river system would be during a dry season rainfall event where runoff entered the river under low flow conditions and low salinities. Calculation of LC_{50} values for the runoff samples tested would serve no useful regulatory purpose since so many factors may influence toxicity of runoff.

Stormwater runoff does pose a serious pollution threat through accumulation of particulate matter and associated pollutants in river sediments. The acute toxicity of river sediments to some bioassay organisms indicates that not all sediment associated pollutants are bound in nontoxic form. It should be noted that the sediment bioassays reported above were carried out under the least toxic conditions of high salinity and high pH. The potential clearly exists for acute and chronic toxic effects to occur in river fauna due to accumulation of stormwater borne pollutants. The presence of carcinogenic agents such as cadmium and certain aromatic hydrocarbons suggests that chronic effects may be expressed in forms other than were analyzed in the present research (i.e., carcinogenesis, teratogenesis, turmorogenesis).

The suspended particulate phase (SPP) bioassays conducted with Hillsborough River sediments were intended to assess the acute toxic potential that might occur after disturbance or resuspension of bottom sediments. These tests were carried out under various combinations of pH and salinity in order to determine the effect of these parameters upon toxicant release from the sediments. The SPP displayed the highest toxicity under conditions of low salinity as was the case with whole stormwater. These results suggest that resuspended sediments from the Hillsborough River could be toxic, especially to invertebrates, if resuspension occurs under low salinity conditions.

Long term improvements in river water quality will only come if procedures are implemented to remove and/or control input of stormwater associated particulates and pollutants. Although the sediment and suspended particulate phase bioassays conducted during this project followed general guidelines established by EPA/COE (1977), they were not intended to assess the suitability of Hillsborough River sediment for ocean disposal following dredging. If appropriate, this assessment should be carried out separately; however, based upon the results of this research, Hillsborough River sediments would not likely pass the bioassay criteria for ocean disposal.

C. Algal Assays

The effects of stormwater runoff upon natural and cultured phytoplankton have been relatively well documented and successfully used to predict potential problems, especially for enclosed water bodies. Stormwater runoff has been shown to be a significant source of nutrients for phytoplankton, often leading to eutrophic conditions and reduced water quality in receiving waters. Yousef et al. (1980) found that high concentrations of stormwater runoff entering Lake Eola in Orlando, Florida, inhibited phytoplankton growth, while diluted stormwater stimulated growth. Gaggiani and Lamonds (1978) reported similar enrichment of lake water due to runoff, leading to phytoplankton blooms in other Florida lakes. There appears to be a balance between phytoplankton growth stimulation and inhibition in runoff that can be attributed to nutrients and toxic chemicals, respectively.

The Hillsborough River system is not an enclosed water body and thus would not be expected to show as severe an effect from nutrient addition as would a lake. Most of the nutrients entering the river via runoff are probably transported to Hillsborough Bay rather rapidly, especially during the wet season.

Algal assays with Artic Street runoff suggest that wet season stormwater stimulated phytoplankton growth even at high concentrations. For management purposes, it would be instructive to know what effect filtration of stormwater would have on available nutrients and how nutrients and toxic chemicals affect phytoplankton growth in dry season runoff.

D. Plankton Studies

Analysis of zooplankton and phytoplankton populations in the Hillsborough River indicates that river flow rates have a profound effect upon these communities. Generally, plankton communities display higher diversity and higher abundance of individuals under marine or estuarine conditions than under freshwater conditions. This is consistent with the observation that plankton densities were higher at all stations during the dry season than during the wet season. Marine organisms were predominant at all but the most upstream station during the dry season and decreased in relative abundance during the wet season. The most downstream station maintained a dominance of marine plankton even during the wet season, indicating that Hillsborough Bay has a strong effect upon the composition of the plankton community throughout the year.

E. Lower Hillsborough River Shoreline Inventory

The Hillsborough River, from the dam to the bay, has been moderately to severely altered by urbanization. Calculations reveal that 54% of the shorelines have been hardened. Of the hardened portions, about 47% are composed of bulkhead, while about 8% are riprap. Approximately 13% of the river's shores are filled but unhardened, and 34% are more or less native (a total of 102% for these figures is due to their nonexclusive nature).

Native vegetation along the river shows a general transition from salt-tolerant species downriver to salt-intolerant forms upriver, although this pattern has been modified due to historical and natural causes.

Four main recommendations can be made based upon the information collected during this survey. These include:

1) The City of Tampa should concentrate on the river section between Sligh Avenue and North Boulevard as the preferred area for immediate shoreline improvements;

2) A three phase plan for shoreline improvements should be developed for the target segment including: a) creation or restoration of vegetated shorelines on public lands; b) removal of exotic plant species from natural and filled shorelines; and c) enhancement of riprap shorelines with native vegetation;

3) The City of Tampa should involve citizens and shoreline owners in waterfront improvement through development of homeowner's guides and incentive programs; and

4) The City of Tampa should seek a formal role in the permit review and approval process affecting dredging, filling or shoreline construction in the Hillsborough River, beyond that currently exercised through planning, review or code enforcement programs.

F. Hydrocarbon Studies

The hydrocarbon content of sediments collected throughout the entire study area (lower Hillsborough River, upper Hillsborough Bay and Hillsborough Reservoir) and from stormwater runoff collected from the Artic Street watershed was dominated by petroleum indicative of crankcase oil-like material. Characteristic biogenic (natural) hydrocarbons were also present in sediments but these were less abundant than the petroleum component. Sediment petroleum content increased from the reservoir downstream to a maximum near the I-275 bridge. Concentrations then decreased toward the river mouth and into Hillsborough Bay.

The hydrocarbon content of particulate matter in the stormwater runoff was about ten times that found in river sediments, indicating that stormwater was a major source of petroleum contamination in river sediment.

Surface and bottom water samples were collected simultaneously with sediment samples and were analyzed for hydrocarbons associated with suspended particulate matter. These analyses revealed no petroleum contamination in surface (freshwater) or bottom (saltwater) samples.

These results show that Hillsborough River sediments are contaminated with petroleum of crankcase oil-like material. The primary source of this material is from stormwater runoff. No upriver transport of resuspended sediment was observed from the bay or river mouth during a rising tide with low river flow conditions.

This last conclusion appears to be in conflict with the contention that upstream tidal transport in the lower river is contributing to sediment accumulation (Metcalf and Eddy, 1983b, pg. 4-11, 6-4). It would seem more likely, based upon the present evidence, that saltwater intrusion into the river may obstruct particulate transport downriver and thus result in accumulation of sediments. This proposed obstruction could occur through physical forces such as higher density saltwater opposing downstream flow of freshwater or through chemical forces such as flocculation of minerals and generally lowered solubilities of metals in saltwater. It may be that during periods of high suspended particulate loads in the river, as occur following heavy runoff, tidal forces may carry some material upstream and contribute to its deposition. Upstream transport, however, does not appear to occur during low river flow conditions. The relationships between river flow and tidal flow need to be addressed under high river flow conditions in order to understand the net effect of freshwater and saltwater interactions. Subsequent studies on sediment chemistry should concentrate on the river section near the I-275 bridge, since this area contained the highest concentrations of petroleum hydrocarbons and also produced the highest sediment oxygen demand (SOD) reported in the river (Metcalf and Eddy, 1983b). This portion of the river probably represents a major interaction point between freshwater from upriver and saltwater from the bay. Chemical analyses of sediment core samples from Sligh Avenue to Platt Street would be useful in determining the volume of contaminated sediments to be dealt with.

G. General Conclusions

Stormwater runoff entering the lower Hillsborough River does not pose an acute toxicological problem to most endemic biota. Rapid dilution rates of stormwater and chemical complexion of pollutants into insoluble forms upon contact with saltwater reduce the direct toxicity of runoff. Based upon chemical composition alone, the acute toxic potential of stormwater runoff would be over estimated, since much of the potentially toxic material is bound in non-bioavailable form. Most state and federal water quality standards are based upon chemical composition rather than actual toxicity and thus urban stormwater runoff may contribute significantly to water quality violations.

Table 27 summarizes the state and federal water quality criteria and compares these values to measured levels in urban runoff and receiving waters. The fact that different water quality criteria have been established for freshwater as opposed to saltwater makes interpretation difficult with respect to a variable system like the Hillsborough River. In addition, no criteria exist for petroleum hydrocarbons, yet these pollutants are present in high concentrations in runoff and sediments and may represent a significant threat to water quality.

Dilution rates of stormwater runoff appear to be sufficient in the river to reduce heavy metal concentrations to below water quality criteria (with the exception of copper and zinc at certain times).

The chemical data presented in Table 27 for "first flush" runoff indicates that pollutant levels may be over seven times higher in this water than in "average" runoff from the same storm event. This suggests that control measures for limiting input of runoff pollutants should include mechanisms to divert or retain this first flush material and prevent it from directly entering the river.

Pollutant loads in average river sediments (Table 27) are alarmingly high and will need to be dealt with before significant improvements in water quality can be expected. Recommended actions to alleviate this problem includes: 1) removal of existing contaminated sediments from the river; and 2) implementation of the stormwater management plan (Metcalf and Eddy, 1983a) and the recommended improvements in the Hillsborough River shoreline (this report) to provide a long-term system for limiting pollutant input into the river.

Table 27. Comparison of water quality criteria with values measured in Hillsborough River sediments, water and runoff.

SOURCE	Copper ug/l	Cadmium ug/l	Lead ug/l	Mercury ug/l	Zinc ug/l	Petroleum ug/g Hydrocarbons
EPA[1]	22 (23)	3.0 (59)	170 (NA)	4.1 (3.7)	320 (170)	--
Florida[2]	30 (15)	0.8 (5)	30	0.2 (0.1)	30 (NA)	--
Average Wet Season Runoff	26	4	207	0.75	166	608
Dry Season Runoff	38	4	500	--	530	618
Dry Season First Flush Runoff	--	30	1600	--	970	2037
Average River Sediments	--	1000	107000 ug/kg (wet wt.)	--	69000 ug/kg (wet wt.)	267
Suspended Particulate Matter[3]	--	10	2800	--	2065	0
River Water[4] April 1982	3-6	--	4-26	--	20-90	--
River Water[4] November 1982	13-57	--	8-22	--	3.6-22	--

[1]EPA Ambient Water Quality Criteria for Protection of Aquatic Life, November, 1980, 45FR (231) and 46FR (40199). Values represent acute freshwater level followed by acute saltwater level; NA = Not available.

[2]State of Florida Water Quality Standards for Class III Waters (Chapter 17-3). Values represent freshwater standard followed by saltwater standard; Fla. Dept. Environ. Reg. Supp. No. 123.

[3]Suspended particulate matter values for heavy metals obtained from laboratory resuspension of sediments (see Section III, Animal Bioassays); hydrocarbon analyses represent field collected particulate matter.

[4]Data from Metcalf and Eddy (1983a).

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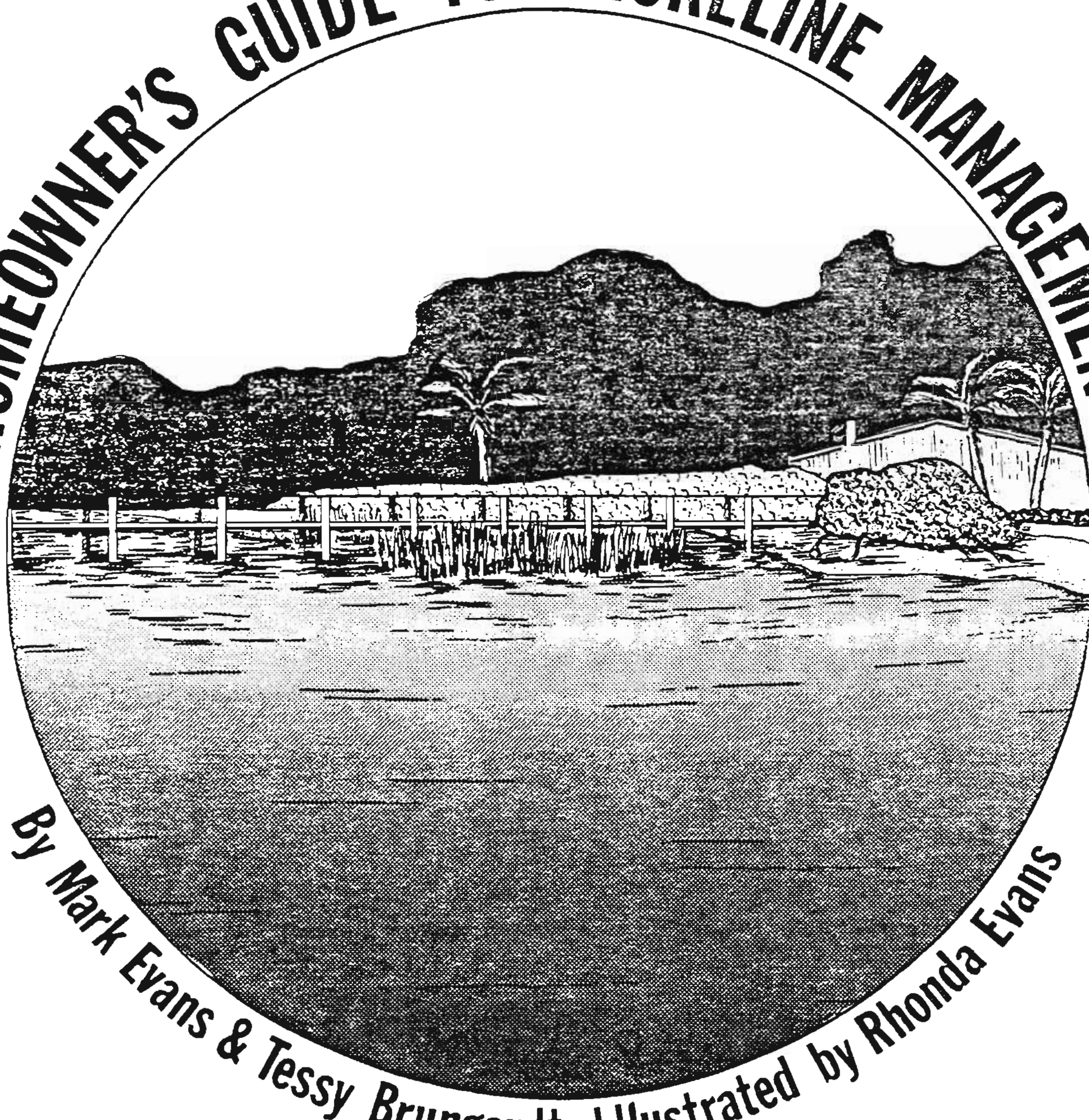
APPENDIX I: Excerpts
from

HOMEOWNER'S GUIDE TO SHORELINE MANAGEMENT



By Mark Evans & Tessy Brungardt · Illustrated by Rhonda Evans

Sponsored by

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TABLE OF CONTENTS

INTRODUCTION

The beaches, bays, bayous, and tidal creeks of Sarasota County are some of the most important resources and attractions of this area. As more people come to the Sarasota area, there is an increased demand for shorefront homesites, marinas, and parks. This demand has resulted in considerable change in the character and function of the shorelines. From 1948, there has been a 20% decrease in mangroves, an 8.3% decrease in salt marsh vegetation, and a 668% increase in seawalls and revetments. Additionally, there has been an increase in shorelines susceptible to erosion due to the spread of Australian pine. Together with the alteration of our shorelines, there must be an effort to maintain and preserve the quality of those areas. There are no easy solutions to the problems of shoreline development, but the following guide is an approach to responsible management.

This booklet is designed to provide the residents of Sarasota County with specific information and techniques necessary for the proper development and maintenance of their shorefront properties along the salt water shorelines in Sarasota County. This booklet will begin with a general description of the ecological processes of the shore. Next, each type of shoreline in Sarasota County will be described with development and maintenance alternatives, including a few selected references that should be of interest to anyone requiring additional information. Finally, information on the use, availability, and maintenance of shoreline plants will be given, along with related local, state, and federal regulations.

TABLE II: ESTIMATED COSTS OF SHORELINE STABILIZATION[1]

	Vegetation		Concrete Seawall		Stone Revetment	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
PERMITS[2]	not req.	not req.	$450	$600	$450	$600
CONSTRUCTION	$0.00	$600[4]	$4500[5]	$10000[5]	$4000[5]	$13000[5]
MAINTENANCE	$0.00	$60/yr.[6]	$225/yr.[7]	$500/yr.[7]	----[8]	----[8]
TOTAL INSTALLATION COST (EXCLUDING MAINTENANCE)	$0.00	$600	$4950	$10600	$4450	$13600

1. Single family lot; 100 feet of waterfront

2. Engineering estimates from Steven Houghton, P.E.

3. Utilizing existing plants or available materials and 'do-it-yourself'.

4. Quoted from Robert M. Snyder, Snyder Oceanographic Services. Conference on Restoration of Coastal Vegetation in Florida., 1978.

5. Based on "Seawall and Revetment Effectiveness, Cost and Construction", C.A. Collier, 1975.

6. Figured as one hour/month for trimming, pruning, etc. at $5.00/hour.

7. Based on 20 year life expectancy and eventual replacement.

8. There are no reliable estimates for revetment maintenance, however, proper maintenance would include: filling voids, restoration of the facing and slope, possibly involving eventual replacement.

APPENDIX I

Shoreline Plants for Conservation and Beautification

This appendix presents a list of useful shoreline plants which are of primary importance to Sarasota County residents. All of the species listed are native to this part of Florida. Native vegetation is recommended for several reasons:

1) Native shore plants play a major role in eco-system dynamics. These plant and animal communities have evolved and interacted for thousands of years and are best suited to the local environment. They are valuable to man for food production, recreation, aesthetic pleasure, and storm protection.

2) Native plants have certain characteristics that insure their survival in the harsh shoreline environment. Salt water inundation, exposure to wind and waves, alkaline soils, periodic cold spells, and the extreme pattern of wet and dry seasons are some of the rigors of the shoreline habitat.

3) Because they are adapted to the harsh environment of the shore, native plants require almost no maintenance, such as fertilizers, insecticides, or watering, after they are established, although some planting guidelines recommend initial fertilization.

At this point, it is important to note the problems associated with exotic and imported plants. Because these plants are not native to this area, most of them are not adapted to the local environment, and require special attention, such as watering during the dry season. The exotics that can grow without special attention often grow unrestrained and eliminate native vegetation through competition, causing problems because they are not effective at stablizing shorelines.

An example of a particularly troublesome exotic plant is the Australian pine (Casuarina sp.). These trees were introduced to southern Florida in the early part of this century and have since spread rapidly. They are highly salt tolerant and often colonize beaches and other shores. They have wide, shallow root systems that are easily undercut by waves, making them susceptible to erosion. This shallow root system, coupled with their relatively great height, makes them extremely vulnerable to strong winds; examples of overturned trees are evident on many beaches. For these reasons, Australian pine is unacceptable as a shoreline plant.

However, many shorelines in Sarasota County are already colonized by Australian pine and need to be properly managed. In areas where the trees are not yet very large, they could be topped and trimmed to be maintained as shrubs or hedges, thus preventing them from becoming top-heavy. Additionally, Australian pines grow and reproduce very rapidly, requiring constant thinning, removal and maintenance. On some shorelines, it is appropriate to gradually eliminate the Australian pines and replace them with native vegetation. This can be accomplished by cutting down one or two trees at a time and replacing them with the appropriate native plants. When these plants have become established, a few more trees can be replaced, and so on until the pines are eliminated.

APPENDIX II

HILLSBOROUGH RIVER STUDY

I. Introduction

A. Purpose of the study

(a) problem identification and analysis
(b) establish principles and standards for use
(c) develop an urban river plan
(d) establish an immediate action program for problem resolution.

B. Scope of the study

(a) delineation of the study area (e.g. from the southern most boundary of Hillsborough River State Park to the Platt Street Bridge.
(b) river uses and controls
(c) adjacent land-use controls (e.g. up to 500' on either side of the river).

II. Research Methodology

A. Survey of existing conditions

(a) physical-environmental
(b) legal jurisdiction and authority
(c) river access-usage
(d) adjacent land-uses
(e) special problems.

III. Findings and Conclusions

A. Problems

(a) aesthetics
(b) traffic
(c) safety
(d) access
(e) water quality, supply
(f) nuisances
(g) use compatibility

B. Principles and Standards

(a) citizen participation

C. Plan Alternatives

(a) citizen participation

IV. Recommended Plan

A. Goals, Objectives

B. Policies, Ordinances (by jurisdiction) "regulatory controls"

C. Action Program (by jurisdiction) "capital improvements).

HILLSBOROUGH RIVER STUDY

Activity 1. Establish Policy Committee

Methodology - A general policy committee should be formed consisting of members representing each of the various agencies and jurisdictions which exercise authority over some aspect of River use. The purpose of this committee is to review staff reports and recommendations for its potential impact upon their jurisdictions and to coordinate the policies and actions of each. All participating agencies and jurisdictions should be asked to adopt the final plan.

Activity 2. Establish Citizen Advisory Committee

Methdology - A Citizen Advisory Committee should be formed consisting of one or more persons from the following groups: property owners within 500 feet of the river, members of organized user groups, and occasional users. These persons should be selected at randon from those in attendance at each of the first two citizen participation meetings. The general public will be encouraged to attend all citizen Advisory Committee meetings.

Activity 3. Data Collection

Methodology - Data collection for this study shall be undertaken in six principle categories as shown on the outline. The first, literature review, will consist of identifying, selecting and reading secondary source material pertaining to similar studies of comparable urban rivers as well as any prior studies of the Hillsboroguh River itself. Data collected in this category will be used to further refine our own methodology, to establish principles and standards, and to transfer the application of successful techniques employed elsewhere.

The Physical inventory is a primary data collection activity which consists of field observations. Staff will prepare base maps and develop codes which can be taken into the field to record all the existing physical features of the river. This will entail one or more boat trips up the river. Examples of the observations to be recorded are riverbank conditions, bridges, clearances, structures in and on the water,among others.

The river use survey is another primary data collection activity. Like the physical inventory,forms must be developed for use in recording various field observations. Because river use is seasonal in nature, this activity is scheduled to take place over an eight month period. This will insure capturing the peak use periods. Because the river is so long and manpower is so short, citizen volunteers, students and City Parks Department Personnel will be recruited for assistance. Examples of observations to be recorded are days of the week, time of day, frequency of traffic by type of craft, etc.

The land use survey will consist principally of in-house mapping as much of this data has already been collected in connection with the land use plan. Existing and proposed land use regulations will be overlayed for easy analysis.

The user survey is distinguished from the river use survey by the fact that the former personally interviews the user with respect to the type and frequency of use as well as his attitudes toward the river. The same result could be obtained in a number of alternative ways (such as a mail questionnaire) although with some compromise of accuracy. The user survey is best scheduled during the peak months of May - July because it allows us to "test" user reactions to various proposed river management policies.

Finally, the public policy review will study the rules and regulations of each governmental jurisdiction for their impact upon river use. The data collected here will be used to develop some sense of commonality and coordination among agencies.

Activity 4. Progress Report

Methodology - Staff will prepare a progress report for the Planning Commission giving the status of all study activities undertaken to date. Since the early part of the study will be mostly data collection, no special meetings, discussions or recommendations are contemplated in connection with the report.

Activity 5. Data Analysis - See #6 below.

Activity 6. Progress Report

Methodology - Various data analysis tasks are timed to coincide with the completion of their respective collection activities so as to produce a problem identification report at the earliest possible date. This report will be the focus of discussion and input from citizens' groups, policy people and the Hillsborough County Planning Commission.

Activity 7. Review and Comment

Methodology - Meetings will be held with all interested parties to seek their comments on the second progress report. The meetings will be scheduled subsequent to the distribution of the report to allow for maximum meaningful participation.

Activity 8. Principles and Standards

Methodology - Based upon prior steps, staff will develop principles and standards to be applied in guiding future river use and development. Those principles and standards will constitute the framework within which all subsequent planning will be conducted. Examples of principles and standards might include minimum acceptable water quality, segregation of clearly incompatible uses, and minimum man-made flow alterations. Such principles will be used to define and delineate the number of alternative use, management and design concepts proposed for each problem identified by prior analysis.

Activity 9. Develop Alternative Use and Design Concepts

Methodology - Recognizing that there is probably no single best solution or a solution which will satisfy everyone, several alternatives will be generated for public discussion. Specification of the topics would be premature at this time except to state that there should be a variety of ways to address each of the problems identified.

Activity 10. Develop River Management Concepts

Methodology - This task will, perhaps, be the most problematic for staff as it may involve the administration of such devices as user fees, capital improvements and rule enforcement. Proposed management concepts will be derived from discussions with the key policy people from each of the relevent jurisdictions.

Activity 11. Progress Report (see 12 below)

Activity 12. Review and Comment

Methodology - The third progress report will be the product of Activities #9 and #10. Meetings will be held and input solicited from all interested groups. Consensus-seeking arrangements will have to be employed among members of the policy committee and the HCCCPC in order to arrive at key policy decisions.

Activity 13. Develop River Plan

Methodology - The River Plan will be the final product of this effort and will contain for each jurisdiciton: goals, objectives, implementation strategies and an action program for the near term. To the extent possible, actions will be coordinated among jurisdictions and functionally linked via their budgets to the responsible line departments.

Activity 14 - 20. Document Approval, Reproduction and Distribution

Methodology - (Self explanatory).