

## ENVIRONMENTAL QUALITY AND PRESERVATION—

# Chemical Pollutants and Toxic Effects on Benthic Organisms, Biscayne Bay: A Pilot Study Preceding Florida Everglades Restoration

## Introduction

The Florida Everglades, designated a National Park in 1947, comprise the largest area of wetlands and mangrove swamps in North America. In the late 1940s following back-to-back hurricanes, a massive flood-control project was instigated to construct levees and canals throughout Central and South Florida. By draining 500,000 acres south of Lake Okeechobee (Fig. 1) and diverting freshwater flow for cattle farming, urban development, and agricultural, industrial, and municipal water supplies, the infrastructure irreversibly damaged the wetlands and associated ecosystems. The canals severely altered regional hydrology and salinity (a measure of dissolved salts) along with habitats and natural fire resistance (Douglas, 1947). Introduction of agrichemicals and pesticides affected wildlife. Since the 1950s, the wetlands have been mined for limestone for use in cement, concrete, and asphalt. Miners have excavated thousands of acres, leaving barren rock pits in place of fertile swamps, and plan to expand operations to include thousands more. The original Everglades watershed was 80 km wide, covered an area of 14,480 km<sup>2</sup>, and extended for 400 km as a single hydrologic unit that flowed from the vicinity of Orlando to Florida Bay. Though only centimeters deep, the watershed was capable of filtering and removing most nutrients from the water. Today, reduced to less than half its size, the watershed filters far less and removes far fewer nutrients than in the past. Restoration of the Everglades is a National priority of branches of both State and Federal governments.

## The Problem

Geologically, the porous limestone of Florida connects the Everglades with Florida and Biscayne Bays, the Florida Keys, and the largest offshore tract of coral reefs in the continental U.S. These areas are also biologically connected because many marine organisms spend different stages of their life cycles in the various ecosystems, most of which are in decline. Against a backdrop of biogeologic connectivity, deteriorating coastal environments, rising sea level and increasing pollution, the problem lies in not knowing how the Everglades restoration will affect the stressed co-joined systems. This report presents results of geochemical, sedimentary, and microfaunal analyses in a 1-year pilot

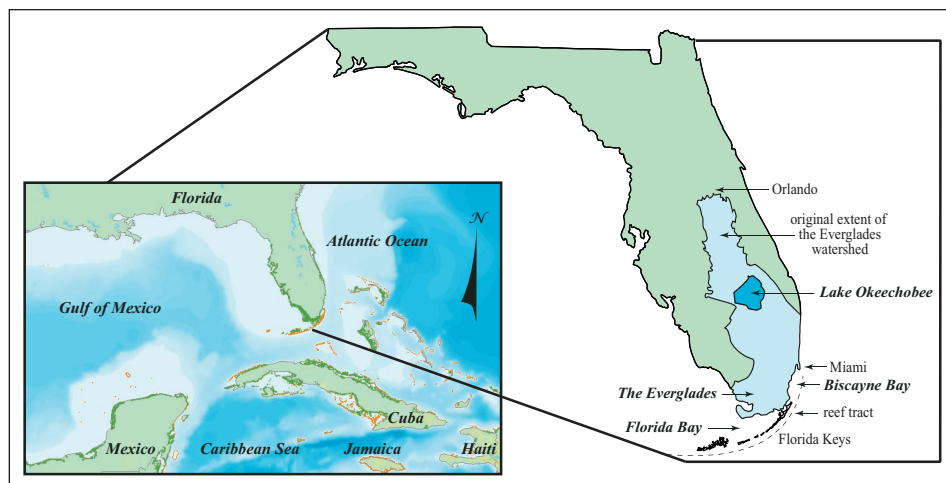


Figure 1. Index map of Florida. Coral reefs are indicated by orange on inset.

study along the western margin of Biscayne Bay (Phase I) and introduces a 2-year project to establish environmental status bay-wide (Phase II) prior to restoration of the Everglades.

## Biscayne Bay

Baseline ecosystem status and pollution data for Biscayne Bay are lacking. An inshore estuary east of the Everglades (Fig. 1), Biscayne Bay is the marine component (vs. terrestrial) of Biscayne National Park (BNP). Within BNP boundaries are the longest stretch of mangrove forest remaining on Florida's east coast, 14 threatened or endangered wildlife species, and the northernmost coral reefs in the continental U.S. The bay acts as a buffer zone for these reefs. Human impacts on the coastal marine environment of South Florida include urban development, air, land, and water pollution, intense recreational and commercial use, introduction of pathogens and nutrients from sewage-disposal injection wells and shoreline landfills, and physical damage to coral reefs and other bottom communities by derelict fishing gear, boat anchors and ship groundings. Nutrient enrichment spurs oxygen depletion in coastal waters, stressing or killing biota. Coastal land-use practices (marina, agricultural and industrial development) cause contamination by chemical pollutants, pesticides, petroleum products, fertilizers, and heavy metals. Each impact alters the coastal ecosystems. Each impact has significant implications for human issues, including swimmers' health, fishery nurseries and resources, and management of coastal land development.

Of particular concern is the \$8 billion Comprehensive Everglades Restoration Project (CERP, signed into law in December 2000) to remove canal and levee infrastructures within the watershed to restore a natural southward flow of water. Resource managers urgently need information on stress responses in organisms that can be compared with data acquired through remote sensing, water quality, and biotic community monitoring. In cooperation with Biscayne National Park (BNP), the National Park Service (NPS), and the University of South Florida (USF), the U.S. Geological Survey (USGS) has begun a new project to evaluate pre-restoration conditions throughout Biscayne Bay using components found in surface sediments. Project strategies are to assess grain size, heavy-metal concentrations, sources, pollution hotspots, distributions of a pollution-sensitive group of marine microfaunas, and biotic community structure as reflected by skeletal sand grains. Long established as paleoenvironmental and pollutant biomarkers, benthic or bottom-dwelling foraminifera (forams) morphologically and geochemically record ambient environment in their shells. The goal is to provide essential baseline data that can readily be used to monitor changes in the estuarine ecosystems during and after implementation of the CERP.

The Phase I pilot study was concentrated along the western margin of Biscayne Bay. The pilot study achieved primary objectives:



- by developing and implementing improved methods using geochemical, sedimentary, and foram analyses to assess and monitor coastal contamination;
- by defining types, distributions, and concentrations of heavy metals relative to grain size of host sediments to obtain a better understanding of heavy-metal sources and sinks;
- by identifying dominant foram assemblages and key biomarker taxa known as pollutant indicators to assess environmental status; and
- by quantifying percentages of normal vs. deformed foram shells to correlate results with concentrations of heavy metals and other pollutants.

Phase II will expand these objectives bay-wide and will assess present biotic community structure by identifying and quantifying skeletal sand grains. Except for coral grains, the most abundant grains of other organisms belong to the groups of living organisms that are dominant. Grain percentages are thus indicators of the type of environment in which the organisms live. In contrast, high percentages of coral grains equate to high rates of coral bioerosion and thus to poor coral health (e.g., Lidz and Hallock, 2000). Living coral polyps form a thin cover of tissue over a skeleton of calcium carbonate. When the polyps die, increased areas of skeletal coral are exposed to bioerosion, or breakdown by grazing and boring organisms. With the exception of damselfishes, which are aggressive specialized herbivores that feed on live coral tissue to promote algal growth within their territories at the base of coral colonies, few grazers and borers in general attack healthy corals. Phase II will integrate Phase I results and will provide bay-wide database contour maps as decision products to improve knowledge of biotic community, pollutant source, transport, distribution, and accumulation in bay sediments.

## The Pilot Study

The Phase I pilot study was conducted on 38 sediment samples collected in December 2000 and July 2001 along four short nearshore transects at the western edge of the bay and in limited mid-bay areas (Hoare, 2002). The transects were off the Dinner Key Marina, Snapper Creek southeast of the marina, and immediately south of a coastal landfill at Black Point (Fig. 2). Sites were chosen from areas believed to possess elevated concentrations of heavy metals as well as from an area (Snapper Creek) considered to be less polluted. Salinity, temperature, and dissolved oxygen measurements were not noted at sampling. Such information, dated within 1 to 2 days of sample collection, was consequently obtained from Southeast Environmental Research Center (SERC, 2000, 2001) records

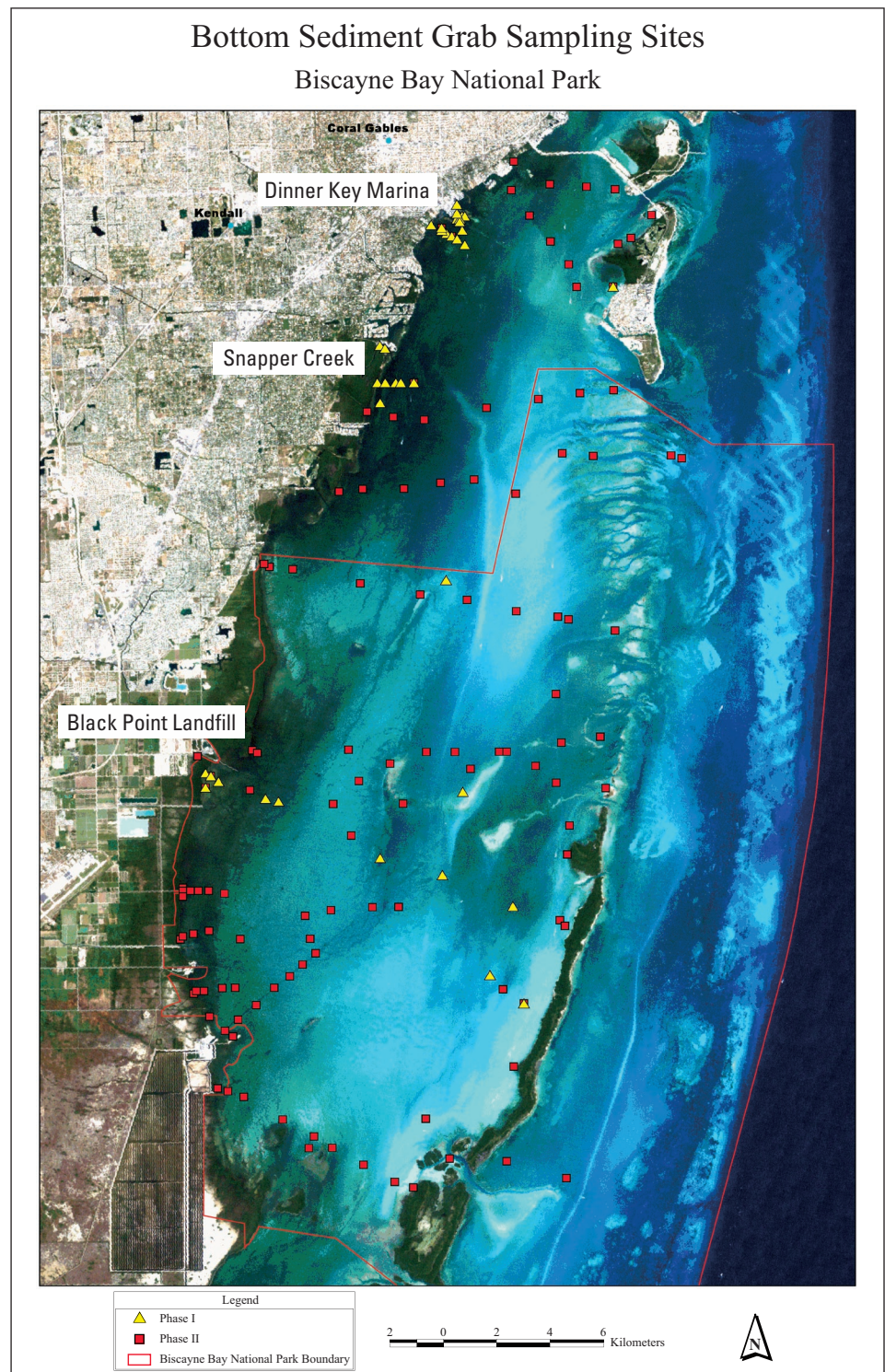


Figure 2. Map of Biscayne Bay shows 38 nearshore sample sites of the Phase I pilot study (yellow triangles) and additional 120 cross bay sites sampled for Phase II analyses (red squares).

maintained at Florida International University. Because sample sites for the pilot study were localized, results are preliminary. Phase II bay-wide analyses may produce trends that differ from those indicated by the pilot study.

## Grain-Size Analysis

Grain-size analysis revealed that most samples were poorly sorted, especially those from the vicinity of Black Point, and that samples at

15 of the 38 sites were composed of >90% sand, ranging from medium to very fine in texture. The muddiest samples (>50%) were confined to small areas in the upper bay. Fine sands were predominant in samples from the Dinner Key Marina and Snake Creek areas. Correlation of the grain-size and foram data indicated that grain size does not affect distribution of benthic forams.



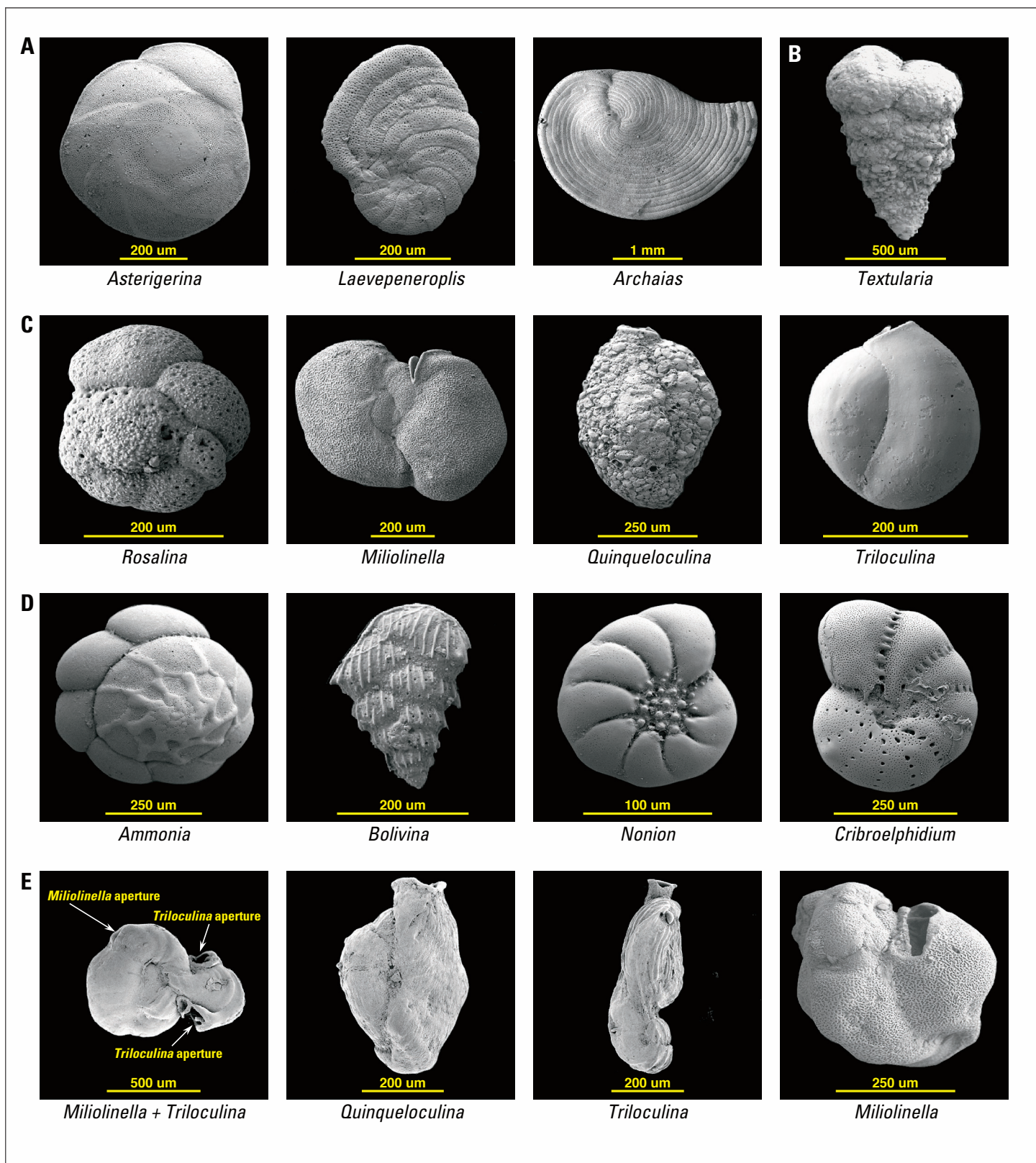


Figure 3. Members of benthic foram assemblages commonly found in Biscayne Bay. When occurring in abundance, each dominant assemblage represents a functional group diagnostic of environment. Except for agglutinated genera, benthic forams secrete their shells from calcium, magnesium, and oxygen dissolved in sea water. Agglutinated taxa build their shells by cementing tiny particles from their environment together. (A) Oligotrophic symbiont-bearing taxa. (B) Agglutinated taxon. (C) Smaller nutrient-tolerant heterotrophic taxa. (D) Opportunistic taxa. (E) Abnormal (deformed or misshapen) specimens.

Oligotrophic: environment low in dissolved nutrients.

Symbiont-bearing: reef-building stony corals and reef-dwelling benthic forams contain symbiotic algae required for their growth, calcification, and color.

Heterotrophic: environment with abundant dissolved nutrients but not to the point of being eutrophic.

Eutrophic: environment saturated with dissolved nutrients that promote prolific growth of non-symbiotic algae.

## Heavy-Metal Analysis

Potential sources of heavy-metal pollution include leachates from copper bottom paint on boats in marinas and a coastal landfill at Black Point, and from one or more of the 25 (3,000-ft-deep) disposal wells located at Black Point. Other potential sources include the highly polluted Miami River, the Turkey Point Nuclear Power Plant and sacrificial anodes on boats docked at marinas. Sacrificial anodes protect other metals on boats from breakdown by electrolysis.

Geochemical analyses indicated that concentrations of silver, copper, lead, and zinc were highest near marinas in the upper part of the bay. Water circulation at these sites is more restricted than at other sites in the pilot study, implying longer residence times for the contaminants. A statistical cluster analysis showed that copper, lead, and zinc clustered strongly with aluminum and iron, which are often associated with clays. Clays in the marine environment suggest a terrigenous source. Of the metals detected in the geochemical analysis, copper, lead, zinc, and mercury were the only ones significantly higher than in normal marine water. Trends indicate a decrease in heavy-metal concentrations from north to south along the shoreline, away from the 'older' part of urbanized Miami, and a general decrease from nearshore to the center of the bay. Strontium and calcium typically occur together in a biogenic environment (i.e., where sediments are derived from organisms) and were accordingly found in the samples.

## Benthic Foram Analysis

Assemblages of specific benthic forams characterize 'functional groups' on the basis of taxa present. In turn, the functional groups characterize the environment in which the taxa live: symbiont-bearing larger forams, nutrient-tolerant smaller taxa, pollution-tolerant opportunists, and agglutinated taxa (Fig. 3A-D). Presence of abundant oligotrophic symbiont-bearing taxa indicates good water quality. The water is warm, clear, and low in nutrient content with normal marine salinities. Such conditions are suitable for growth of corals and coral reefs. Smaller nutrient-tolerant heterotrophic taxa indicate presence of organic-rich food sources. These conditions are neither suitable for coral growth nor heavily polluted. Opportunistic taxa tolerate a wide range of stressful conditions, notably environments low in oxygen, variable in salinity, and high in anthropogenic pollution. Agglutinated taxa generally inhabit areas where water is undersaturated with respect to calcium carbonate, such as in estuarine or brackish environments. The abundance of abnormally developed vs. normal specimens indicates the degree of stress in the environment. Studies elsewhere have shown that deformed specimens can develop in presence of heavy metals and that deformed shells contain higher levels of

heavy metals (lead, zinc, copper, chromium, and cadmium) than normal shells.

The pilot study yielded 53 identifiable foram genera typical of estuarine environments. Opportunistic taxa, abundant at all sites, indicate the bay ecosystem is experiencing stress whether from salinity, nutrients, heavy metals, or other pollutants. Deformed specimens, which belonged primarily to a single group of heterotrophic taxa, were found at 27 sites and ranged from subtle to very grotesque in appearance (Fig. 3E). Surprisingly, distributions of high heavy metal concentrations and high percentages of abnormal foram specimens showed little correlation. Highest metal concentrations were found in the upper part of the bay near the city of Miami, but highest deformity percentages occurred off the Black Point landfill, indicating possible leaching of contaminants into the bay.

General trends indicate an offshore increase in diagnostic symbiont-bearing forams and an offshore decrease in opportunists and abnormal specimens. These trends signify that the quality of water in the central bay is better (closer to normal marine conditions) than near shore. The opportunistic forams consistently showed strong correlation with most of the heavy metals and with aluminum and iron. Statistical analysis of the foram assemblages confirmed that bay characteristics are estuarine but also indicated that conditions are stressed. Comparison of present low percentages of symbiont-bearing taxa in the bay, a group physiologically similar to symbiont-bearing reef-building corals, with previous higher percentages measured by others (Ishman et al., 1997) is a particularly significant indication that general water quality in the bay has declined over the 3-year period.

## Summary

In a cooperative study with the NPS and BNP, the USGS and USF are assessing environmental quality in Biscayne Bay to provide pre-Everglades restoration baseline data and decision products that will facilitate restoration and/or preservation of ecosystems within the bay. The study is based on components of surface sediments. The data will be used to construct contour maps of grain size, heavy-metal distribution and concentration, foram assemblages diagnostic of pristine to heavily polluted waters, and dominant types of skeletal sand grains. These products will establish present conditions in the bay and can be applied to monitor future changes in biota (i.e., environment, water quality, and pollution) as well as to document past changes by comparison with historical records determined from analogous studies of sediment cores.

In general, overall results of the Phase I pilot study along the western bay margin indicate that the highest concentrations of heavy metals are found off densely urbanized areas, that most abnormalities in foram shells are found off the Black Point landfill, and that nearshore ecosystems within the bay are under stress. The stress is probably due both to natural (rising sea level) and anthropogenic (increasing pollution) causes. The Phase II bay-wide geochemical, sedimentary, and microfaunal analyses will delineate more precise trends in pollution and will include the origin of biogenic sand grains that will identify the biotic structure of benthic communities.

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