Tampa Bay Estuary Program
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NS&T Program

Tampa Bay

Chemical Contamination: Extent, Toxicity, Potential Sources and Sediment Quality Management Plans

Center for Coastal Monitoring and Assessment
National Centers for Coastal Ocean Science
National Ocean Service
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U.S. Department of Commerce

Cover photo: *Mangrove islands along the eastern shore of Tampa Bay*

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Chemical Contamination in Tampa Bay:

Extent, toxicity, potential sources and possible sediment quality management plans

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Special Report 1999

Tampa Bay National Estuary Program
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Executive Summary

Tampa Bay, Florida has been subjected to numerous modifications and stresses associated with urban and industrial growth. Contamination by mixtures of toxic chemicals has occurred as a result of a variety of municipal, industrial, agricultural, and other activities in the region. NOAA and other agencies have documented the types and degree of contamination and the adverse biological effects associated with the presence of toxic substances throughout the estuary.

As a part of its National Status and Trends Program, NOAA has documented adverse biological effects in Tampa Bay sediments, oysters, and fishes. Methods used in Tampa Bay were equivalent to those used elsewhere by NOAA in surveys of toxicant effects. Data were analyzed to determine the concentrations of potentially toxic chemicals, presence and severity of adverse biological effects, the spatial patterns and extent of bioeffects, and correlations between measures of effects and concentrations of toxicants.

The toxicity of sediments was determined with a battery of acute laboratory bioassays coupled with measures of the concentrations of toxic substances. Toxicity was most severe in regions of northern Hillsborough Bay. Moderate toxicity was observed in regions of western Old Tampa Bay, along the western shore of ,Middle Tampa Bay, and in lower Boca Ciega Bay. Portions of Old Tampa Bay, and Middle and Lower Tampa Bay were least toxic or nontoxic. The most toxic samples had relatively high concentrations of petroleum hydrocarbons, chlorinated pesticides, other chlorinated hydrocarbons, ammonia, and trace metals - all of which could have contributed to toxicity.

Potentially toxic chemicals in the tissues of oysters collected throughout the estuary ranged widely in concentrations. Generally, the concentrations of toxicants in oysters followed a pattern similar to that observed in the sediments. Oysters collected in northern

Hillsborough Bay, and to a lesser extent, Bayboro Harbor on the western shore of Middle Tampa Bay had the highest chemical concentrations. Measures of the biological responses of the oysters to the presence of toxicants in their tissues failed to show clear patterns associated with the chemical concentrations

Several species of marine fishes were collected in Tampa Bay to determine if these animals had been exposed to and were adversely affected by toxicants. As with the sediments and oysters, chemical concentrations were highest in many of the fish collected in northern Hillsborough Bay. Highest chemical concentrations in fish tissues were accompanied by elevated measures of physiological responses to these substances, and adverse biological effects.

Data from the NOAA surveys have been combined with data from similar research performed by the Tampa Bay National Estuary Program (TBNEP) and other agencies to provide an overview of the patterns in chemical contamination in sediments, identify toxic hotspots that may require the most immediate attention, document chemicals of potentially highest ecological concern, and identify possible management actions to minimize risks associated with toxicants. The TBNEP instituted a number of projects and action plans in response to the information generated by NOAA, TBNEP, and others on sediment quality. All of these actions were designed to decrease the probabilities of biological effects and increase the quality of sediment habitats in the estuary.

This document provides a record of the research conducted by NOAA on toxicant effects in Tampa Bay, a synopsis of the results of that research, a brief account of the cooperation between NOAA and TBNEP, and a description of the uses of sediment quality data in establishing management actions to enhance and protect sedimentary habitats in the bay.

Purpose

Clean sediments are important to the abundance and diversity of local biological resources, such as shrimp, fish, and sea birds, that are essential for sustainable use of the bay. Attainment of clean sediments is a goal shared by many different agencies, public interest groups, and citizens who work or recreate in Tampa Bay or manage its resources. This goal can be reached only with reliable and useful information on the areas in which sediments are degraded, the severity and extent of degradation, and the likely contributing causes and sources of degradation.

Although local communities have made significant progress in improving water quality in Tampa Bay, the quality of sediments in some regions of the bay has been impaired by potentially toxic substances. Studies conducted throughout the bay by the National Oceanic and Atmospheric Administration (NOAA), the Florida Department of Environmental Protection (FDEP), and the Tampa Bay National Estuary Program (TBNEP) have revealed relatively high levels of some contaminants in sediments from several bay sites. The TBNEP has initiated many important steps in partnerships with local governments to identify the sources of these contaminants and, ultimately, to minimize or curtail their release into the bay.

The purpose of this report is to summarize the information developed by the NOAA and the TBNEP to characterize chemical contamination of sediments and its effects in Tampa Bay, to document how this information was used by the TBNEP in preparing its management plans, and to provide an example of implementation of specific actions for improving environmental quality of Tampa Bay. This report provides documentation of the chronology of important steps taken to develop an understanding of the problem of sediment contamination in the bay.

Tampa Bay has been impacted by a wide variety of human activities that have, collectively, stressed components and regions of the estuary. Such activities have included dredging of navigation channels, filling of wetlands and sea grass beds, over-fishing, nutrient enrichment, inputs of pathogens, and losses of shoreline mangroves, as well as other valuable habitats and species. The primary focus of concern regarding the environmental quality in Tampa Bay through the late 1980’s and early 1990’s was on the interrelated issues of water quality, nutrient enrichment, light attenuation, and losses of valuable sea grass beds. Because limited information was available on the concentrations of potentially toxic chemicals in Tampa Bay, the potential threats of toxic chemicals upon living resources were poorly known.

In 1991 there was considerable bay-wide information on the presence of toxic chemicals in sediments, but for only a limited number of substances. There were no effects-based interpretive tools to evaluate the potential significance of the chemical concentrations observed in sediments. There were no bay-wide estimates as to whether the chemicals occurred at sufficiently high levels to warrant concern. There was no information collected bay-wide with which to estimate the spatial scales of sediment toxicity, if any. Resident oysters and fish had not been examined throughout the estuary to determine the presence of toxicants and to document their adverse effects.

As a component of its National Status and Trends (NS&T) Program, NOAA conducts a nationwide program of monitoring and research on the distribution, concentration, and adverse biological effects of toxicants in selected regions. Surveys are conducted to estimate the severity, spatial extent, and distribution of adverse effects and their relationships with mixtures of toxicants in each region. Information gained in these surveys is used by NOAA and other federal, state, and local governments to identify the scope of sediment contamination, and to prioritize areas and chemical substances most in need of management actions.

Several factors contributed to the selection of Tampa Bay for a regional bioeffects assessment. First, there was evidence from a number of previous surveys that chemical contamination was sufficient in some areas to warrant concern for living resources such as fish and shellfish. Chemical analyses of oysters collected as a part of the NS&T Program’s Mussel Watch Project from several locations showed relatively high concentrations of many different substances. Chemical concentrations in surface sediments were relatively high in some areas.

Second, the FDEP expressed a great deal of interest in obtaining additional information on toxicants and their effects in the estuary. A state-wide atlas of sediment contamination information compiled by the FDEP clearly showed that among the estuaries and bays of Florida, some portions of Tampa Bay were highly contaminated. Third, NOAA received funding to perform a hydrographic survey of the Tampa Bay estuary to provide information needed for maritime vessels and collaboration between the bioeffects survey and hydrographic survey was anticipated.

An atlas of sediment contamination information compiled by the FDEP clearly showed that among the estuaries and bays of Florida, some portions of Tampa Bay were highly contaminated.

Figure 1 provides a brief synopsis of major activities conducted in Tampa Bay by NOAA and by TBNEP and outcome or products of these events. Research conducted by the University of South Florida (USF) demonstrated the presence of toxicants in sediments. The NOAA Mussel Watch Project began chemical analyses of oyster and sediment samples in 1986, roughly during the period the USF conducted their bay-wide chemical surveys for selected substances in sediments. The data from both projects indicated high chemical concentrations in some regions of the bay. In 1991 NOAA published a literature review in which available data suggested that chemical concentrations in sediments exceeded effects-based guidelines in some regions (Long et al., 1991).

Since 1986, NOAA has conducted numerous analyses of potentially toxic substances in oysters, sediments, and fishes and assays of their adverse effects in the Tampa Bay estuary. The locations sampled during these studies are shown in Figure 2. Collectively, the information gained from these studies has provided a broad basis for comparing conditions within the estuary and identifying both areas and chemicals of greatest concern. This information was used extensively by the TBNEP in developing management plans for the estuary as expressed in the Comprehensive Conservation and Management Plan (TBNEP, 1996).

Figure 1. Chronology of important events and the products or significance of those events in the characterization of chemical contamination and toxicity in Tampa Bay.

TBNEP Activites			NOAA Activites	
Products of Activities	**Activity or Event**		**Activity or Event**	**Products of Activities**
		1986	USF sediment quality surveys	• Identified depositional areas • Identified contaminated areas
		1990	NOAA hydrographic survey initiated	• Up-dated info on water currents and speed
			NOAA Mussel Watch data summary	• Indicated high chemical concentrations in oysters at some sites
			Fish bioeffects surveys inititated by NOAA	
• Coalesced management of Tampa Bay • Began evaluation of water quality related issues	TBNEP initiated	1991	NOAA Literature survey completed	• Identified hotspots exist • High potential for effects in some areas • Documented data availability
			Phase I of NOAA sediment quality survey initiated	• Toxicity present • Identified spatial patterns
			Phase I of oysters bioeffects surveys initiated by EPA-GB	• Methods developed • Some oysters stressed
• TBNEP recognized need for sediment action plan	NOAA presentation to TBNEP	1992	Phase II of NOAA Sediment quality survey Initiated	• To confirm spatial patterns To provide additional coverage
			Analysis of benthic sampler from NOAA stations	• To complete the sediment quality triad
• To provide interpretive tools	FDEP initiates derivation of state SQAGs	1993	Phase II of oyster bioeffects surveys initiated by EPA-GB	• Contaminants found in oysters • Some oysters affected
• Provided additional data * Benthos altered at some locations	Annual benthic surveys initiated by TBNEP			
• Field-verified in Tampa Bay • Some Tampa Bay sediments exceeded SQAGs	FDEP publishes state SQAGs	1994	Results of NOAA sediment quality surveys published	• Estimated severity and magnitude of degraded sediments • Identified chemicals of concern
• Identified hotspots and their dimensions • Identified types of contaminant sources • Stormwater important	Sources and loadings report published	1995		
• To evaluate adequacy of available data • To adopt data analysis approach	First SAG meeting convened by TBNEP			
• Adopted triad approach • Identified potential chemicals of concern	SAG report published			
• Confirmed spatial patterns • Confirmed hotspots with weight of evidence	Triad assessment report published	1996	Fish bioeffects article published by NOAA	• Contaminants present in fish • Contaminant-induced responses documented
• Confirmed toxicological chemicals of concern • Identified bioaccumulative chemicals of concern	Risk assessment report published	1996/1997	Sediment quality article published by Carr et al	• Spatial extent of toxicity • Severity of toxicity • Toxicity/chemistry relations
• Developed numeric sediment quality metrics and targets	Second SAG meeting convened	1997		
* To identify sources in priority basins [On-going]	Sources Inventory			

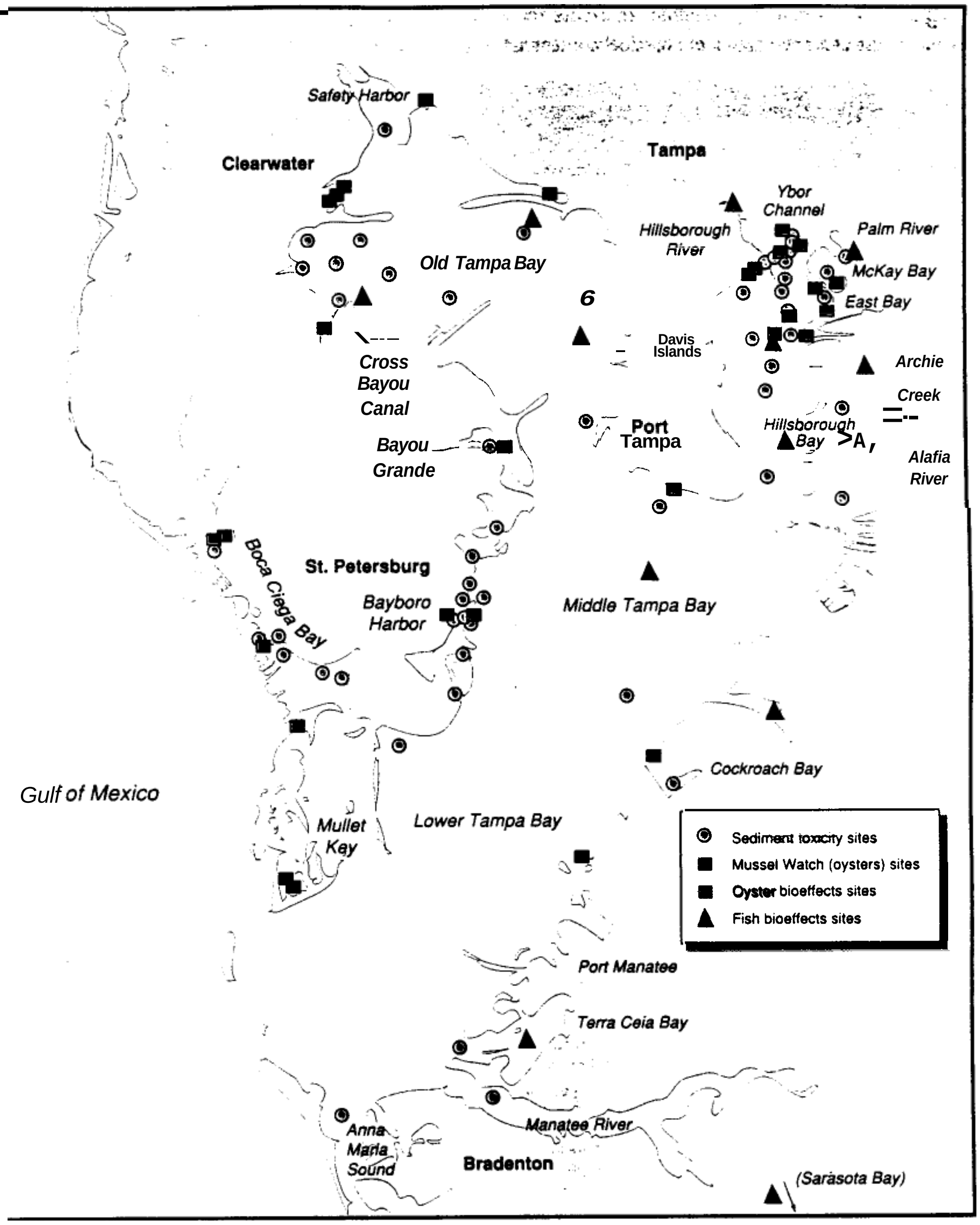


Figure 2.

NOAA has conducted studies at numerous sampling sites throughout Tampa Bay to determine the degree of biological effects of toxicants.

Historical data

Many sediment quality studies had been performed in Tampa Bay before NOAA began its surveys of contaminant effects. Previous studies were conducted either in small portions of the estuary or were restricted to certain selected chemicals. Data were compiled from these individual surveys and were compared with numerical sediment quality guidelines to estimate the potential for biological effects (Long et al., 1991). Figure 3 shows the percentages of chemical concentrations from sediment samples that exceeded ERL (Effects Range-Low) guidelines and ERM (Effects Range-Median) values (from Long and Morgan, 1990) in the nine major regions of the estuary. Most ERM values are about 10 times higher than the corresponding ERL values; therefore, the percentages of samples exceeding the ERMs are lower than those exceeding the ERLs.

These historical data showed that chemical concentrations were most frequently elevated in the samples from the lower Hillsborough River and considerably lower in all other regions (Figure 3). Samples from the river frequently had very high concentrations of lead and petroleum hydrocarbons, often indicative of urban runoff. The percentages of samples from the lower Hillsborough River with chemical concentrations greater than at least one ERL (77%) or ERM (35%) were higher than in a nationwide database (i.e., 42% and 27%, respectively; Long et al., 1998). Chemical concentrations in samples from Old Tampa Bay, Middle and Lower Tampa Bay, Terra Ceia Bay and the Gulf of Mexico rarely exceeded the ERM guidelines. Those from Boca Ciega Bay and the lower Manatee River were intermediate in levels of contamination.

Based upon a review of these historical data, most of the focus of attention in the NOAA studies was upon the northern Hillsborough Bay region where effects of toxicants were most probable. Therefore, sampling effort in this area was higher than in other regions of the estuary (Figure 2).

Sediment toxicity

In 1991 and 1992 NOAA analyzed 165 sediment samples from 55 locations (Figures 1 and 2) throughout the bay with a battery of laboratory toxicity tests and chemical measurements (Long et al., 1994). The data were intended to provide information on the presence, if any, of toxic conditions in surficial sediments (upper 2-3cm) that were assumed to represent recent contaminant inputs. The survey was designed to estimate the severity and spatial extent of toxicity, if present, and the apparent relationships between measures of toxicity and chemical concentrations.

Sediment samples were collected throughout the bay to ensure a broad representation of conditions in all major regions (page 1). Within each region, major physiographic features, such as basins and waterways, were identified as

Sediments were collected with a grab sampler

Samples were subdivided for several different chemical analyses and toxicity tests

Toxicity tests of sediments were performed in the laboratory under controlled environmental conditions sampling strata. Often, strata were delineated by points of land or causeways. Although sampling locations were not selected randomly, they were selected to represent integrative, average conditions within each stratum. Results of toxicity tests, therefore, were believed to be reasonably representative of conditions within each stratum. They were weighted to the surface area (km^2) of each stratum to determine the spatial extent of toxicity. All stratas combined covered a total surface area of about 550 km^2.

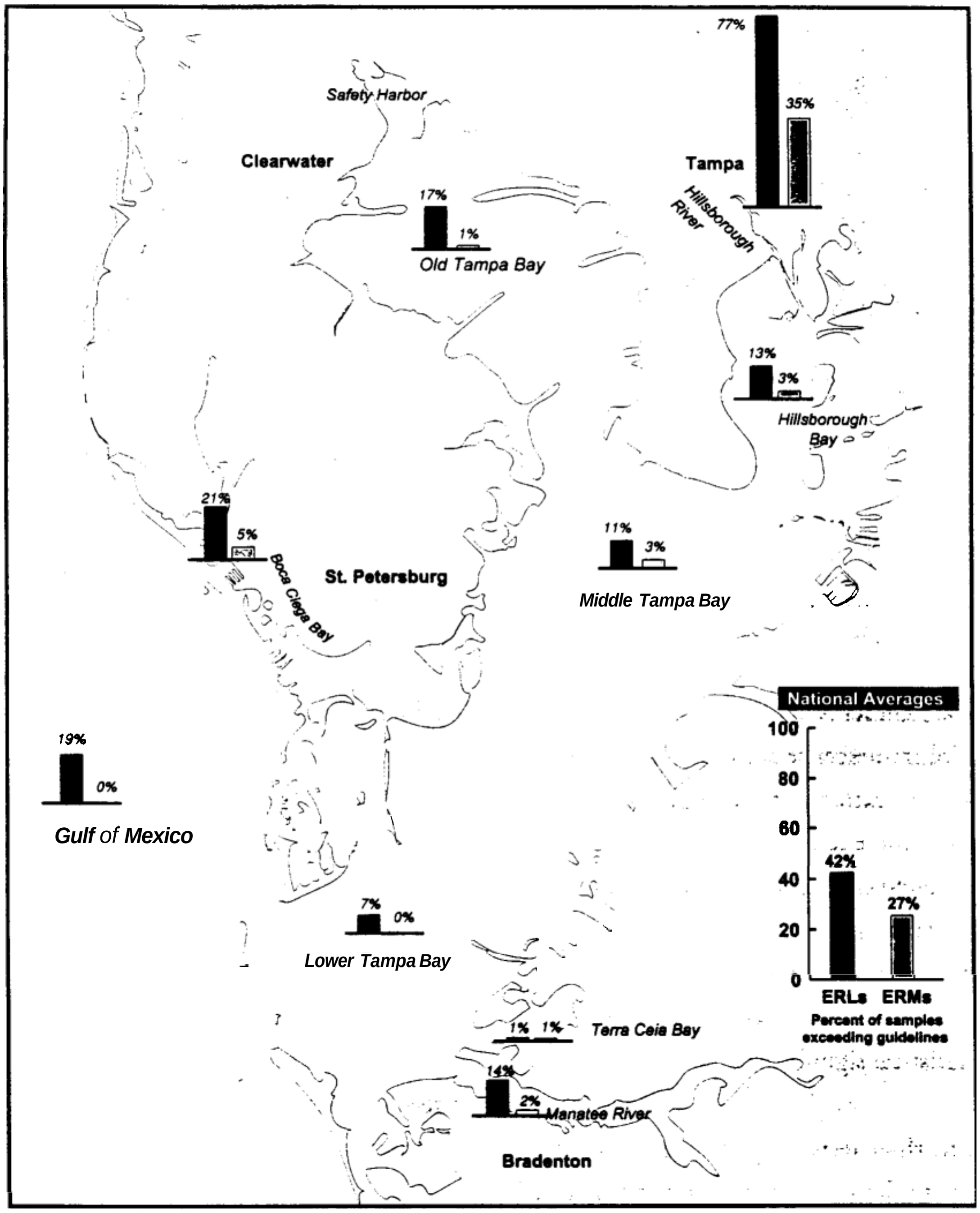


Figure 3.

Percentages of samples that exceeded sediment quality guidelines were greatest in Hillsborough River and lowest in Lower Tampa Bay and Terra Ceia Bay (from Long et al., 1991). "National averages" (from Long et al., 1998).

Toxicity was determined in three laboratory bioassays: (1) a test of amphipod survival in exposures to solid-phase (or "bulk") sediments, (2) a test of sea urchin fertilization when exposed to three concentrations of pore waters extracted from the sediments, and (3) a test of microbial bioluminescence activity in exposures to solvent extracts of the sediments. Data from these tests were intended to provide a weight of evidence regarding the toxicity of the sediments. Results of tests of Tampa Bay samples were compared to those of non-toxic controls to determine statistical significance.

Table 1. Prevalence and spatial extent of toxicity in Tampa Bay sediments collected during 1991-1992 (from Long et al., 1994) and in sediments collected nationwide during 1991-1996 (from Long et al., 1996 1998)

Toxicity Test	No. of samples	Prevalence of toxicity (%)	Spatial extent of toxicity (km2)	(Percent of area)
Amphipod survival				
• Tampa Bay	165	16.5	0.5	0.1
• National average	1,176	39.8 [b]	277	10.9
Microbial bioluminescence				
• Tampa Bay	90	26.7	0.6	0.1
• National average	848	44.6 [b]	1,482	61.3
Sea urchin fertilization				
• Tampa Bay				
- in 100% porewater	165	78.8	464	84.3
- in 50% porewater	165	60.0	59	10.8
- in 25% porewater	165	40.6	13	2.3
• National average				
- in 100% porewater	942	70 [b]	886	42.6
- in 50% porewater	942	nd	233	11.2
- in 25% porewater	942	nd	105	5.1

[a] Data from Long et al., 1996

[b] Data from Long et al., 1338

nd = no data (not calculated)

The three tests showed different sensitivities to the samples and overlapping distributional patterns in toxicity throughout the bay (Long et al., 1994). In the least sensitive test, amphipod survival was significantly reduced in 16.5% of the samples, representing approximately 0.1% of the study area (Table 1). In the microbial bioluminescence tests, 27% of the samples were toxic; these samples representing about 0.1% of the surface area. In contrast, sea urchin fertilization in 100% pore water was significantly reduced in 79% of the samples; representing about 84% of the area. The incidence and severity of sea urchin toxicity decreased as pore waters were diluted with clean seawater. In tests of 50% and 25% pore waters, the percentages of the study area that were toxic were 11% and 2%, respectively.

In calculating these estimates of the spatial extent of toxicity, three large regions of Middle Tampa Bay were represented by only one sampling site each. If these three regions were deleted from the calculations, the estimates of the spatial extent of toxicity would be 0.2% of the study area for amphipod survival, 0.3% for microbial bioluminescence, and 65.9% for urchin fertilization in 100% pore waters.

The areas of toxicity in Tampa Bay as indicated in the amphipod and microbial bioluminescence tests (0.1%) both were considerably lower than the areas estimated nationwide (10.9% and 61% respectively) in other surveys using similar methods (Table 1). However, toxicity as indicated in the sea urchin tests of 100% pore waters (84.3% of the area) was approximately double the nationwide estimate (42.6%). In tests of 50% and 25% pore waters, the estimates of the spatial extent of toxicity in Tampa Bay and nationwide were very similar (10.8% vs. 11.2% and 2.3% vs. 5.1%, respectively).

Table 2.

Percent of samples that were toxic in sea urchin and amphipod tests in sediment samples from major regions of Tampa Bay (from Long et al., 1994).

Region	Number of samples	Sea urchin fertilization			Amphipod survival
		100%	50%	25%	
Northern Hillsborough Bay	48	96	88	73	19
Southern Hillsborough Bay	12	100	42	25	0
Western Old Tampa Bay	18	89	50	50	0
Eastern + central Old Tampa Bay	18	50	33	22	0
Middle + Lower Tampa Bay	9	100	56	11	0
St. Petersburg shoreline	33	52	52	24	0
Boca Ciega Bay	18	72	72	22	6
Terra Ceia Bay + Manatee River + Anna Maria Sound	9	100	33	33	0

• concentrations of pore water

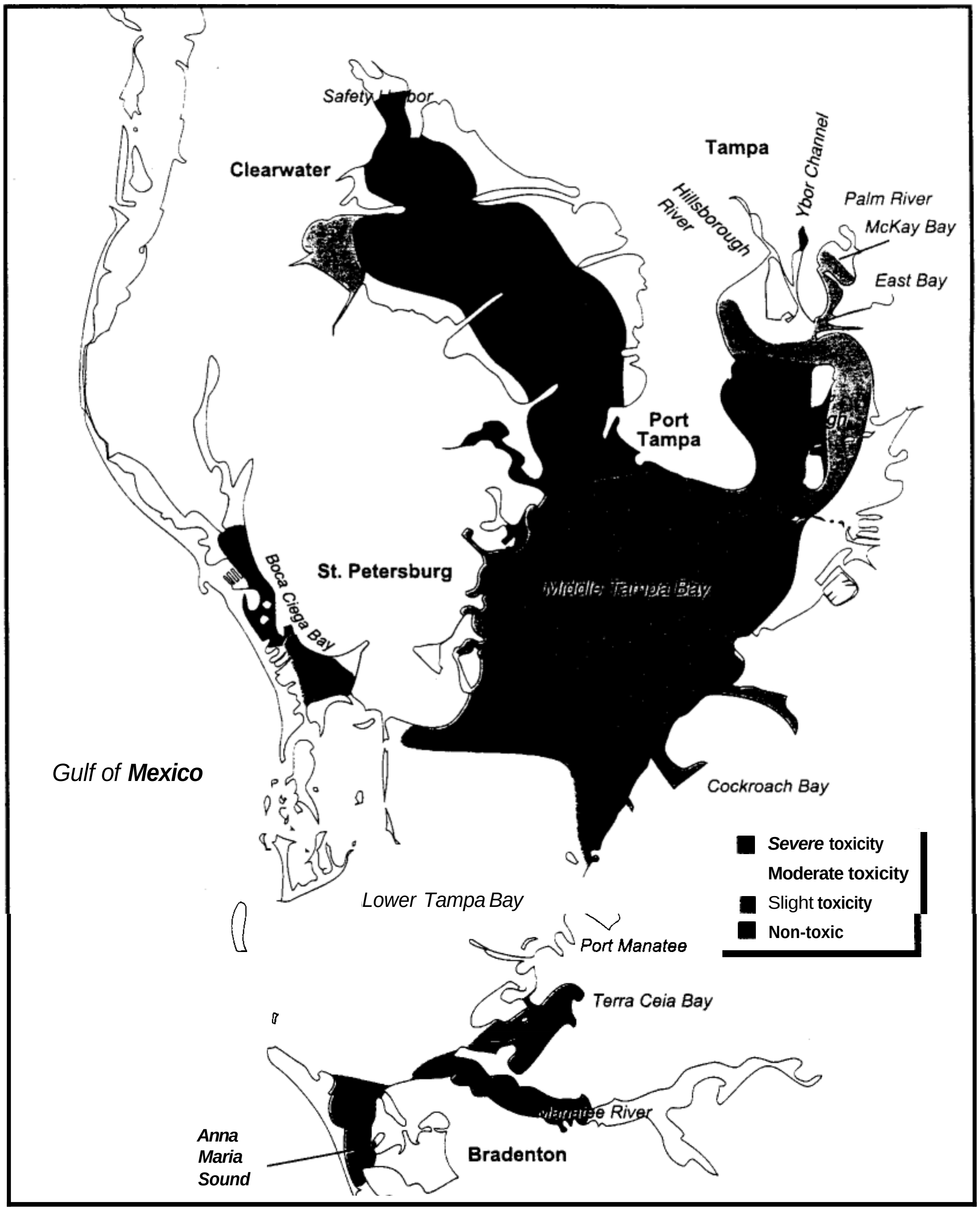
The percentages of samples showing toxicity in the tests differed considerably among regions of the estuary (Table 2). In the amphipod survival tests, 19% and 6% of the samples from northern Hillsborough Bay and Boca Ciega Bay, respectively, were toxic whereas none of the samples were toxic in all other regions. In the sea urchin tests performed with pore waters diluted to 25% strength, 73% of northern Hills-borough Bay samples were toxic, whereas 11% to 50% of samples from other regions were toxic. Fifty percent of the samples from western Old Tampa Bay were toxic in the sea urchin tests of 25% pore waters. The least toxic samples were collected in Middle and Lower Tampa Bay.

Data from the three tests were compiled to illustrate the overall pattern in toxicity

(Figure 4). Severe toxicity, in which amphipod survival was significantly lower than controls ($p<0.05$) and less than 40% of controls, occurred only in samples from the Ybor Channel in the northern end of the bay. Samples in which moderate toxicity (amphipod survival significantly different from controls, but greater than 40% of controls) occurred throughout a larger portion of northern Hillsborough Bay and one portion of lower Boca Ciega Bay. Slight toxicity (in which significant decreases in sea urchin fertilization or microbial bioluminescence occurred) was apparent throughout much of Hillsborough Bay, Middle and

Figure 4.

Severe and moderate degrees of toxicity were observed mainly in the northern Hillsborough Bay area (from Long et al., 1994).



Lower Tampa Bay, the western lobe of Old Tampa Bay, and other areas. Much of Old Tampa Bay and southern Hillsborough Bay was non-toxic in all of these tests.

Sediment contamination

Chemical analyses were performed on a subset of the 165 samples tested for toxicity (Long et al., 1994). Trace metal concentrations were determined in 141 samples and the concentrations of both trace metals and organic compounds were determined in 61 of the same samples.

An index of chemical contamination by mixtures of substances was calculated as an indicator of the overall pattern in the distribution of mixtures of toxicants. The index, known as the mean ERM quotient was calculated for each sample as the mean of the chemical concentrations divided by the respective ERM values (from Long et al., 1995). In independent evaluations, the incidence of highly toxic conditions in amphipod tests was 12%, 32%, and 71% among samples (n=1068) in which mean ERM quotients were <0.1, 0.11 to 1.0, and >1.0, respectively (Long et al., 1998).

The mean ERM quotients were highest in samples from northern Hillsborough Bay, especially in the Ybor Channel where relatively severe toxicity was observed. A moderate degree of contamination was apparent in samples from McKay Bay, and several areas along the western shoreline of Middle Tampa Bay. However, relatively low concentrations were apparent in the majority of the samples.

Relationships between toxicity and contamination in sediments

The chemical substance(s) that caused toxicity could not be determined in these studies. However, statistical analyses indicated that there were strong associations between measures of toxicity and concentrations of many chemicals (Long et al., 1994; Carr et al., 1996). These associations were particularly strong with the data from the sea urchin fertilization tests and five individual substances. In scattergrams (Figures 5-6) the relationships between fertilization success in 100% pore water and chemical concentrations in sediments are shown along with the EFU and ERM values from NOAA (Long et al., 1995), and the anologous Threshold Effects Level (TEL) and Probable Effects Level (PEL) values derived for the state of Florida (MacDonald et al., 1996). Ammonia concentrations in pore waters were compared to the toxicity thresholds – No Observable Effects Concentration (NOEC) and Lowest Observable Effects Concen-

Chemical concentrations were highest in sediments from northern Hillsborough Bay, particularly in Ybor Channel.

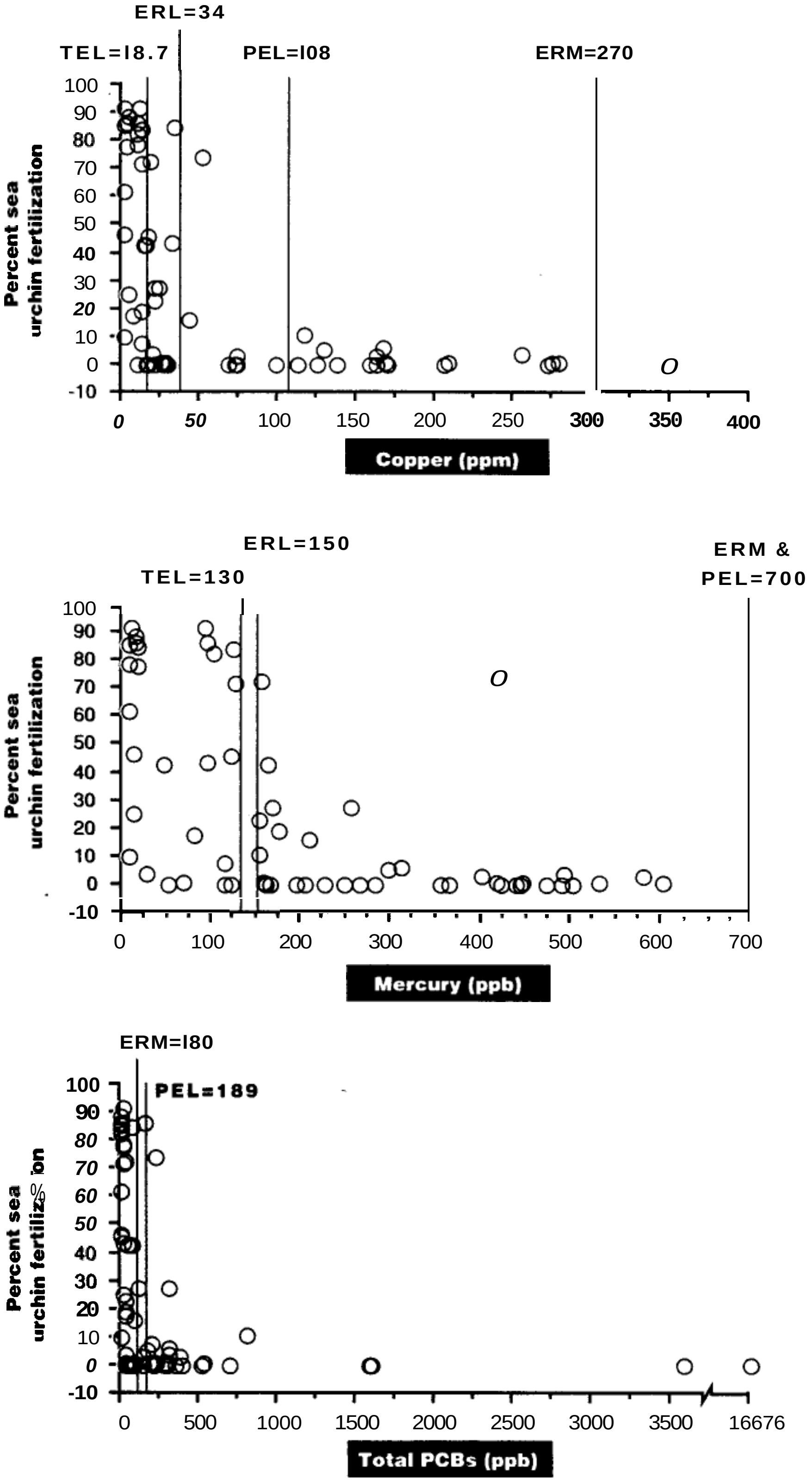


Figure 5.

Percent sea urchin fertilization decreased with increasing concentrations of copper, mercury, and total PCBs in sediments. Concentrations of these substances often exceeded numerical guidelines in toxic samples (from Long et al., 1994).

tration (LOEC) – developed for the urchin fertilization test as interpretive benchmarks.

Nearly all samples in which copper concentrations in the sediments exceeded the TEL or ERL values were highly toxic (Figure 5). Percent fertilization success dropped to less than 10% among samples in which copper concentrations exceeded the PEL and ERM concentrations. Although none of the samples had mercury concentrations that exceeded either the PEL or ERM values, toxicity was apparent in most samples in which the ERL and TEL concentrations were exceeded.

Very strong correlations were apparent between toxicity and the concentrations of both total DDTs and total PCBs; both groups of chemicals exceeded the respective ERM and PEL values in many samples, and nearly all of these samples were highly toxic in the sea urchin tests. The un-ionized (most toxic) form of ammonia occurred in a small minority of samples in sufficient concentrations to contribute to the observed toxicity. The observation that toxicity was associated with complex mixtures of substances was noted when the mean ERM quotients were plotted against urchin fertilization (Figure 6).

The statistical correlations and apparently strong associations between measures of toxicity and contamination were instrumental in the efforts of the TBNEP to identify chemicals of potential concern in Tampa Bay. Chemicals of highest concern were those in which (a) toxicity increased as concentrations increased; (b) concentrations were significantly higher in toxic samples than in non-toxic samples; and (c) concentrations in the toxic samples exceeded PEL or ERM guidelines.

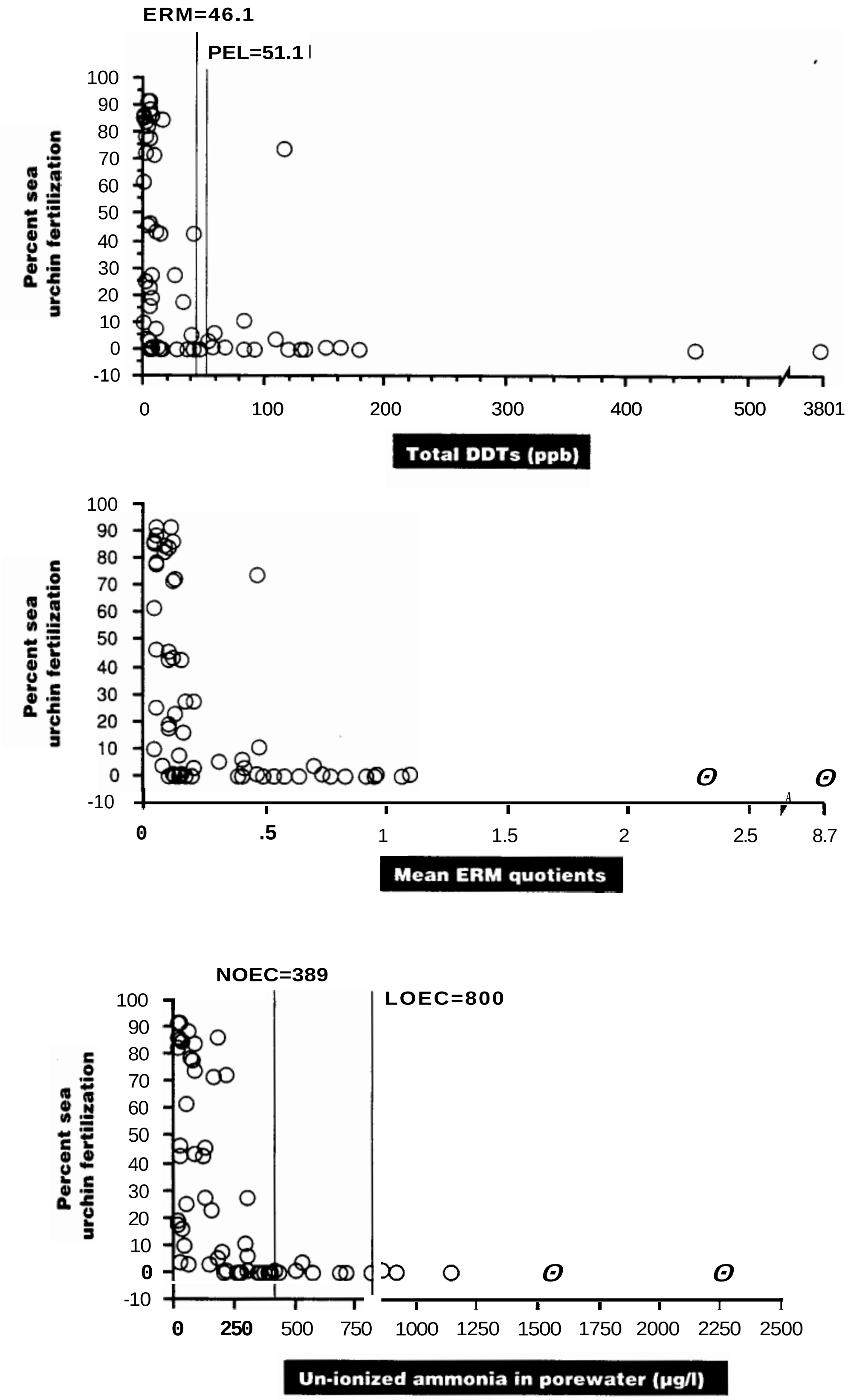
Toxicity in sediments was associated with complex mixtures of chemical substances.

Contamination and bioeffects in resident oysters

In 1991 and 1993 NOAA funded the work of an U.S Environmental Protection Agency (EPA) scientist to determine if there were indications of adverse biological effects among resident oysters living in Tampa Bay attributable to toxic substances. Unlike fish, adult oysters are unable to move, therefore, observations of adverse biological effects on the animals can be readily attributable to the sites from which they were collected. However, the biological measures of effects in these animals are not as well developed as those for fish. Therefore, exploratory research was conducted in Tampa Bay to determine which assays, if any, would show patterns in effects consistent with measures of chemical contamination.

Figure 6.

Sea urchin fertilization decreased with increasing concentrations of total DDT, ammonia, and mixtures of toxicants (as indicated with mean ERM quotients) in sediments (from Long et al., 1994).



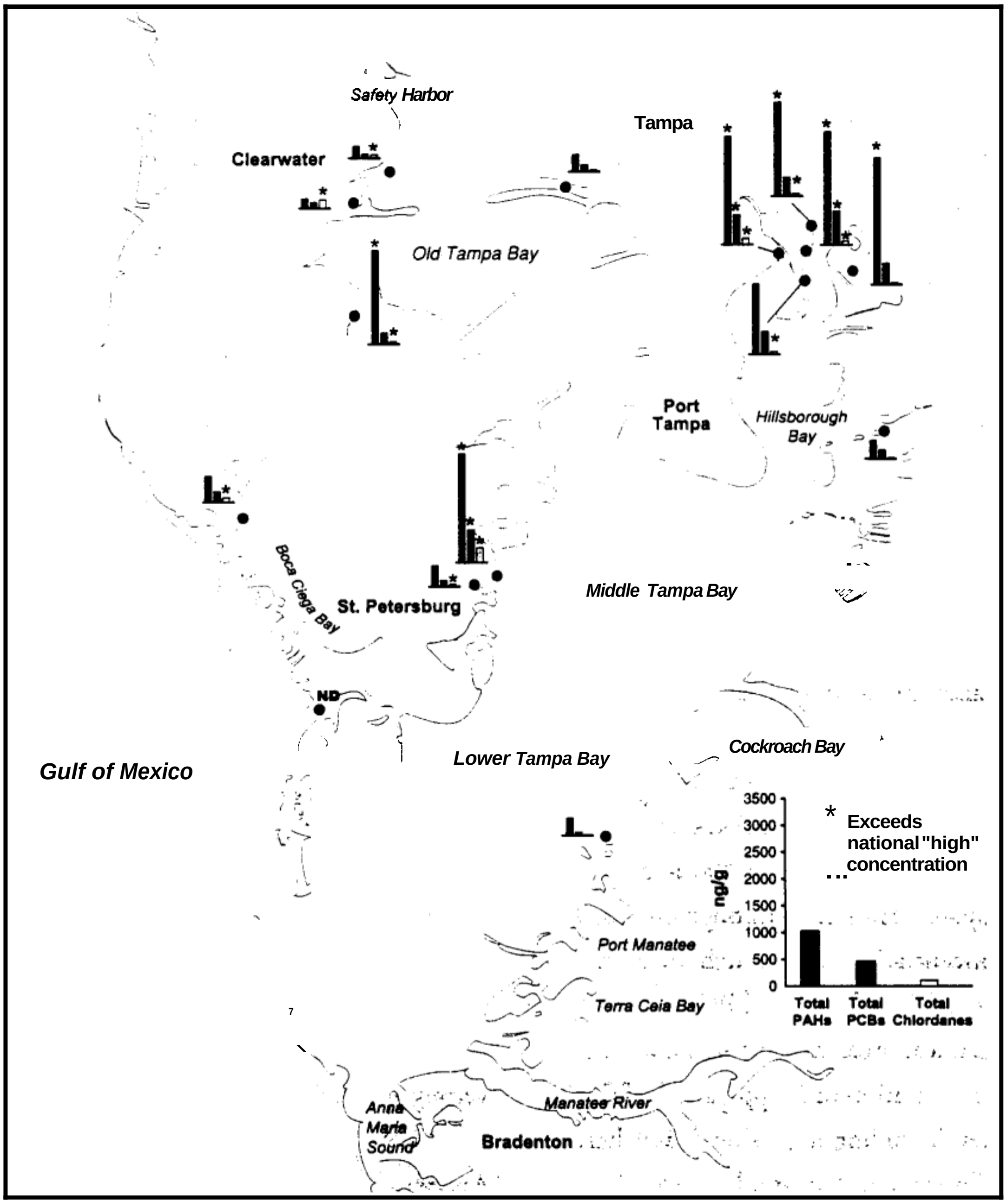


Figure 7.

Concentrations of most organic toxicants were highest among resident oysters collected in northern Hillsborough Bay and lowest in oysters from Old Tampa Bay and Lower Tampa Bay (data from Dr. Bill Fisher, U.S. EPA-Gulf Breeze).

Oysters were collected from 6 locations in 1991 and 16 locations in 1993 (Figure 2) and tested in the laboratory with a battery of assays. Chemical analyses were performed on samples from 19 of the sites. Concentrations of total polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and chlordane pesticides shown in Figure 7 exemplify the patterns in contaminant levels observed in this study. The concentrations of these three classes of toxicants co-varied, generally indicating highest levels in northern Hillsborough Bay and lowest concentrations in Old Tampa Bay, Lower Tampa Bay, and Boca Ciega Bay.

Concentrations of toxicants in oyster tissues were highest in northern Hillsborough Bay and exceeded national high values at many locations.

To provide perspective to the oyster data, sampling locations in which chemical concentrations exceeded national “high concentrations determined statistically in NOAA’s Mussel Watch Project (O’Connor and Baliaeff, 1995) are indicated in Figure 7. “High” concentrations provide no perspective as to the risks posed by the chemicals to the health of the oysters or to animals or humans that might eat them. Total PAHs exceeded the national “high concentration of 1020 ppb in samples from eight sites; specifically, nearly all the northern Hillsborough Bay sites, the Cross Bayou Canal site north of Clearwater and the Bayboro Harbor site at St. Petersburg. Total PCBs exceeded the “high” concentration of 470 ppb at five sites; four in northern Hillsborough Bay and one in Bayboro Harbor. Although chlordane concentrations were much lower than those of the PAHs and PCBs, this class of chemicals exceeded the national “high” concentration of 31 ppb at 14 of the 22 sites; including most sites in northern Hillsborough Bay and both sites in Bayboro Harbor.

Many different biochemical and immunological assays were performed on the oyster tissues to determine if these animals were adversely affected by exposure to contaminants. The data indicated that some physiological defense mechanisms appeared to be heightened in animals with the hightest trace metals concentrations. In addition, the data indicated that some oysters from Tampa Bay were exposed to high parasite burdens, periods of low water salinity, periods of elevated ambient water temperatures, periods of starvation, as well as relatively “high’ concentrations of toxicants.

Contamination and bioeffects in resident fishes

Four species of fish were collected at a number of locations (Figure 2) by NOAA’s National Marine Fisheries Service (NMFS) during 1990 and 1991. Analyses were conducted on these fish to determine levels of contamination in liver tissues and the prevalence of measures of adverse effects, such as lesions in these tissues (McCain et al., 1996). These data were intended to provide information on the degree, if any, to which resident fish were exposed to and adversely affected by toxicants in the bay.

Analyses of chemical contamination, biochemical responses to contaminants, and histopathological effects were performed on fishes from 12 sites, including a reference site in Sarasota Bay (McCain et al., 1996). The average concentrations data of total PCBs are indicative of the pattern observed for most chemical groups found in the fish‘s liver tissues (Figure 8). Total PCBs were consider-

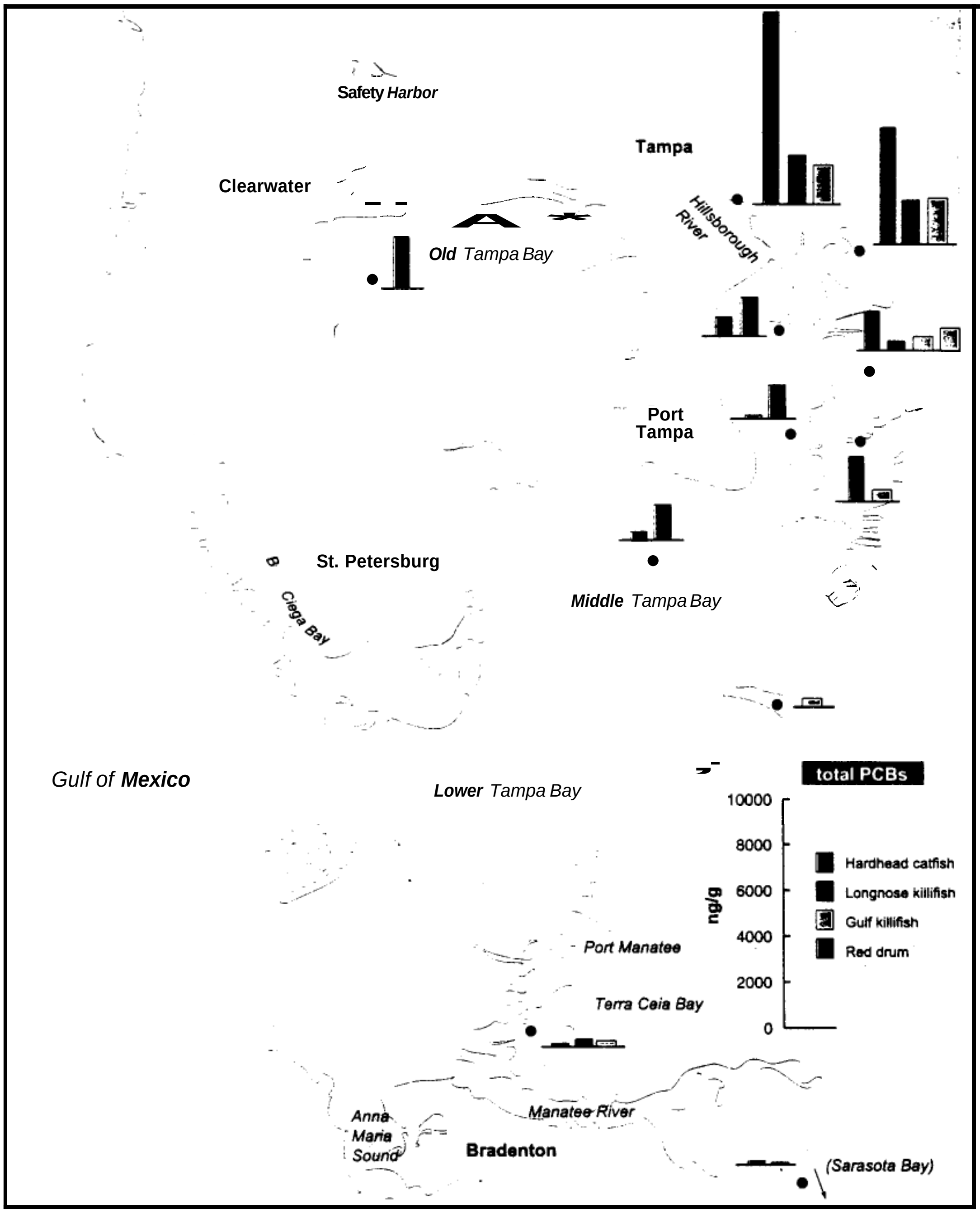


Figure 8. Concentrations of total PCBs in liver tissues were highest among juvenile red drum collected in the lower Hillsborough and Palm rivers (from McCain et al., 1996).

ably higher in red drum caught in the lower Hillsborough and Palm rivers than in all other samples. Concentrations generally diminished down the estuary and were lowest in fish collected from Terra Ceia Bay and Sarasota Bay. Hardhead catfish were sampled twice (1990 and 1991) and differences in average concentrations were apparent between years. Total PCBs were somewhat lower in the other species of fish, but, nevertheless showed a similar pattern of relatively high concentrations in tributaries to northern Hillsborough Bay and lowest concentrations in fish from tributaries nearer the Gulf of Mexico.

PCB concentrations in red drum from the lower Hillsborough and Palm Rivers were considerably higher than those from all other areas.

Aromatic hydrocarbons (PAHs), although potentially toxic to fish, are readily chemically changed (metabolized) by the liver and other organs of the fish and excreted, thus making these substances difficult to detect in chemical analyses of tissues. The metabolites may be either more or less threatening to the fish. Because the detection of the parent compounds in fish is very difficult, it is necessary to conduct analyses of the bile to measure the amounts of hydrocarbon metabolites to which the fish were exposed. Therefore, the concentrations of higher molecular weight metabolites of aromatic hydrocarbons in the Tampa Bay fish were determined along with the more conventional chemical analyses of the liver tissues.

Concentrations of high molecular weight PAH metabolites were highest among fish collected in tributaries to northern Hillsborough Bay – notably in Archie Creek and Hillsborough River (Figure 9). Concentrations of these substances were significantly lower in Sarasota Bay, Terra Ceia Bay and Manatee River, and in western Old Tampa Bay.

The liver cells of fish are known to respond to the presence of certain toxic substances by attempting to detoxify and excrete them. One measure of this detoxification response is the CYP1A enzyme activity of the hepatic tissue. Highest activity rates were recorded in fish caught in Archie Creek, Palm River, and Hillsborough River (Figure 10). CYPlA activity invariably diminished into Old Tampa Bay, down-estuary toward the Gulf and in Sarasota Bay.

Perhaps the most obvious evidence of the adverse effects of toxicants upon resident fish is the prevalence of liver lesions which are known to be associated with exposure to some of these substances. Among the catfish caught at five locations, the prevalence of a variety of lesion types was often highest in fish collected in northern Hillsborough Bay (Table 3). The most serious rype of lesion, neoplasms, occurred only in two fish (2.2% of total) both collected from the northern Hillsborough Bay site.

The histological characteristics of lesions differ considerably among species of fish. Therefore, comparisons of the prevalence of specific lesion types among species often are not useful. Nevertheless, data similar to those obtained for Tampa Bay are compiled in Table 3 to provide perspective for the Tampa Bay data. In a similar study performed by the NMFS in bays of the northeastern USA, 3.1% and 0% of winter flounder from lower Mystic River near Boston and Narragansett

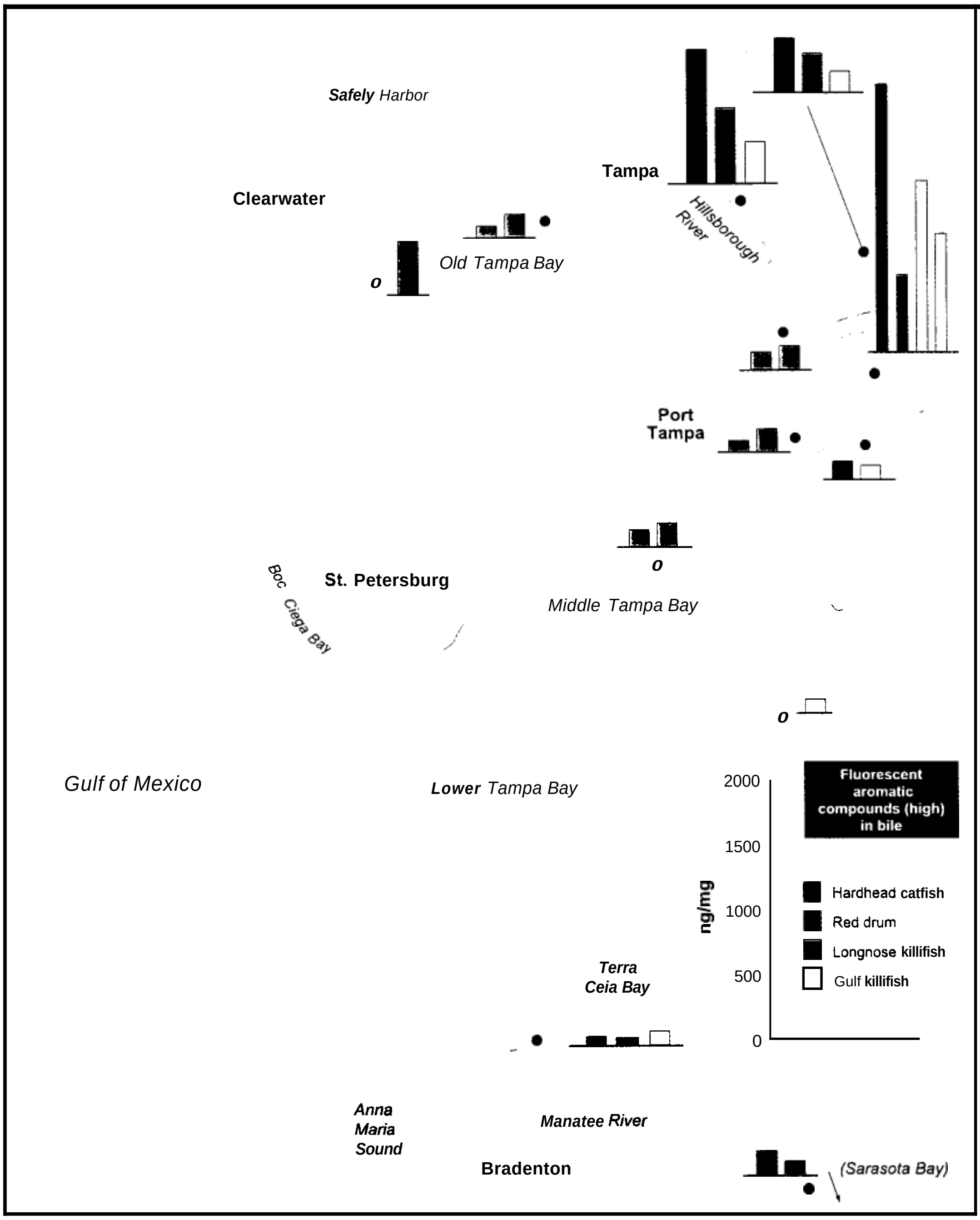


Figure 9.

Fish collected in northern Hillsborough Bay locations were exposed to the highest concentrations of petroleum hydrocarbons (from McCain et al., 1996).

Bay in Rhode Island, respectively, had hepatic neoplasms, similar in frequency to those in Tampa Bay fish. In contrast, the prevalence of neoplastic lesions in English sole caught in two locations in Puget Sound were much higher: 16% the Duwamish River near Seattle and 12% in Everett Harbor (Table 3).

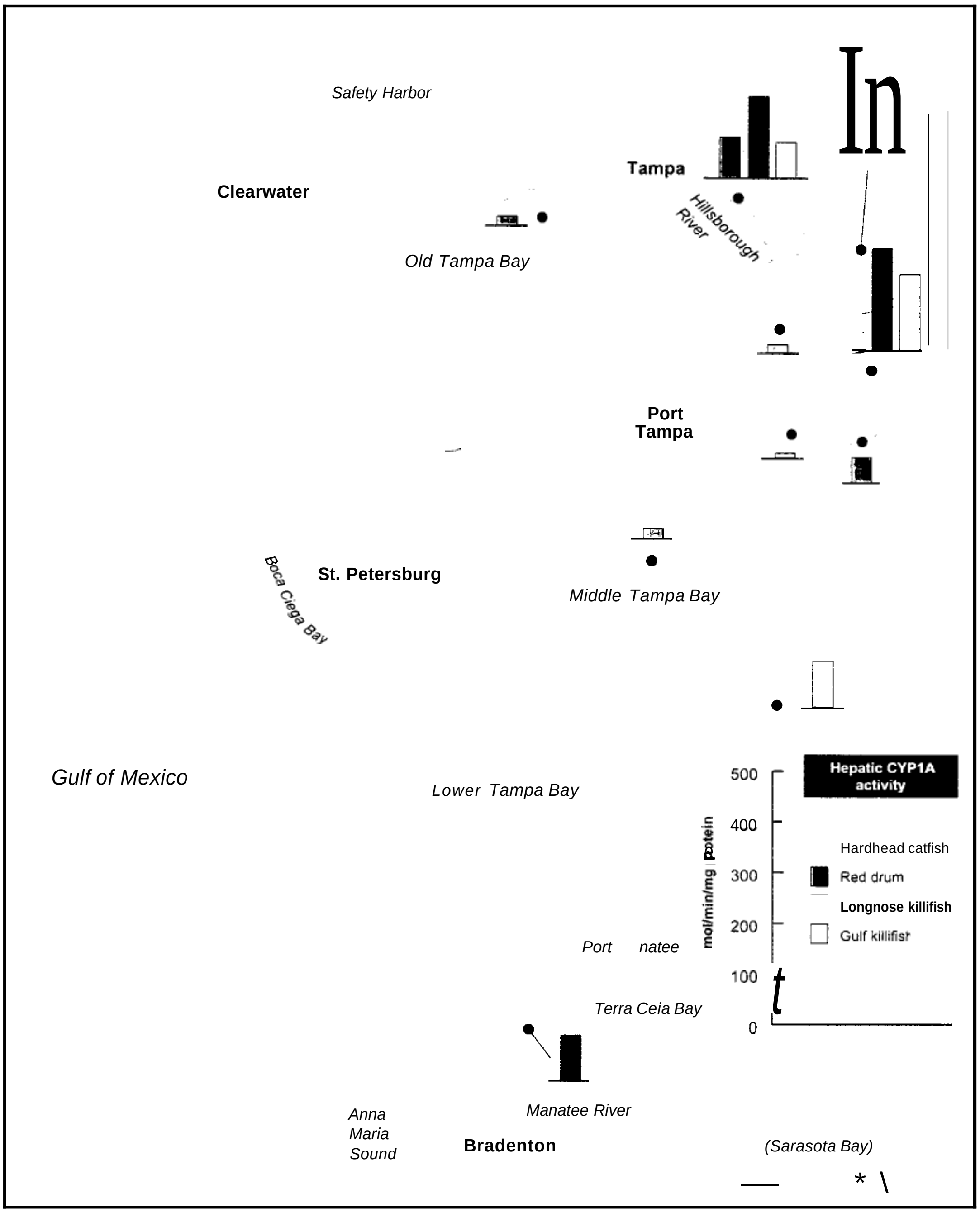
> The prevalence of neoplastic lesions in the livers of fish was very low at all sites.

Temporal trends in contamination

Data compiled in 1991 from several different studies in Tampa Bay indicated

Figure 10.

Fish collected from northern Hillsborough Bay locations showed the highest biochemical responses to toxicant exposures (from McCain et al., 1996).



Fish caught in Archie Creek and Hillsborough River were exposed to the highest PAH concentrations.

no bay-wide trends of increasing or decreasing concentrations of toxicants (Long et al., 1991). Concentrations of some substances appeared to be decreasing in some areas, increasing in others, or remained relatively unchanged from year to year.

Beginning in 1986 the soft tissues of resident oysters collected from four locations were analyzed for toxicants as a part of the nationwide network of Mussel Watch sites (O'Connor and Baeliaeff, 1995). A fifth sampling location was added in 1988 and sixth and seventh sites were added in 1989.

The concentrations of total PCBs, total PAHs, and lead are plorted for each year in Figures 11-13. The national average and "high" concentrations are shown in the maps to add perspective. The Mussel Watch data appear to indicate the same lack of a bay-wide pattern as reported in 1991. PCB, PAH, and lead concentrations in oysters from Mullet Key and Cockroach Bay were consistently lowest from year to year. PCB concentrations appeared to decrease at the Boca Ciega Bay and Bayou Grande sites. Also, PAH concentrations decreased at the Davis Islands site. PCB concentrations at the Davis Islands site and PAH concentrations at four sites were highly variable from year to year with very high PAH concentrations occurring in 1984 and 1996 at the Alafia River site. Lead concentrations appeared to increase at most sites during 1986 to 1990-1992, followed by a slight decrease beginning in 1993-1994.

Overall, the available data suggest that no consistent bay-wide patterns of increasing or decreasing concentrations have occurred over recent years.

Table 3.

Prevalences of liver lesions in hardhead catfish collected from five locations in Tampa Bay during 1990 and 1991 (data from McCain et al., 1996) and in winter flounder from Mystic River, MA and Narragansett Bay, RI (data from Johnson et al., 1992) and in English sole from Duwamish River, WA and Everett Harbor, WA (data from Malins et al., 1984).

Location	Number of fish examined	Prevalence of Liver Lesions (%)			
		Neoplasm	Basophilic Foci	Eosinophilic Foci	Clear cell Foci
No. Hillsborough Bay	89	2.2	2.2	9	5.6
So. Hillsborough Bay	89	0	0	7.9	4.5
Middle Tampa Bay	89	0	0	12.4	3.4
Old Tampa Bay	90	0	0	1.1	2.2
Sarasota Bay	84	0	0	9.5	1.2
Mystic River, MA[a]	96	3.1	nd	nd	nd
Narragansett Bay, RI[a]	87	0	nd	nd	nd
Duwamish River, WA [b]	136	16	nd	nd	nd
Everett Harbor, WA [b]	66	12	nd	nd	nd

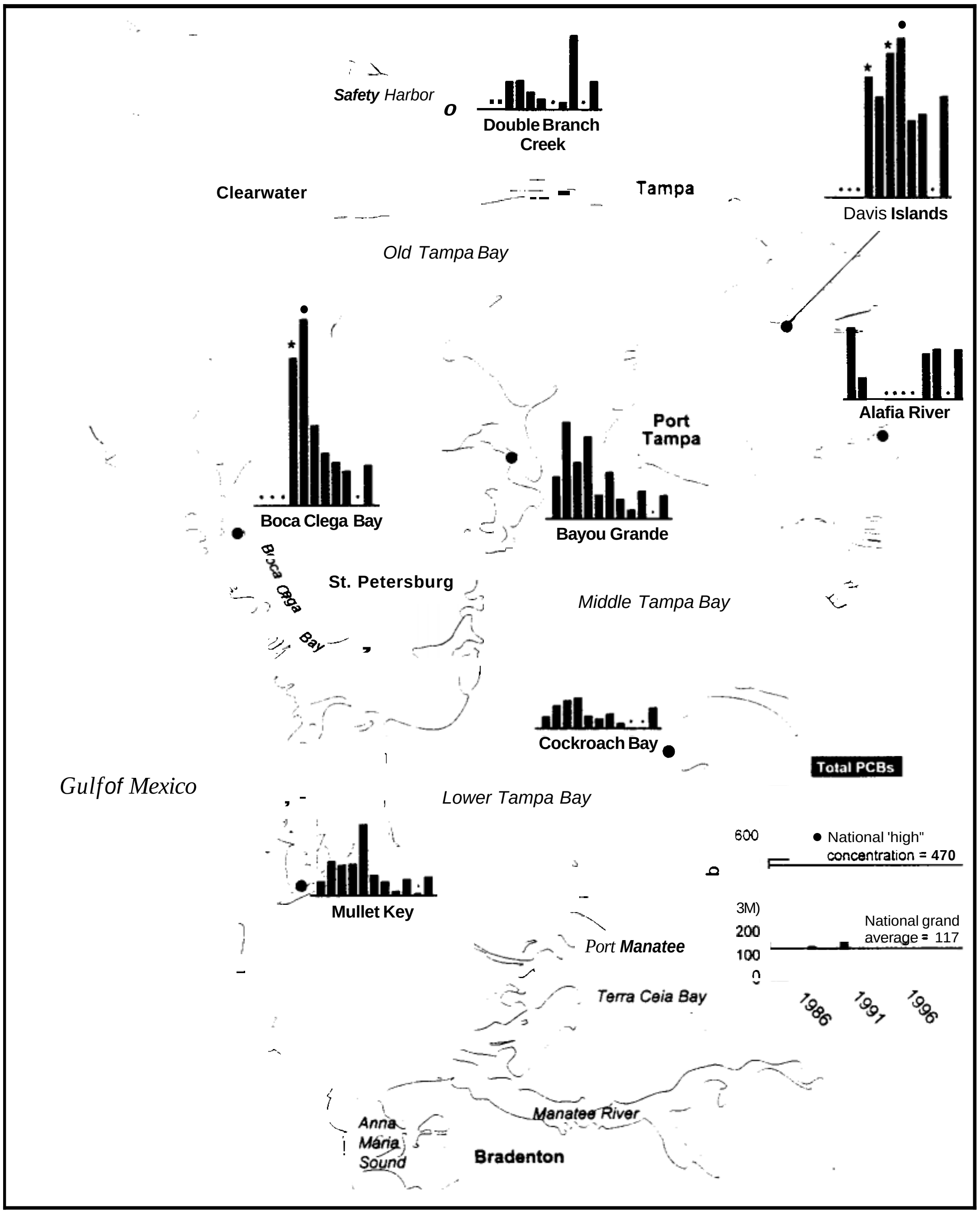
[a] Winter flounder (from Johnson et **al.**, 1992)

[b] English sole (from Malinser al., *1984)*

nd = **no** data

Figure 11.

Concentrations of total PCBs in oysters sampled each year from 1986 to 1996 have shown differences among years at some sampling locations (from NOAA's Mussel Watch).



Summary

Data from chemical and toxicological analyses of sediments, chemical analyses of oyster tissues, chemical and biomarker analyses of resident fish showed a remarkable degree of concordance. All, evidence indicates that northern Hillsborough Bay was the most contaminated region of the estuary. Other small areas in western Old Tampa Bay, along the western shore of Middle Tampa Bay, and in lower Boca Ciega Bay also showed signs of degraded sediment quality. The chemical analyses indicated that mixtures of many different substances occurred in sediments, probably acting together to induce toxicity and other biological effects. The presence of these contaminants in tissues of oysters and fish, observations of biochemical responses in fishes, and the occurrence of toxicity in laboratory tests indicate that chemicals were bioavailable in the sediments. Observations of acute and sub-lethal toxicity in sediment toxicity tests and biomarker responses in fish, furthermore, indicate these chemicals may pose a toxicological risk to local biological resources.

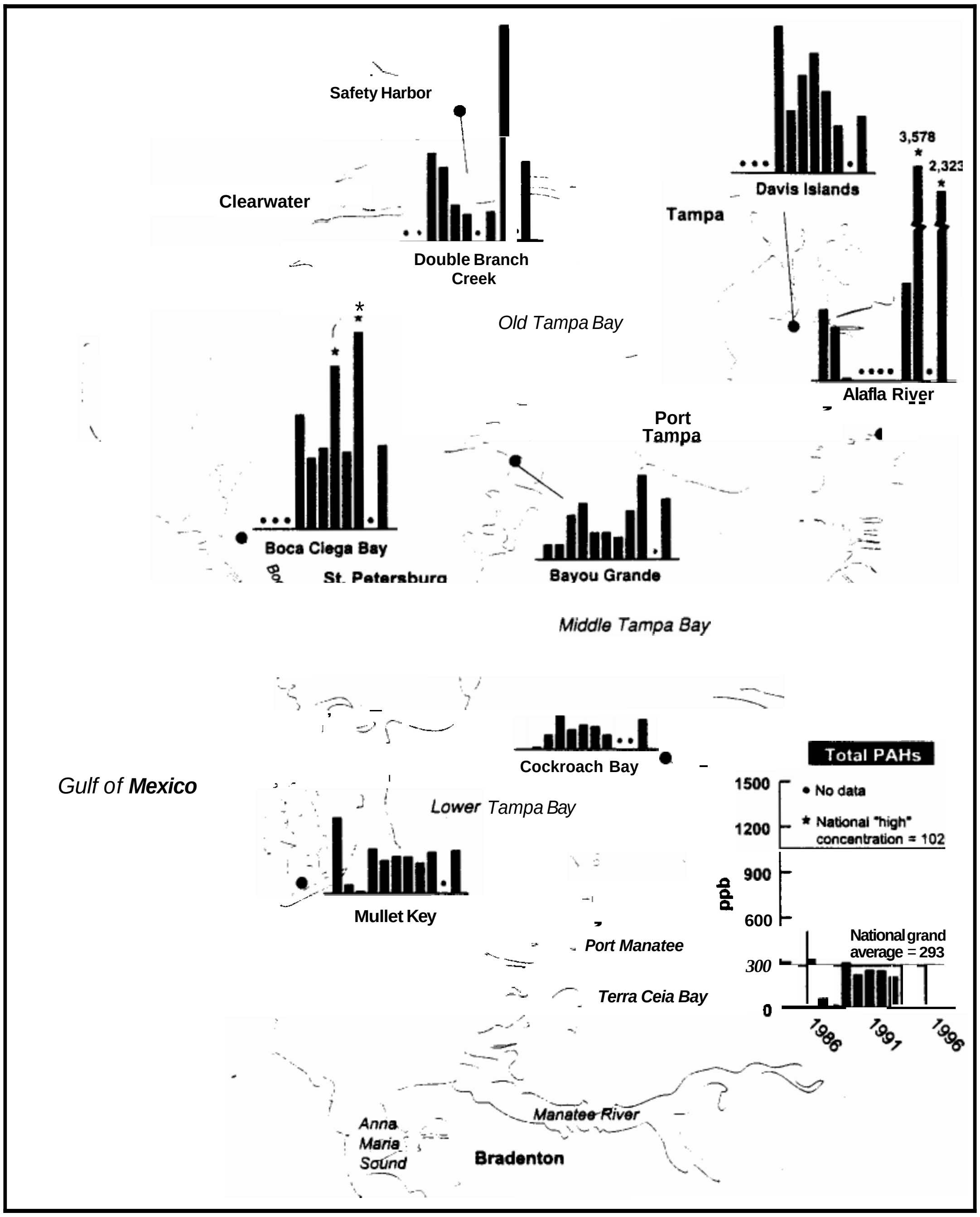
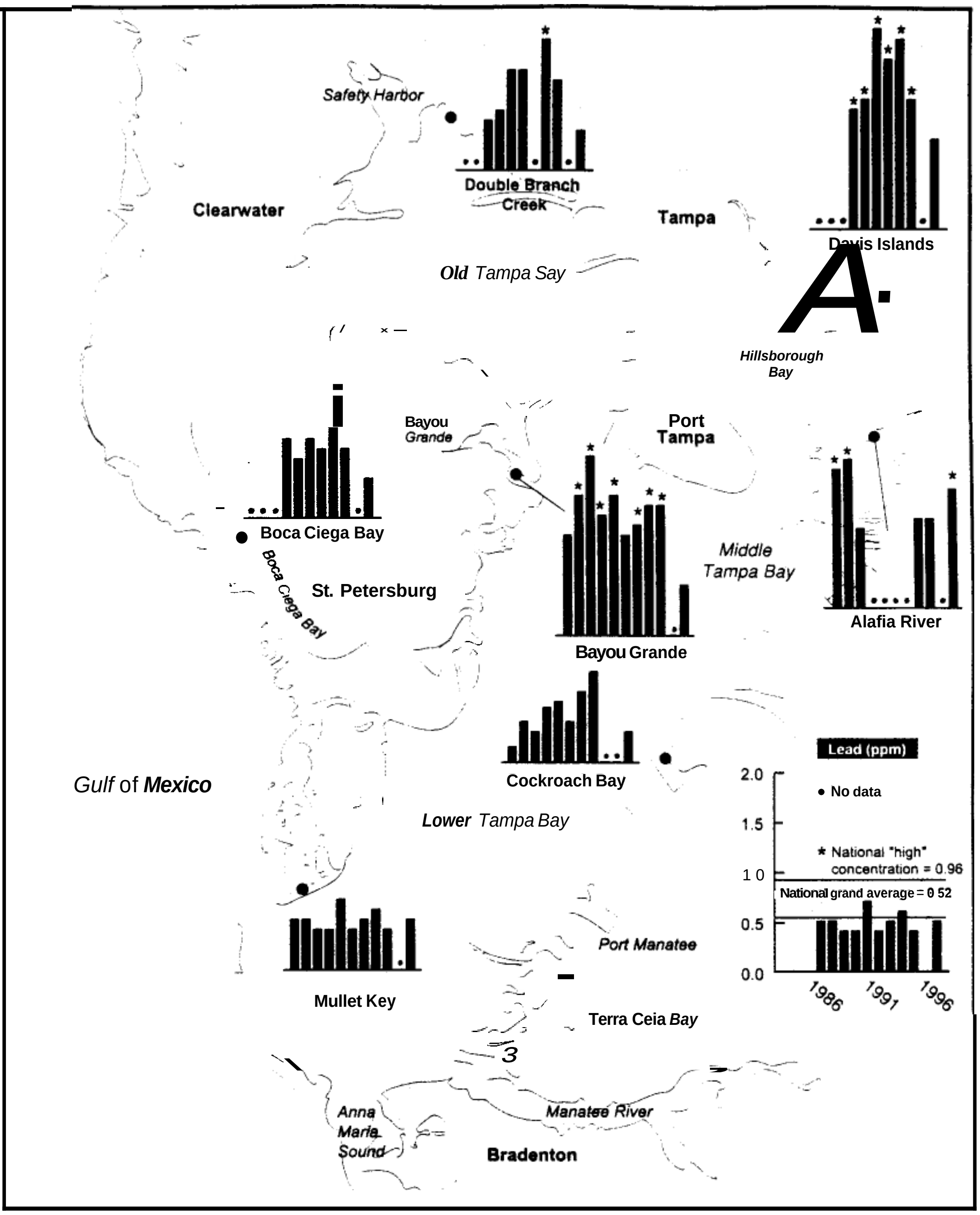


Figure 12. Concentrations of total PAHs in oysters sampled each year from 1986 to 1996 have shown differences among years at some sampling locations (from NOAA s Mussel Watch).

Figure 13. Concentrations of lead in oysters sampled each year from 1986 to 1996 have shown differences among years at some sampling locations (from NOAA s Mussel Watch).



All evidence indicated that northern Hillsborough Bay was the most contaminated region.

Relatively high chemical concentrations were observed in sediments, oysters, and fish from harbors and other urban sites.

Background

Building upon the studies conducted by NOAA and others, in which contaminated areas in Tampa Bay sediments were identified, the Tampa Bay National Estuary Program (TBNEP) implemented a series of projects to further characterize sediment quality patterns, to quantify potential ecological risks, to help define objectives for the restoration of sediment quality, and to develop specific management actions which would contribute to obtaining those objectives. These projects included the following:

- *Summarize the distributions of toxic contaminants to Tampa Bay and their major sources (Frithsen et al. 1995)*
- *Assess sediment contamination using the sediment quality triad approach (Zarbock et. al. 1996)*
- *Estimate human health and ecological risks attributable to toxic substances (McConnell et al. 1996)*
- *Develop management actions for those specific watershed basins draining to "hot spots" of sediment contamination. An example of implementation of specific management actions designed to address an identified hot spot, McKay Bay in northern Hillsborough Bay has been initiated (Cabezas et al. 1997)*

The restoration and protection of living resources of Tampa Bay (the fish, invertebrates, and other organisms found in and around the bay and the habitats on which they depend) have been the primary focus of resource managers in Tampa Bay for many years. Through the consensus-based process of the TBNEP, regulatory agencies and local government participants have mutually agreed upon long-term goals for the restoration and protection of the bay's critical habitats, including measurable targets for seagrass and tidal wetlands (TBNEP, 1996; Greening et al. 1997). Throughout the six-year planning process, the TBNEP has focused upon the importance of watershed management to reach the agreed-upon goals in the Comprehensive Conservation and Management Plan (CCMP) for Tampa Bay, entitled *Charting the Course* (TBNEP, 1996).

The TBNEP has developed resource-based water quality targets as defined by the environmental requirements of critical living resources, where current scientific understanding allows identification of these requirements. Environmental conditions necessary to achieve the restoration of seagrass acreage to historic (1950) levels form the basis for determining resource-based nitrogen loading targets for each of the bay's segments. Similarly, specific numeric goals for the restoration of shoreline habitats were based on the needs of estuarine-dependent species.

However, due in part to the difficulty of quantifying the links between sediment contamination concentrations in the bay and loadings of contaminants from the watershed, the TBNEP is defining risk-based targets for toxic materials and associated load reduction management options based on potential effects and risks to ecosystem and human health, rather than the resource-based approach used for seagrass and shoreline habitats. The data generated by NOAA and others in assessments conducted in Tampa Bay have been critical elements to this process and provided catalysts for many subsequent analyses of information (Figure 1).

To assist with development of specific steps to define management objectives for toxic materials in Tampa Bay, the TBNEP convened a Science Advisory Group (SAG) on sediment assessment in Tampa Bay in 1995. The SAG,

Table 4.

Procedures (objectives) adopted by the TBNEP to characterize and manage sediment quality in Tampa Bay and significant accomplishments.

Procedures	Accomplishments
1. Characterize sediment quality	• NOAA completed surveys • TBNEP completed follow-up surveys • TBNEP prepared data synthesis reports
2. Develop sediment quality assessment elements and procedures	• Convened Science Advisory Group • Followed recommendations of SAG
3. Delineate and map contaminated "hotspots"	• Prepared overlay maps with chemical data
4. Identify contaminants of most [illegible]	• Analyzed sediment quality triad data • Prepared risk assessment for both wildlife and human health
5. Identify potential sources of chemicals of concern	• Analyzed categorical types of sources • Identified specific potential sources in watershed
6. Develop indicators of sediment quality, specific metrics, and numerical targets	• Convened second SAG • Prepared lists of each that satisfy goals and objectives of TBNEP
7. Assess management options for potential sources	• Ongoing
8. Monitor sediment quality to assess changes, if any, and progress toward targets	• Prepared monitoring plans • Initiated monitoring in 1995

consisting of scientists and program managers from state (FDEP), federal (NOAA, NBS), and local governments (Hillsborough, Pinellas and Manatee counties and the Southwest Florida Water Management District) plus TBNEP consultants reviewed the existing sediment quality data and recommended a series of consecutive steps (Table 4; MacDonald 1995).

Characterization of sediment quality throughout the bay

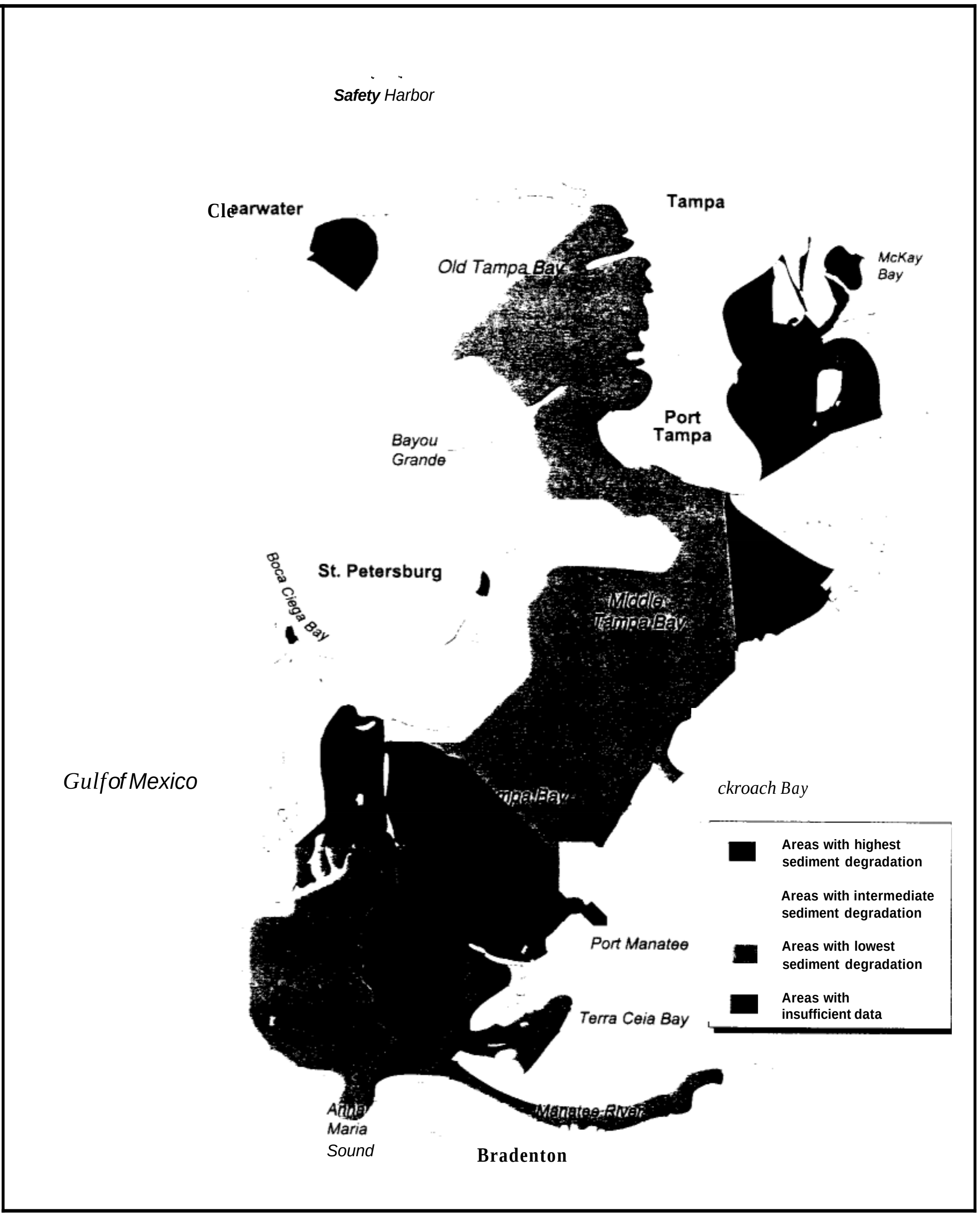
Following the recommendations of the SAG, the TBNEP sponsored a study of sediment quality based upon the triad of measures, including sediment chemistry, toxicity and benthic community structure. Zarbock et al. (1996) compiled chemical data from more, than a dozen studies conducted in Tampa Bay and compared concentrations to the state Sediment Quality Assessment Guidelines (SQAGS; MacDonald et al. 1996). Data from toxicity tests were compared to non-toxic controls, and data from benthic community analyses were compared to reference conditions within the bay. Each component of the triad was given an index score and the three scores combined to provide a weight of evidence indicating overall sediment quality. A complete triad of information was not available for some portions of the bay. The resulting map (Figure 14) shows that, in general, the combined data sets indicated sediment contamination in Tampa Bay was more severe in the regions of the bay that receive inputs from urban and industrial activities in the watershed. These regions include Hillsborough Bay (especially the northern and eastern basins near the Port of Tampa); Bayboro Harbor adjacent to downtown St. Petersburg; and Boca Ciega Bay which receives runoff from a highly urbanized watershed (Zarbock et al. 1996). Trends observed from the combined data sets from many sources closely matched the patterns in sediment quality reported in NOAA data sets for individual sediment quality indicators (Figures 3, 4 and 5).

Identification of contaminants of concern and potential sources

To further assist with evaluation of specific chemical contaminants of concern, an assessment of potential ecological and human health risks associated with these contaminants was conducted using techniques developed for evaluation of risks from hazardous materials (McConnell et al. 1996). The risk-based approach allows consideration of factors in addition to the measures of acute toxicity used in the triad approach to determine the magnitude of risks. Significantly, it accounts for the potential for

Figure 14.

General categories of chemical contamination were based upon measures of sediment chemistry, toxicity, and benthic community structure in 674 samples collected by many different programs (from TBNEP, 1996).



cumulative effects of multiple contaminants, bioaccumulation of persistent chemicals, and adverse effects on higher trophic level organisms.

Contaminants of concern identified by either the sediment quality triad approach or the risk assessment for each of the hot spots in the bay are summarized in Table 5. They include eight trace metals, eleven pesticides (including DDTs, heptachlor and lindane), PCBs, and high molecular weight PAHs. The potential impacts of these substances range from

Table 5. Chemicals *of* concern, their potential impacts, and possible sources in Tampa Bay (from TBNEP, 1996).

Chemicals of Concern	Potential Impacts	Possible Sources
Cadmium	Acute toxicity	Electroplating, plastics, batteries, and sewage
Chromium	Acute toxicity Mammalian carcinogen	Atmospheric, alloys, coal combustion, electroplating/metal finishing, wastewater, urban runoff, and phosphate fertilizers
Copper	Acute toxicity	Oil/fuel combustion, antifouling paints, metal cleaning, plating, pigments and dyes, copper pipes, wood preservatives, and sewage
Lead (Banned in US gasoline)	Acute toxicity Chronic effects Human health hazard	Atmospheric (from gasoline additive), paints, batteries, and sewage
Mercury	Acute toxicity Bioaccumulates in biota Behavioral toxin Growth and development reduction	Atmospheric/incinerators, paints, batteries, and electrical switches
Zinc	Acute toxicity	Metals coatings, batteries, tires, municipal wastewater, sludge, industrial discharges, and urban runoff
DDTs (Banned)	Animal carcinogen Human carcinogen Impairs bird reproduction Biomagnifies	Agricultural, silvicultural, and household pesticide
Chlordane (Banned)	Acute toxicity	Agricultural pesticide, and residential termite and beetle control
Mirex (Banned)	Neurotoxin Growth/development reduction Reduced bird reproduction	Fire ant control, fire retardant in electrical devices, fabrics, and plastics
Endosulfan	Neurotoxin Acute toxicity Bioaccumulates	Agricultural pesticide
Dieldrin (Banned)	Liver damage Suppression of immune system Decreased fertility Carcinogenic to some animals Mutagenic to some cells	Agricultural pesticide, termite and moth control, and breakdown product of pesticide aldrin
PCBs (Banned)	Carcinogenic Biomagnifies Acute toxicity	Insulator for electrical equipment, hydraulic fluids, paints, adhesives, municipal sewage, leachates for disposal sites, and incineration
PAHs	Acute toxicity Carinogenic/mutagenic	Crude oil, petroleum products, and combustion by-products, stormwater, atmospheric deposition, refinery fly ash, spills, leaks, maritime accidents, marinas, and drilling fluids

acute toxicity to impaired growth and behavior to impaired reproductive success and cancer. The potential sources of these substances are also wide-ranging and include industrial, municipal, residential and agricultural categories.

The patterns in Tampa Bay sediment quality suggest that contaminants originate from both localized point sources and diffuse nonpoint sources. In general, metals enter the bay through urban runoff, although point sources (including wastewater treatment and industrial

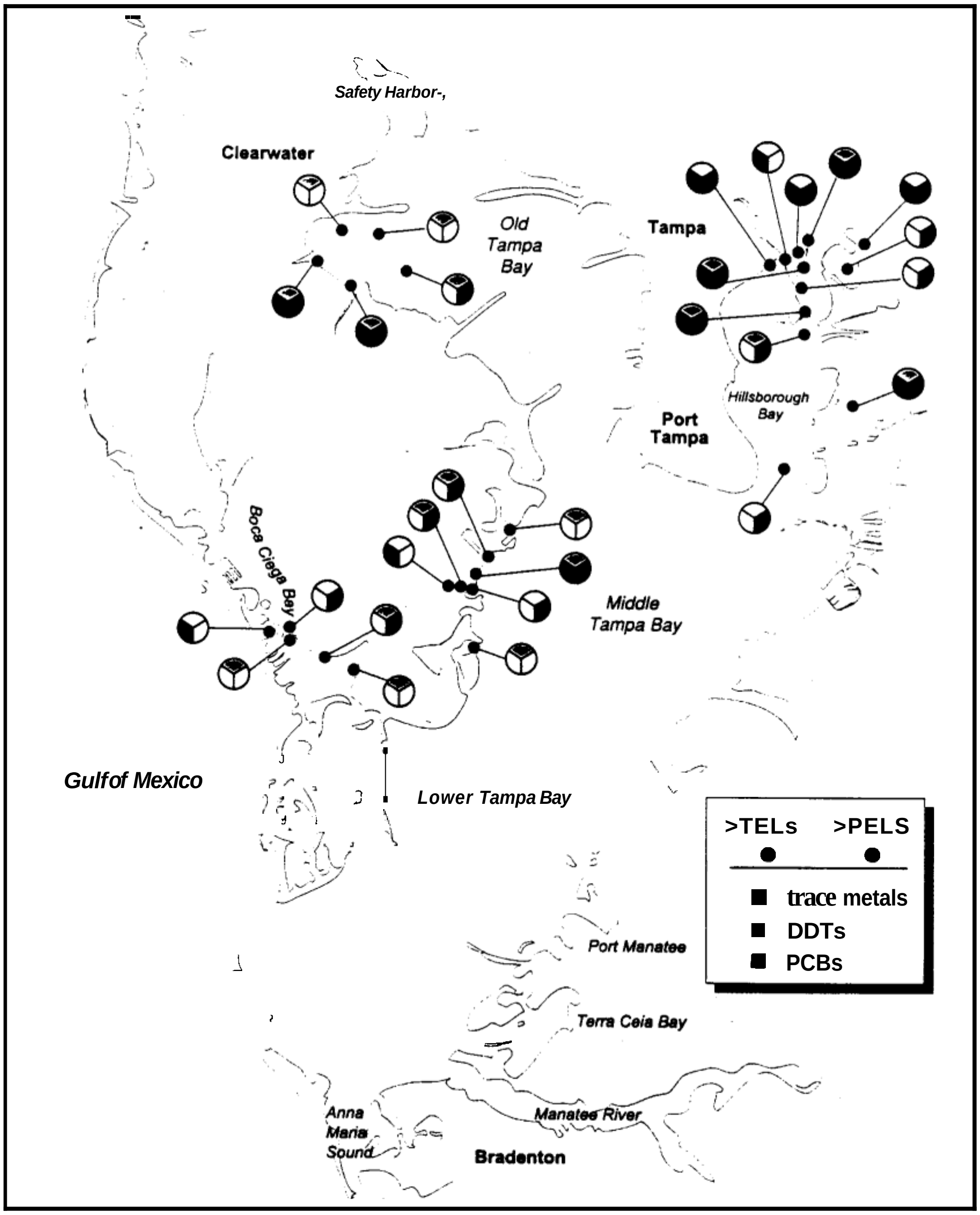


Figure 15.

Sampling locations were designated as hot spots when chemical concentrations exceeded at least one TEL or PEL guideline value (from Zarbock et al., 1996).

facilities) and atmospheric deposition also are important sources. The principal source of pesticides is agricultural runoff in the eastern areas of the bay, however, high levels of pesticides also are found near residential areas such as Boca Ciega Bay. Additionally, the presence of chemicals which have been banned for up to 20 years indicates their longevity in the environment. Atmospheric deposition also contributes to organochlorine pesticide levels in Tampa Bay. Local “hot spots” were identified where chemical concentrations exceeded state SQAGs (Figure 15). Stations in which chemical concentrations exceeded Threshold Effects Levels (TELs) are shown with black symbols and stations in which at least one Probable Effects Level (PEL) was exceeded are shown with red symbols.

Data to identify the key sources of PAHs and PCBs are not available, although they are found in stormwater runoff and atmospheric deposition. Principal sources for mercury, one of the contaminants most likely to affect humans, also are not identifiable in spite of significant efforts at the national and state level to reduce inputs (Frithsen et al. 1995). Ongoing work to be completed in 1998 will identify potential and specific sources of contaminants of concern in selected basins and specific management options to address these sources.

Development of measurable targets for sediment quality

The SAG reconvened in August 1997 to initiate identification of priority indicators, metrics, and target values of sediment quality indicative of either uncontaminated or contaminated conditions (MacDonald 1997). Two objectives and a number of associated indicators were recommended to support the restoration and protection of sediment quality in Tampa Bay:

- *Maintain environmental conditions in Tampa Bay sediments such that the benthic community, including benthic infaunal species, is protected, and, where necessary, restored.*

  Indicators identified to monitor this objective included:
  - sediment quality triad
  - physical characteristics, including grain size, sediment type, currents and physical impacts
  - water chemistry, including dissolved oxygen and pH

- *Maintain and, where necessary, restore environmental conditions in Tampa Bay sediments such that fish and other aquatic organisms are safe to consume, both by humans and wildlife.*

Indicators identified to monitor this objective included:

- tissue chemistry of fish tissues
- biomarkers of contaminant exposure and stress in fish

Criteria used to evaluate and select indicators of sediment quality included their relevance, sensitivity, diagnostic capability, feasibility, and cost-effectiveness (MacDonald 1997). Metrics of sediment contamination included comparisons with numeric guidelines to either ensure conditions protective of infaunal communities or to identify unacceptable conditions that would constitute a risk to these resources. Metrics of toxicity included the absence of significant acute effects in laboratory tests to either ensure high sediment quality or unacceptable toxicity indicative of poor sediment quality. The selection and further development of specific metrics and numerical targets indicative of acceptable and unacceptable conditions will be ongoing over the next several years. NOAA, other federal agencies, state and local agencies, and others will be involved with these activities. Draft metrics and targets developed to date are shown in Table 6. Results will be expressed as both assessment targets indicative of acceptable conditions and remediation targets indicative of the need to implement clean-up strategies

Development and implementation of management actions

Based on these studies, the TBNEP has proposed a series of management actions that address contaminants most likely to cause adverse effects in ecological or human receptors in priority basins. High priority areas (TBNEP, 1996) include the Hillsborough River and McKay Bay, Boca Ciega Bay, Bayboro Harbor and western Old Tampa Bay (Figure 2).

Stormwater runoff, particularly from urban areas, represents approximately 60 percent of total loadings of metals including chromium, zinc, mercury and lead (Frithsen et al. 1995). Where possible, ongoing improvements to stormwater treatment facilities should be concentrated in drainage basins where high levels of toxic contaminants have been identified. TBNEP has created a computer model to assist local governments in selecting the most cost-effective mix of best management practices to employ in a given area.

Alternatives for addressing hazardous waste at its source also must be considered. Households and small commercial or industrial generators pose a potentially significant source of toxic contaminants, and improper handling, storage and disposal of these materials can lead to air, soil, surface water and groundwater

Ecosystem Health Indicator	Measure of Sediment Quality	Relative Priority	Assessment Targets	Remediation Targets
Sediment quality triad	[illegible]	High	[illegible]	[illegible]
Sediment chemistry	Chemical concentrations	High	Low probability of adverse biological effects	High probability of adverse biological effects
Sediment toxicity	Amphipod survival	High	Not significantly toxic	Highly toxic (>MSD)
	Sea urchin egg fertilization	High	Not significantly toxic	Highly toxic (>MSD)
	Sea urchin embryo development	Low		
	Microtox/Mutatox	Low		
	Polychaete growth	Low		
	Seagrass seed germination	LOW		
	Seagrass growth	Low		
	Cytochrome P-450 RGS	LOW		
	Cumulative hazard quotients	LOW		
Benthic infaunal structure	Diversity	High	>75% of reference	ND
	Evenness	High	ND	ND
	Biomass	LOW	ND	ND
	Benthic index for Tampa Bay	High	>.11.2	<4.9
	Indicator species '	High	Crustaceans present	ND
Physical characteristics	Grain size	High	ND	ND
	Total organic carbon	High	ND	ND
	Sediment settling rate	High	ND	ND
	Percent depositional area	High	ND	ND
Water chemisfry	Chemical concentrations	High	<state WQ standards	ND
	Dissolved oxygen	High	Percent of bay hypoxic	ND
	Dissolved oxygen in ponewater	LOW	See bioassay protocols	ND
	Ammonia in porewater	Low	See bioassay protocols	ND
	Hydrogen sulfide in porewater	Low	See bioassay protocols	ND
	BOD in porewater	Low	See bioassay protocols	ND
Tissue chemistry	Chemical concentrations in fish and shellfish	High	<FDA action levels for human health <Tissue residue levels for wildlife	ND
	Number of fish consumption advisones	High	<=1 (for Hg only)	ND
	Ecological hazard quotients	High	<1	ND
Biomarkers in fish	Number of preneoplastic and neoplastic lesions	High	0	ND
	internal parasites in fish	Low	ND	ND
	External parasites in fish	Low	ND	ND
	Hepatic cytochrome P-450 activity	Low	ND	ND

MSD = minimum significant difference from controls; ND = not determined, WQ = water quality. FDA = Food and Drug Administration
BOD = biochemical oxygen demand

* Assessment targets are results indicative of acceptable conditions that may warrant further assessment or monitoring
** Remediation targets are results indicative of unacceptable conditions that may warrant clean-up. remediation, or other similar actions

Table 6.

Recommended metrics, relative priorities, and numerical targets for assessing Tampa Bay sediment quality (from MacDonald, 1997).

Improper disposal of household wastes can lead to contamination of air and water.

contamination. These materials may be discarded into storm drains or in regular trash collections because options for households and small businesses are limited.

Ports and marinas also are likely contributors to both point- and nonpoint-source toxic contaminants based on studies of nearby sediments. Ports, along with shipyards and associated industrial facilities, use and release toxic substances including petroleum products, metals, metal treatment chemicals and anti-fouling paints, and contaminants associated with ship repair and scrap iron stockpiles. Marinas often are key point sources of petroleum products, paints and related solvents and anti-fouling chemicals, as well as "gray" water containing detergents and sewage discharged directly from boats.

New federal legislation requires that states adopt programs to control various sources of coastal nonpoint-source pollution, including best management practices for marinas and boaters which will be evaluated as part of the effort to design an effective pollution prevention campaign. Additionally, state and local programs are helping to address contamination from ports and industrial users.

Point-source discharges also are key contributions to the contaminants of concern in Tampa Bay, with estimated annual loadings of more than 30 percent of the total cadmium and copper, and about 27 percent of the bay's chromium loadings (Frithsen et al. 1995). Existing permit limits for point-sources address some, but not all, chemicals of concern. Additional restrictions may be required on large discharges that contribute to priority basins where toxic contaminants already pose a risk to ecological and human receptors.

Specific projects identified to reduce toxic contaminants loading to the bay are expected to emphasize stormwater improvements in heavily contaminated basins, but may also include point-source controls or pollution prevention strategies in specific basins. Actions included in Tampa Bay's Comprehensive Conservation and Management Plan to reduce contaminant loadings are:

- *Address hot spots of contaminations*
- *Improve opportunities for proper hazardous waste disposal*
- *Reduce toxic contaminants from ports and marinas*
- *Promote Integrated Pest Management on farms to reduce pesticide in runoff*

Example of implementation: the McKay Bay Management Plan

The McKay Bay Management Plan, developed by the Southwest Florida Water Management District (a partner in the TBNEP), is an excellent example of a basin-specific management plan designed specifically to reduce contaminants loading which directly affects an identified area of sediment contamination. McKay Bay is a small urban estuary located northeast of Hillsborough Bay, and has been identified through the studies outlined above to contain contaminants that exceed regulatory guidelines and may pose potential ecological or human health risks (Long et al. 1971, 1994; Zarbock et al. 1976; McConnell et al. 1996). Potential sources of contamination loading to McKay Bay include historical point sources (no longer discharging) and nonpoint sources with concentrated outfalls. Stormwater was identified as a major contributor to sediment contaminant loads to McKay Bay (Cabezas et al. 1997).

Steps in the development of the McKay Bay Plan included:

- *Identification of contaminants of concern in McKay Bay sediments, using data from Long et al. 1994, Grabe et al. 1995, and risk-based screening criteria.*

- *Priorization of drainage basins based on toxicity of contaminants, location of the stormwater discharge point in the watershed, and the total pollutant load from contributing basins. The priorization method used conventional modeling approaches to estimate contaminant loading with an additional step to weight contaminant loads based on relative hazard.*

- *Identification of potential stormwater projects within priority basins.*

Identified contaminants of concern in McKay Bay included those identified for Tampa Bay in general, with metals (cadmium, chromium, lead and mercury) posing particularly high risks. The McKay Bay Plan identified three major subbasins as priorities; project design is currently ongoing in all three. A primary element of each of these urban subbasin designs is the inclusion of improved capacity to trap sediments within the existing stormwater systems. By reducing the amounts of particulates entering the bay, the concentrations of trace metals attached to the sediments would be reduced. One element has been installed in a priority subbasin; a 3-celled baffle box designed to maximize detention times and minimize velocities while not causing unacceptable impacts to local flood stages.

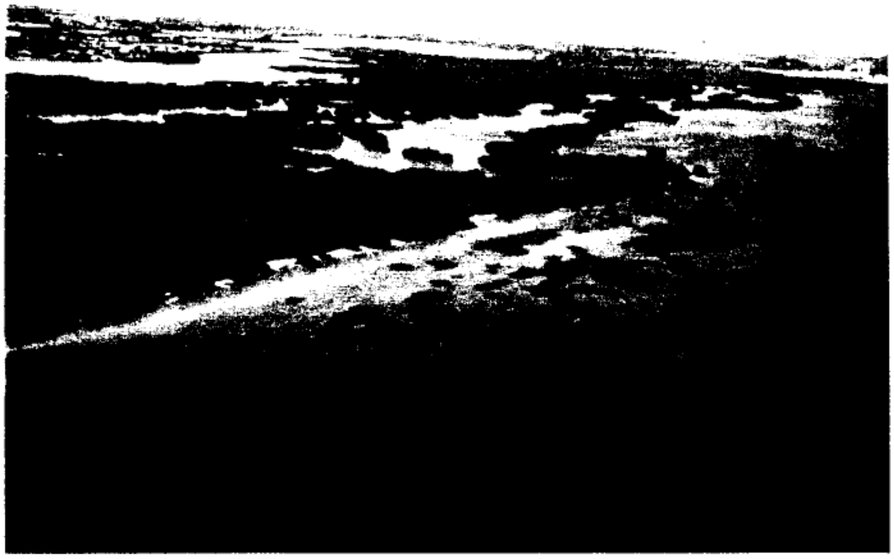
Actions were outlined in the Comprehensive Conservation and Management Plan to reduce contaminant loadings.

Monitoring to assess change

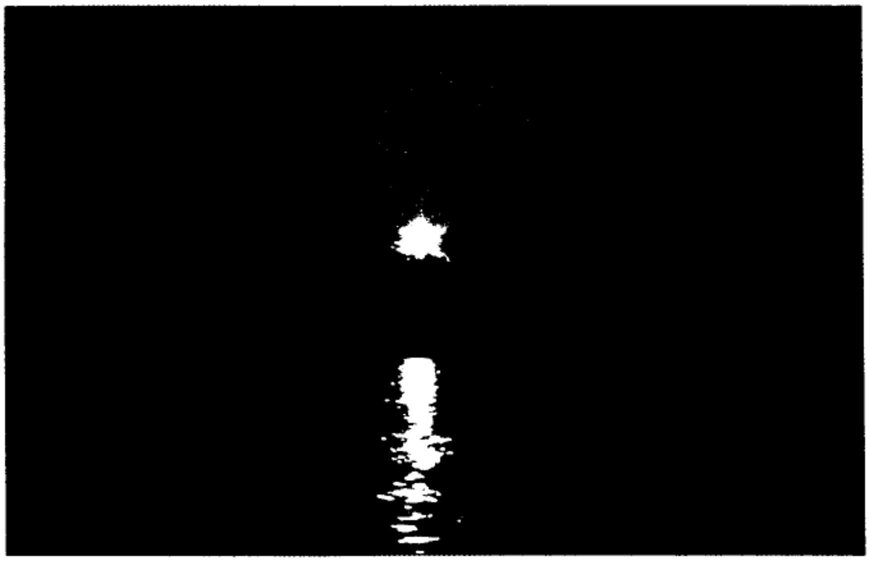
To track the status of sediment quality from year to year, the Baywide Benthic Monitoring Program was initiated in 1993. It is conducted jointly by Hillsborough, Manatee and Pinellas counties with funding assistance from the TBNEP Sediment chemistry, water quality, and benthic community structure are measured each year with plans to initiate limited toxicity testing in 1999. Sampling in the monitoring program is based on a stratified random sample design. Currently, more than 100 stations are sampled throughout the bay per year.

From Assessment to Management in Tampa Bay: The importance of credible data collection and interpretation.

The Tampa Bay management community has agreed that protection and restoration of the bay's living resources and habitats are of primary importance.



A critically important element in development of specific measurable targets and management actions needed to help reach those targets has been the assurance that the process used to develop targets for restoration is based on credible data collection and interpretation.



The partnership developed between NOAA and the TBNEP in developing a sediment quality restoration strategy for Tampa Bay was initiated with the realization that careful data collection and interpretation (NOAA's primary contribution) and involvement by those entities who will be implementing the final strategy (TBNEP's primary role) are equally important. The partnership developed between NOAA and TBNEP in Tampa Bay, from initial data collection and assessment through development of a management strategy, has proven to be an essential element for the restoration of Tampa Bay.

Acknowledgments

Dr. Jawed Hameedi (NOAA) and Ms. Gail Sloane (FDEP) provided encouragement and inspiration to prepare this report. The graphics, tables and text of the report were formatted and assembled by Ms. Kimberly Galimanis (EVS Environment Consultants).

Glossary of Abbreviations

CCMP	Comprehensive Conservation and Management Plan
COCS	Chemicals of concern
CYP1A	cytochrome P4501A enzyme
DDT	dichloro-dephenyl-trichloro-ethane)
DNA	deoxyribonucleic acid
EPA -GB	U. S. Environmental Protection Agency - Gulf Breeze
ERL	Effects Range Low
ERM	Effects Range Median
FDEP	Florida Department of Environmental Protection
LOEC	Lowest Observable Effects Concentration
NBS	National Biological Survey (now a part of U. S. Geological Survey)
NMFS	National Marine Fisheries Service (of NOAA)
NOAA	National Oceanic and Atmospheric Administration
NOEC	No Observable Effects Concentration
NOS	National Ocean Service (of NOAA)
NS&T Program	National Status and Trends Program
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyls
PEL	Probable Effects Level
SAG	Science Advisory Group
SQAGs	Sediment Quality Assessment Guidelines
TEL	Threshold Effects Level
TBNEP	Tampa Bay National Estuary Program
USF	University of South Florida

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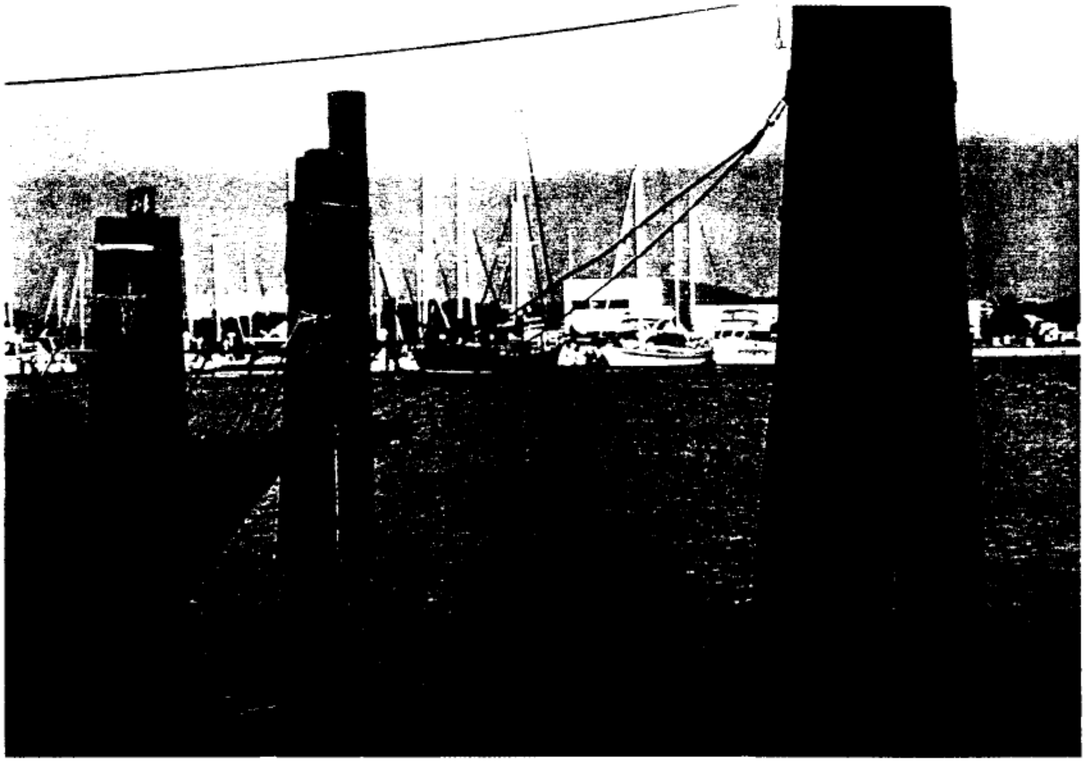

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