REPORT

TRACE METALS AND PESTICIDES IN SEDIMENTS AND ORGANISMS IN JOHN PENNEKAMP CORAL REEF STATE PARK AND KEY LARGO NATIONAL MARINE SANCTUARY

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EXECUTIVE SUMMARY

Introduction

The study area is located in the Atlantic Ocean seaward of Key Largo, in the John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary. Biscayne National Park is immediately north of the area. Together, these three refuges contain a major portion of the Florida reef tract, the only shallow-tropical coral reef ecosystem on the north American continental shelf. The coral reefs, seagrass meadows, and mangrove forests support highly diverse tropical biological resources found nowhere else in the continental United States.

This ecosystem supports a major tourist industry focused on recreational activities of fishing, snorkling, and scuba diving. There are also major finfish and lobster commercial fisheries in the immediate area. Recent economic estimates of the coral reef habitat report that larger reefs in the system (Molasses Reef) are worth $400 million based on the entire spectrum of use; the park and sanctuary reef resources are thus valued at $1.6 billion (Mattson and DeFoor, 1985).

The recent rapid urbanization of upland and coastal areas of Key Largo and the adjacent Keys are a cause for concern. Increased population density, boat usage, liquid and solid waste disposal, channelization, dredging, marina construction and activities threaten environmental quality through contamination and physical degradation.

A number of large, coastal, urban developments are proposed along the John Pennekamp Coral Reef State Park boundary. This study was conducted prior to the construction of these developments.

Purpose

The purpose of this two-year study was to establish a reliable information base on the trace metal, pesticide, PCB, and pthalate concentrations found in surface sediments and representative organism tissues from 20 sites in John Pennekamp Coral Reef State Park and adjoining Key Largo National Marine Sanctuary. Other chemical characteristics of the sediments and organisms were also collected. The information will be used in support of monitoring environmental quality and resource management.

Results

The information indicates that trace metals are present in sediments and plant and animal tissues in part per million concentrations. Copper appears to be relatively high. Filter feeding organisms concentrate aluminum and iron. Pesticides were present at all stations in part per billion concentration. Some of the compounds detected are currently banned or restricted. The DDT and deterioration compounds were persistent in sediments and tissues. There was considerable spatial and temporal variability in the information. Contamination is not restricted to the coastal area; offshore reef sites had similar contamination characteristics.

There is concern regarding the cummulative effect that the trace metals, pesticides, PCBs, and pthalates have on the organisms. Some tissue samples contain in excess of ten different high risk compounds.

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INTRODUCTION

Purpose

Baseline data is required to evaluate current environmental quality in John Pennekamp Coral Reef State Park and Key Largo National Marine Sanctuary. This is accomplished by investigating the presence of certain chemical parameters in the sediments and marine organisms. Based upon this information, future monitoring will make it possible to identify any changes that may disclose degradation of the resource and indicate trends. Although a long-term monitoring program should be developed, we must first accomplish a short-term study to establish a data base before additional onshore residential and commercial developments are completed.

Along with an on-going water quality monitoring program conducted by the Department of Natural Resources for the past four years at John Pennekamp Coral Reef State Park, this joint DER/DNR project is designed to establish baseline levels in bottom sediments and tissue samples for chemical parameters listed at stations located in John Pennekamp Coral Reef State Park and Key Largo National Marine Sanctuary. This study will complement present data by providing additional information beyond water quality, and additional parameters and stations. Besides interacting with the monitoring program in the park mentioned above, and monitoring in the adjacent Key Largo National Marine Sanctuary and Biscayne National Park, the proposed study will interact with section 205J water quality study in Marathon. Results will also be provided to the Department of Community Affairs and the Monroe County Planning Department, and federal agencies involved.

Resource Historical Patterns

John Pennekamp Coral Reef State Park is a portion of the only living coral reefs in the continental United States and was established on Key Largo in 1959. Some 88 square miles of coral reefs, seagrass beds, mangrove swamps, and hardwood hammocks are protected here as a representative example of natural Florida, providing a wide range of recreational and aesthetic opportunities. Extending seaward three nautical miles, the park contains 2,290 upland and 53,722 submerged acres. From the three-mile limit, the area extending seaward to the 300 foot depth contour was established as the Key Largo National Marine Sanctuary in 1975. The sanctuary administered by the National Oceanic and Atmospheric Administration encompasses 100 square miles, for a total protected area of 188 square miles. The Park and Sanctuary are listed on the National Register of Historic Places.

John Pennekamp Coral Reef State Park is located on Key Largo, approximately 50 miles south of Miami, on U.S. Highway 1. It has a north/south distance of approximately 20 nautical miles. It extends eastward from Key Largo for three nautical miles to the State's territorial limit (Figure 1). In 1975, the area of the three-mile limit to the 300 foot contour line in the Florida Straits was established as the Key Largo National Marine Sanctuary. The Park and Sanctuary are separate entities. The Park is a state-regulated resource, while the Sanctuary is governed by the National Oceanic and Atmospheric Administration under Federal statutes and administrative procedures. Biological and hydrological processes functioning in the seaward portion of the Park are identical to those occurring in the Sanctuary.

The location is at the northern geographic limit of the proper environmental conditions necessary for reef development. Natural forces such as hurricanes and the intrusion of cold water subject the reefs to stressful conditions. In addition to such natural forces, the Park's and Sanctuary's coral reefs are stressed by recreational and commercial activities. Hundreds of thousands to over a million visitors are attracted to the reefs annually. Many local businesses are tied to the existence of healthy, thriving coral reefs, while others are dependent on the tourists. Nonetheless, much coral damage occurs, caused by careless fishing, boating and diving practices. Coral growth is so slow that it takes many years for recovery of damaged portions.

Rapid development in the Keys during the last 10 years has made the task of protecting the park waters and reefs more difficult and complex. Pressure for more and higher density urbanization on North Key Largo which borders the park has increased greatly. In order to protect the natural resources, the cumulative effect of all development on park waters and marine resources--especially the reef corals in both parks and sanctuary--must be carefully evaluated. Sixteen major developments are presently planned for North Key Largo; together they would house more inhabitants than all of Key West (Miami Herald, Sept. 1982). Most plans are for condominium projects, many with marinas connected to the open water. The demand for large marinas is increasing, compounding the problems.

Pollution and turbidity associated with this sort of development are known causes of stress in the marine environment. If North Key Largo is developed according to plans, the resulting stressful conditions will not be temporary, as in the case of an occasional oil spill or dredging, rather

they will be chronic. The previously undisturbed natural shoreline would be destroyed by bulkheading, dredging and filling. Aside from terminating the park visitor's aesthetic experience of an undisturbed coastline, development will destroy adjacent mangroves and uplands, and will bring the threat of man-made pollution to this relatively remote part of the park's waters. Recent improvements in drinking water supply and access roads and the technology of waste disposal have led to construction proposals for nearly 7,000 housing units in this area. In the last ten years Monroe County has approved the construction of 4,206 units on land bordering John Pennekamp Coral Reef State Park, and the pressure to develop the Upper Keys will continue.

As development on the uplands replaces the natural environment adjacent to park waters, the marine resources will suffer degradation through exposure to pollution caused by human activity. Pollutants include silt, sewage, fertilizers, oils and greases, pesticides, PCBs, plasticizers, and trace metals which can enter the marine environment directly or through runoff. Once in the water, pollutants are spread through wind, wave, and tidal action.

Coral reefs cover only a small percentage of submerged bottom in the Park and Sanctuary. By far the largest areas are seagrass beds, sand, or hard bottom (fossil reefs). Together with extensive coastal mangrove forests, these areas are vital to the existence of the reefs because they supply nutrients to all other plants and animals in the marine environment, including food and game fish. Activities such as dredging and filling cause siltation and clouded water (turbidity); housing developments, marinas, and boating are sources of many pollutants. Besides having an

effect on inshore sea life, turbidity and pollution will eventually decrease the reef's viability because the degraded water is transported to the reefs via wind and tide.

The rationale for conservation and prudent stewardship of these valuable resources can be divided into three categories. First, reefs are an aesthetic natural wonder, a Florida treasure similar to the Everglades and the Grand Canyon and should be conserved for the enjoyment and enlightenment of future generations. For example, Carysfort Reef is approximately 5200 years old. It has weathered all forms of natural climatic and oceanic stress; however, if it were destroyed by human activity, it could not be restored or replaced.

Second, coral reefs in the Park and Sanctuary are economically important to the surrounding human community. Monroe County's primary industry, tourism, is highly dependent on pristine water, fishing, colorful reefs, and a lush tropical setting. Fishing, diving, and lobstering establishments, educational institutions, gift shops, motels, restaurants, etc., all gain economic benefit from the coral reefs and other living resources.

Third, ecologically, the natural processes that have created the biological diversity in these coral reefs must be allowed to continue without undue interference from external human influences. While the basic functioning of these processes may still be a mystery, a conservative approach offers the best chance for maintaining the system.

Recent awareness of the increasing negative impact of onshore development and associated resource and water usages in Key Largo has prompted the Governor and Cabinet to request a report describing the

situation and recommend actions to enhance existing resource protection at John Pennekamp Coral Reef State Park and the contiguous Key Largo National Marine Sanctuary (Skinner and Jaap, 1984).

As explained in the report, the coral reefs off Key Largo are a part of the total marine environment based on and sustained through the intricate interrelationships of biological communities and the delicate balance of dynamic natural phenomena. Disruption of only one segment of the ecosystem can initiate a chain reaction of events which will eventually impact the whole system. The following points are important:

1. The reefs are at the northern geographic limit of environmental conditions suitable for their survival. Thus, natural phenomena (such as low temperatures) could place the reefs under stress and weaken resistance to additional stress imposed by human activities (such as turbidity and pollution).
2. The marine environment may be stressed by the deterioration of water quality caused by development of the uplands and nearshore areas.

The concern expressed for the survival of a healthy marine environment is based on real threats and is supported by documentation from the Department of Natural Resources and the Department of Community Affairs. Visitors to the park have increased approximately 25% in the last ten years, with an approximate increase of 17% in 1983 alone. These figures are based only on gate receipts at the state park; they do not account for the many visitors who reached the reefs on boats originating elsewhere.

Many of the visitors to the park and sanctuary waters are non-resident

tourists, but an increasing number will be residents of the Upper Keys if development of this area proceeds as currently planned.

Ecological Information

The Florida Park Service's and National Oceanic and Atmospheric Administration's aim is to preserve a part of the Florida Keys' natural environment, and to maintain the natural function and appearance of some of the original Keys, surrounding waters, and reefs. Until recently, protective State and Federal statutes assured that Park and Sanctuary resources would exhibit a vitality superior to other areas in the Keys.

A number of plants and animals in the Park and Sanctuary and immediate vicinity are on State and Federal lists of protected species. Among them are marine animals such as manatees, whales, porpoises, and sea turtles, as well as the endangered American crocodile, and land animals such as the Key Largo woodrat, Key Largo cotton mouse, and the bald eagle.

The subtropical climate in the Keys supports a diverse biological resource resembling more southerly Caribbean areas. This is the only region in North America supporting such a tropical ecosystem.

In a progression from the upland terrestrial habitats seaward to the 91 m (300 ft) depth boundary of the Sanctuary (13-7 km off the coast), a succession of habitats forms a mosaic whose parts are interrelated and interdependent for the success of resident species. The upland tropical hardwood forest gives way to a coastal mangrove forest. At the land-sea interface the mangroves are replaced by a limestone fossil reef rock dominated by attached algae. Mud flats line the mangroves and rocky shores. Seaward, a mixture of sand, seagrass, and rocky outcrops that

support hardy corals, sponges and algae occur. A few miles seaward, patch reefs and seagrass-sand areas dominate. Beyond Hawk Channel (a natural navigation passage between the Keys and major reefs further offshore), there is an increasing abundance of living coral reefs. The most seaward reef community, the bank reef (such as Molasses [Figure 2] or French Reefs), is the most dramatic resource in the Sanctuary. Bank reefs terminate at about 130-140 ft. depth. Beyond this depth, a sandy or rubble bottom with a few sponges and occasional outcrops of rock occurs.

Florida's living coral reefs are 4000 to 7000 years old. They exist in a precarious balance as the northernmost bastion of shallow water tropical reefs in North America and are the most unique resource in the Park and Sanctuary.

Reefs are complexes of corals and other animals and plants with the ability to extract calcium from seawater to construct limestone skeletons that form the reef framework. The bulk of reef mass is subsequently added by the breakdown of the skeletons into sediments which are cemented to the reef. Coral calcification is driven by solar energy derived through photosynthesis: microscopic plants (zooxanthellae) within the coral tissue provide the energy and nutrients, recycle animal wastes, and provide oxygen for the coral animals. This process requires light; therefore, murky water inhibits coral reef development.

Florida's reefs form a discontinuous chain of banks and inshore patches, paralleling the Keys, from Fowey Rocks near Miami to Dry Tortugas. Reef development occurs within a very narrow range of environmental parameters, controlled by type of available substrate (rocky or consolidated), light penetration of the water column (low sedimentation

rate, clear water), and water temperature (65°-90°F). Winter cold and summer heat both stress the system, but potentially the most severe natural impact to a coral reef is the hurricane. Storm-driven waves can devastate shallow coral reefs, often dislodging large coral colonies. Storm waves also resuspend silt, reducing light penetration and requiring the coral to expell sediments from their surfaces. Chronic sediment fallout (as associated with dredging) on coral surfaces causes stress which, if unabated, leads to death.

Reefs exist in this region primarily because of 1) the Gulf Stream; and 2) the Keys island archipelago. The Gulf Stream is a warm water current that moderates winter temperatures while the island chain (particularly Key Largo) forms a barrier against water movement from Florida Bay into the Atlantic. During the winter, extreme cold fronts chill shallow Florida Bay waters to as low as 9.4°C (49°F) [the lower thermal limit for reef corals is about 15°C (59°F)]. Cold Florida Bay waters are transported to the Atlantic by winds and tidal flux. Key Largo forms a barrier to water transport out of Florida Bay. Generally, coral reef development does not occur where there are large channels connecting Florida Bay and the Atlantic.

The mangrove and seagrass communities are also important, functioning as nursery habitats for juvenile fish and lobsters, shoreline stabilizers, sediment filters, food, and breeding grounds. The mangrove swamps of the low coastal islands and shorelines are important to the integrity of the nearshore and offshore ecosystems. Intertidal mud flats, lining the mangroves, exposed during low tide and flooded at high tide, attract wading birds which also feed on the marine organisms, extending the food chain to land animals.

The marine environment is not a closed system; it is dependent on a continuing supply of organic materials delivered by circulating water. Mangrove leaf litter is a source of organics and the base for a food chain. The leaf litter is broken down by bacterial and fungal action into detritus which in turn serves as food for small organisms. The detritus of mangroves makes up 35-60% of suspended material in inshore waters. The detritus-feeders, some of which are larval forms of important commercial species (e.g., pink shrimp), are preyed upon by larger organisms which attract other predators. Among fish and shellfish using coastal mangroves as nursery grounds are mullet, mangrove snapper, snook, tarpon, sea trout, shrimp and blue crab. A close interdependence exists between mangroves and seagrass beds because larval organisms move from the mangroves to continue their development in the grass beds. These organisms may later move out into the reefs or stay inshore, depending on the species.

Large areas of submerged bottom in the Park, such as the 10-15 ft. deep Hawk Channel separating the Keys from the reef tract, are covered by seagrasses. These seagrass beds are highly productive areas since they serve as habitat for numerous organisms and as nursery and feeding grounds for many species of fish and invertebrates migrating between the reefs, seagrass beds and mangroves on a daily or seasonal pattern. Among these important species are mangrove snapper, black mullet, spiny lobster and pink shrimp.

The grasses support attached flora and fauna which, in turn, constitute a food source for other organisms grazing on seagrasses. Endangered green and hawksbill turtles feed on the seagrasses. Grass beds also trap suspended sediment, protecting the reefs by keeping the water

clear, a necessity for the existence of reef corals.

Spiny lobsters and mangrove snapper are examples of animals whose life cycle pattern is dependent upon all three communities. Breeding occurs in or above the reef; larvae hatch in waters near the reef; larvae remain in the water column for a period of time growing to juvenile stages which inhabit the coastal mangrove fringe; larger juveniles move seaward to live in the patch reefs and rock outcrops; subadults move into the bank reefs where they find refuge in the reefs during the day and venture to the seagrass meadows to feed on shrimp, crabs, and small molluscs at night. Survival of these species depends on the quality of the several different habitats; the demise of any one habitat will impact the population and abundance of both species.

Past Research

The historical data base dealing specifically with trace metals, chlorinated hydrocarbons, and pthalates for John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary is not extensive. Manker (1975) reported on some trace metal concentrations in suspended and bottom sediments in the Key Largo region. Manker's work detailed elevated levels of several trace metals in the sediments adjacent to heavily urbanized areas. Water quality from five stations in JPCRSP were collected since 1982. This ongoing project monitors nutrients, ammonia, coliform counts, oils and greases, trace metals, pesticides, PCBs, and PAEs. Several studies indicate that coral (Scleractinia) skeletons contain historical information on the concentration of certain metals and chemicals (Dodge and Gilbert, 1984; Dodge et al., 1984). Neoplasm tumors (calicoblastic

epithelioma) are reported from Acropora palmata colonies from Carysfort Reef and Grecian Rocks Reef (Peters et al., 1986). The tumors may be related to environmental contamination. Several papers have offered the hypothesis that pollution is affecting reef vitality (Voss, 1973; Dustan, 1977). This work will examine the nature of contaminants that are possibly affecting the vitality of the Park's and Sanctuary's biological resources. Problem areas that are detected may be selected for monitoring and to seek point sources so mitigative measures may be taken. The Key Largo National Marine Sanctuary and John Pennekamp Coral Reef State Park funded research projects that deal with a variety of issues and subjects. Much of the work was completed and the findings are available as technical reports. These include the following, listed chronologically:

1972 - Reef sedimentation, Harbor Branch Foundation

1974 - Reef Biology, Florida Reef Foundation

1974 - Dredging in the Florida Keys, Harbor Branch Foundation

1974 - Effects of offshore oil drilling, U.S. Geological Survey

1979 - Effects of drilling muds on coral, Texas A&M University

1981 - Biological inventory, University of Miami

1982 - Water currents, General Oceanics

1982 - Water quality, Biscayne National Park

1981-85 - Quantitative reef monitoring, FDNR Bureau of Marine Research

1982 - Water quality and monitoring, Applied Biology

1982 - Tumors in the bicolor damselfish, University of Miami

1982 - Stromatolites at French Reef, Virginia Polytechnical Institute

1982 - Survey of Carysfort Reef, College of Charleston

1982 - Water quality monitoring, DNR Div. of Recreation and Parks

1983 - Transplanting seagrass, NOAA & Corps of Engineers

METHODS AND MATERIALS

Station Information

During 1985, collections were made at twenty stations (Figure 2). Because of budget constraints, we reduced the original number during 1986 first to fourteen, then to eight, but retained the same numerical designations. Stations were distributed as follows:

Stations 1 through 12; and 18: nearshore stations

(1) Broad Creek
(2) Ocean Reef north
(3) Ocean Reef south
(4) Carysfort Yacht Club
(5) Harrison development
(6) Post/Nichols development
(7) Valois development
(8) Garden Cove
(9) Largo Sound
(10) South Sound Creek west
(11) South Sound Creek east
(12) Hidden Harbor
(18) Navigation marker 32

Stations 13 through 15, offshore stations:

(13) Deep reef near Benwood wreck
(14) Grecian Rocks
(15) Carysfort Reef

Stations 16, 17, 18, 20, Hawk Channel/intermediate stations:

(16) Turtle Rocks
(17) Basin Hill Shoals
(19) Rodriquez Key
(20) Mosquito Banks

Distances from shore range from 10 to 1000 m for nearshore stations, from 7.2 to 10.2 km for offshore stations on the outer reefs, and from 1.5 to 7.0 km for the stations of intermediate locations.

STATION CHARACTERIZATIONS

(1) Broad Creek station (25°20.4'N, 80°15.0'W) lies immediately adjacent to the north boundary between John Pennekamp Coral Reef State Park (JPCRSP) and Biscayne National Park in Broad Creek. Depth varies from 1 to 2 m, sediments range from fine to coarse calcium carbonate particles in a thin layer over hard limestone bottom. The benthic flora consists mainly of turtle grass (Thalassia testudinum) and the calcareous green alga Halimeda sp., the benthic fauna includes both soft and hard corals (Porites porites) and sponges among a variety of species.

(2) Ocean Reef north (25°18.9'N, 80°16.1'W) lies at the mouth of a residential canal system north of marker 18. Depth of water and type of sediment are similar to (1) above, but the sediment layer is thicker at this location. This is an area of dense turtle grass beds (T. testudinum) and a number of species of algae, including Halimeda sp.

(3) Ocean Reef south (25°18.6'N, 80°16.4'W) is located at the approach channel to the club's marina next to marker 12. It is similar to station (2).

(4) Carysfort Yacht Club (25°15.2'N, 80°18.4'W) is located at the approach channel north of marker 4. The substrate is hard bottom with pockets of sediments and patches of turtle grass (T. testudinum) and algae, among them Halimeda sp., as well as finger coral (Porites porites).

(5) Harrison development (25°12.2'N, 80°18.9'W) and

(6) Post/Nichols (25°14.1'N, 80°19.0'W) are very similar to station (4). In both cases the location is next to a marked access channel; bottom configuration, sediments, and benthic communities are similar.

(7) Valois development (25°11.7'N, 80°21.3'W) station is located very close to shore in shallow water of .5 to 1.0 m. Sediments are fine to coarse, >10cm deep in parts of this area. Distribution of turtle grass (T. testudinum) and the alga Halimeda sp. is patchy.

(8) Garden Cove (25°10.4'N, 80°21.8'W) at the mouth of the entrance canal to the Port Bougainville development is characterized by soft deep sediments and deposits of flocculent material which become suspended above the floor by even slight water movement: Divers collecting samples cause clouds of turbidity which take some time to clear. Turtle grass (T. testudinum) growth is lush, blades are 20 to 30cm long, creating a dense carpet. A few patches of Halimeda sp. occur in the vicinity of marker 18B. Several spots of hard bottom in the channel indicate recent propeller scouring.

(9) Largo Sound (25°07.6'N, 80°23.9'W) at marker 21 is the only station located in the sound, an enclosed water body connected to the Atlantic Ocean through an intricate system of tidal mangrove creeks. Depth ranges from .7 to 1.0 m, sediment is coarse to medium calcium carbonate particles in a layer of 10 to 15 cm thickness. Benthic flora consists of lush beds of turtle grass (T. testudinum) and a number of algae, including Halimeda sp. This station is located close to the wading beach at JPCRSP.

(10) South Sound Creek west (25°06.0'N, 80°24.6'W) at the exit of the creek into the Atlantic is the shallowest station in the series. Many of the mudbanks in the vicinity are exposed at low tide. Samples are from a depth

of 40 to 60 cm at the edge of the channel where turtle grass (T. testudinum) and algal growth is denser than on the shallow banks. Besides Halimeda sp., a species of the green alga Caulerpa occurs extensively in this area.

(11) South Sound Creek east (25°05.9'N, 80°25.2'N) consists of a limestone hard pan with few sediment deposits, depth ranges from 2-2.5 m. Sponges and octocorals are attached to the limestone, algae and seagrass are found in the sediments.

(12) Hidden Harbor (25°04.9'N, 80°26.2'W) is again located at development access channel. Sediments are medium to coarse, 10 to 20 cm deep with deeper pockets. In addition to a benthic flora of mixed algae (including Halimeda sp.) and turtle grass (T. testudinum) in large patches, the benthic fauna includes some octocorals and sponges, as well as shallow water hard corals (Siderastrea radians).

(18) Marker 32 (25°08.9'N, 80°21.2'W) lies near the exit of the Garden Cove channel into Hawk Channel north of Rattlesnake Key. Depth is approximately 3 m. This station has lush seagrass with algae and sponges.

(19) Rodriguez Key station (25°03.1'N, 80°26.4'W) is located north of the key at the park boundary. Depth is shallow, ranging from .6 to 1.0 m, the sediment layer is thin, except in depressions, covering limestone bottom. Turtle grass (T. testudinum) occurs more sparsely than at nearshore stations, and grass blades are short. In addition to Halimeda sp. and turtle grass, samples included Porites porites.

(13) Deep reef: Between French Reef and the Benwood wreck (25°02.08'N, 80°19.9'W) the collection site is located at a reef outcropping, 28.9 m depth. The sea floor is a fine carbonate sediment with scattered

buttresses of Montastraea annularis outcropping upwards 1 to 2 m in relief. Other scleractinian corals include Agaricia agaricites, Montastraea cavernosa, Stephanocoenia michelinii, and Mycetophyllia aliciae. Some of these coral heads are undermined with tunnels and caves that provide shelter to invertebrates and fish.

(14) Grecian Rocks Reef is a shallow reef community intensively used by snorklers. Our sampling was concentrated on the southwestern inshore portion of the reef (25°06.7'N, 80°18.4'W). The organism distribution pattern ranges from dense seagrass meadows of Thalassia testudinum inshore of the reef to a mosaic of coarse carbonate sediments and patches of seagrass extending outward from the reef approximately 20 m. Close to the reef, small thickets of staghorn coral (Acropora cervicornis) are common. At the reef fringe there are isolated large heads of star coral (M. annularis). One of these heads lies atop an old ship's cannon. At the inshore reef face a wall of coral and limestone juts upward close to the surface. Most of the wall was constructed by elkhorn coral (Acropora palmata). Corals and Halimeda algae were collected from this area. The reef becomes progressively shallower toward its interior. At low tide much of this region is unaccessible to snorklers due to its shallowness.

(15) Carysfort Reef is located in the northeastern portion of the Key Largo National Marine Sanctuary (25°13.4'N, 80°12.5'W). A prominent feature of Carysfort reef is the old lighthouse that was built between 1848 and 1852. The lighthouse sits on a shallow flat that is dominated by elkhorn coral (A. palmata). Sampling was conducted in the shallow reef flat as well as in a forereef habitat at 13.7 m depth. The deeper area is dominated by large colonies of M. annularis and Colpophyllia natans. Sediments were

collected in channels (grooves) that seperate ridges of reef limestone and coral at the deep collection site.

(16) Turtle Rocks site is near intracoastal local marker 3 and next to an old daymarker piling (25°06.7'N, 80°18.4'W). The seafloor is hardpan limestone with sparse benthos. Short octocorals (sea plumes, whips, and fans) dominant. Diploria clivosa, a brain coral characteristic of turbulent environments, is conspicuous. A strong current was always experienced while sampling this station. Sediments were collected in shallow depressions where sparse deposits accumulate.

(17) Basin Hill Shoals is a small patch reef east of intracoastal marker 31 (25°12.9'N, 80°17.3'W) was sampled. The reef is surrounded by a halo of carbonate sediments and sparse seagrass and algae. The reef is very shallow, it had been hit several times by boats. The principal framework coral is Montastraea annularis. The water was turbid as the reef is very close to Hawk Channel.

(20) Mosquito Bank patch reef is northeast of the light tower that marks the Mosquito Bank area (25°04.4'N, 80°23.0'W). It has the same general characteristics as the Basin Hill Shoals station. The reef surface is very close to sealevel. Many corals are morbid and there are signs of boat groundings on the reef. Seagrasses and sediments are found peripheral to the reef.

Field Methods

Field physical data.

Stations were sampled 10-11 July 1985, 3-5 December 1985, 25-27 February 1986, and 10-12 June 1986.

Field data were collected using the following techniques. Stations

were located using visual landmarks and a loran C navigational instrument (Figures 1, 2). Tide level was determined from tide tables (NOAA, 1984, 1985). Station depth was determined from diver's depth gauge and/or a tape measure. Hydrogen ion (pH) concentrations were measured from the water column with an electronic pH meter. Salinities were determined with a refractometer. Water temperature was measured with a thermometer. Illumination at surface and depth was measured with a quantum scalar irradiance meter. Sediment samples were collected by divers. Acid washed 16 and 32 oz jars were taken underwater and filled with sediments. Three replicates were collected at each station. Based on an evaluation of dominant organisms, two to four species were collected by divers at each station (Table 1). Organisms were brought aboard the boat, sorted, labelled, and wrapped in aluminum foil. Sediments and organism samples were kept cool in an ice chest until return to shore. Samples were placed in a refrigerator for storage and then transported to Dr. Corcoran's laboratory at the Rosenstiel School of Marine and Atmospheric Sciences for analysis.

Quality Assurance:

Great care was taken during the sampling and subsampling process to insure that contamination was kept to a minimum and chain of custody was maintained. This was accomplished by adhering to strict clean procedures, keeping all samples under lock and key and maintaining detailed field and laboratory records.

Laboratory methods

Analysis of petroleum hydrocarbon analyses were conducted by

subsampling from the center of the sediment sample. This was done by removing a subsample with hexane-rinsed stainless steel spatulas, and placing it on clean aluminum foil. An inner plug was removed by inserting a cleaned, organic-free 50 ml glass beaker through the center of the subsample. The sample was placed in an organic-free glass jar and covered with a foil lined screw top. It was then transferred to a locked freezer until extracted.

Sediment Grain Size Analysis

A representative subsample of the collected surface sediments was analyzed for grain-size fractions and distribution. The samples were freeze-dried in a Virtis Model No. 10-146-MB-BA freeze dryer. A representative subsample was obtained by recovering 35 $\pm$ 5 g from a Jones-type, H.W. Curtin sediment splitter. The samples were fractionated into three size classes, >2000u (gravel), 2000 to >63u (sand) and <63u (silt-clay) by mechanically dry sieving for 15 mins. through 2000u and 63u sieves.

The >2000u fraction (gravel) was dried at 105°C to a constant weight, cooled to room temperature in a desiccator, weighed and archived. The <63u fraction was transferred into a labeled one-liter cylinder. The 2000u to >63u fraction was mixed with a 496 (w/v) solution of sodium hexametaphospate and placed in a Bransonic 12 sonic bath for 15 mins. After sonification this fraction was rinsed onto a 63u sieve with one liter of distilled water. The particles which passed through the 63u sieve were combined with the <63u previously stored in the one liter labeled cylinder. The <63u fraction was transferred to a labeled aluminum weighing dish,

dried to a constant weight at 105°C, cooled to room temperature in a desiccator and weighed.

The weight of the <63u fraction was calculated by subtracting the sum of the >2000u and the 2000u - >63u fraction weights from the total sample weight. From this data, dry weight percentages for gravel (>2000u), sand (2000u to >63u), and silt-clay (<63u) fractions were calculated.

Organic Content Analysis

The determination of the total organic matter of the sediments was performed by using a modified version of Gralle and Runnel's (1960) weightloss on ignition process. The procedure uses a high temperature muffle furnace to oxidize organic matter. This method has been proven to be 100% efficient for the recovery of total organic matter in marine sediments (Byers et al., 1978; Dean, 1974).

Freeze dried, representative quantitative subsamples were obtained by using a Jones-type, H.W. Curtin sediment splitter. The split samples were stored in clean 25 ml Erlenmeyer flasks, oven dried at 105°C to a constant weight and cooled to room temperature in a desiccator. A sample of approximately 10 g was transferred into a ceramic crucible of known weight. The combined crucible and sediment was then weighed, and placed in a rack for ignition.

The samples were placed in a muffle furnace and ignited for 2 hours at 500°C. They were then cooled in a desiccator to room temperature and weighed. The difference (i.e. weight loss) between this weight (minus the crucible weight) and the initial dry weight was the quantity of total organic matter (TOM) in the sediment (equation 1).

1. Dry wt. sample - wt. after ignition at 500°C = wt. TOM.

The percentage by weight of TOM in the sediment was calculated using equation 2.

2. $\frac{\text{wt. TOM}}{\text{dry wt.}} \times 100 = \%$ dry wt. TOM

The organic carbon was calculated as 55% of the TOM.

Hydrocarbon Analysis

Sediment

Wet sediment (25-75 g) was weighed into cellulose thimble preextracted with 1:1 benzene: 0.5N ethanolic KOH solution. Five grams of sample were weighed onto a watch glass and placed in an oven at 105°C for 3 hours for dry weight determination. Sediments were extracted and saponified by refluxing for 48 hours with the 1:1 benzene: 0.5N ethanolic KOH solution. A plug of clean, light copper turnings was placed beneath the cellulose thimble to remove the elemental sulfur from the sample. A 0.5 ml volume of androstane and o-terphenyl (1 mg/ml) was added to each sample as an internal standard. Blanks were run with each set of 6 samples.

After 48 hours, the solution containing the extracted hydrocarbons was removed from the Soxhlet and poured into a 500 ml separatory funnel. Any residue left in the round bottom flask was washed with three small aliquots of hexane and these washings were added to the extract.

Three successive 50 ml volumes of hexane were shaken vigorously with the extracted ethanol:benzene mixture, separating the aqueous and organic layer, the three successive hexane-benzene mixtures were then combined and the methanol aqueous phase was discarded.

The hexane-benzene mixture was washed first with organic free water (prepared by passing distilled water through a large XAD-2 resin column)

and then with a saturated sodium chloride solution to remove trace amounts of ethanolic KOH. The combined extracts were dried over 1 g of anhydrous sodium sulfate to remove residual water. The ethanol and water were discarded. The extract was concentrated to 5 ml in a Kuderna-Danish apparatus using a rotovapor. The benzene-hexane concentrate was transferred into a 12 ml evaporator tube, then the concentrate was dried in a block heater under a stream of pure nitrogen gas. The dry sample was then diluted to 1 ml with hexane placed in a 5 ml vial with a foil-lined screw top and stored under refrigeration at 4°C.

An alumina-silica gel column was pre-wet with 12 mls of hexane and the sample was transferred onto a (10 x 1 cm) column packed with 1.25 cm of alumina over 2.5 cm of silica gel. Both the alumina and silica gel had been partially deactivated with 2% organic free water prior to packing. The aliphatic fraction (f_1) was eluted with 12 ml of hexane and a similar volume of benzene was used to remove the aromatic fraction from the column. Care was taken to allow the hexane level to go below the alumina layer during aliphatic elution. The aliphatic fraction was reduced to 1 ml on a block heater under a stream of pure nitrogen gas, while the aromatic fraction (f_2) was brought to almost dryness and then diluted to 0.2 ml. The resultant samples were then refrigerated until they were analyzed by gas chomatography.

Tissue

The procedure for tissue analysis was similar to those described for the sediment and consisted essentially of saponification, separation into aliphatic and aromatic fractions and quantitative determination. However,

it was found that more complete and faster extraction could be attained by placing the homogenized tissue in a round bottom flask, adding 150 ml of ethanolic KOH and extracting it for four hours under a reflux condenser.

Gas Chomatographic Analysis

A 1.0 to 2.0 ul volume of the concentrate was injected into a Tracor model 565 gas chromatograph which was equipped with dual flame ionization detectors and two fused quartz capillary columns. The columns used were two 30 m J & W columns coated with SE 30 for better resolution. Hydrogen was used as the carrier gas and a flow of 30 ml/min. was maintained. The temperature programming was such that the injector and detector temperatures were maintained at 300°C and the chromatograph was programmed for oven temperatures of 100° to 300°C at 8°C/min with no initial hold and a final hold of 5 minutes. A full description of conditions is shown in Table 2. All samples were injected in the splitless mode. Two Hewlett - Packard integrators model 3390A were programmed to record the retention time, areas under the peaks and to calculate the amounts of hydrocarbons from C_{12}-C_{30}. The integrators were calibrated with a standard mixture. The aliphatic mixture contained hydrocarbons from C_{12} through C_{30} including phytane, pristane and androstane. The calibration mixture used for the aromatics had naphthalene, phenanthrene, dibenzothiophene and pyrene as well as the internal standards o-terphenyl and 1-methylphenanthrene. The standard mixtures were run daily and the integrators were recalibrated as necessary.

The quantification of the chromatograms involved evaluating the known and unknown peaks, the internal standards and the unresolved complex

mixture for their retention times and areas. Calibration mixtures were run to determine response factors (concentration injected divided by the area of peak). The integrators were programmed with time windows to detect all reference peaks in the C_{12} to C_{30} range and label them. In addition, it determined the area for all other peaks. The response factors for the internal standards, androstane for the aliphatics and o-terphenyl for the aromatics, were used to quantify the concentration of all unknown peaks and the unresolved complex mixture.

The integrators were capable of integrating under only one set of parameters, therefore, the unresolved complex mixture was quantified separately. This involved tracing the unresolved area on a sheet of paper, cutting it out, determining its area and correcting to units which were comparable to the other data generated by the integrator. The areas of the unresolved tracings were determined by a Hayashi Denko, Type AAM-5 Automatic Area Meter. This unit is a photoelectronic apparatus that automatically determines the area of any opaque or semitransparent material by the amount of light it reflects. The area was reported in cm^2 by the area meter and converted to integrator units by a conversion factor. This information, the areas for the known and unknown peaks, the response factors, sample number, dry weight, volume injected and final dilution volume were all entered into a computer program written to calculate and quantify this data. The program calculated the ug/g concentration for all of the reference peaks, resolved (includes reference peaks and resolved unknown peaks) and unresolved (unresolved complex mixture) areas, total hydrocarbons, the carbon preference index (CPI), the percent recovery, and the following ratios: resolved/unresolved, pristane/phytane, C_{17}/pristane, and C_{18}/phytane.

Pesticides and Phthalates

Both the tissue samples and the sediment samples were extracted in the Soxhlet extractor for four hours using 150 ml of hexane-acetone (1:1). For the sediments a cellulose thimble was used, but the tissue samples were placed in the 250 ml round bottom flask for extraction. The extracts were washed free of acetone with organic-free water using large separatory funnels. Hexane extract was concentrated with a rotovapor and chromatogrammed on a column of Floricil topped with anhydrous sodium sulfate. Three fractions were collected using 200 ml each of 6% ether-hexane, 15% ether-hexane, and 50% ether-hexane. Each fraction was then concentrated to 2 ml. A 5 ul aliquot was injected into a gas chromatograph equipped with 6 foot glass columns and electron capture detector. Columns were packed with 1.5% SP2250/1.95% SP2401 and 5% SP2401. Fraction 1 (6% fraction) was saponified and checked for PCBs. The integrators used in connection with the GCs were programmed for the detection of 21 organochlorine pesticides and 4 plasticizers.

Oils and Grease

Sediments were extracted with lipid solvent (hexane-acetone mixture), and the resultant lipid material was weighed.

Coliforms, Detergents, Nutrients, and Trace Metals

For the determination of these parameters methods were followed as described in Standard Methods for the Examination of Water and Wastewater, 14th edition, 1976, by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation.

Coliforms: Standard Total Coliform Membrane Filter Procedure, pg. 928, 909A.

Detergents: Methylene Blue Method for Methylene-Blue-Active Substances, pg. 600, 512A.

Trace Metals: Metals by Atomic Absorption Spectrophotometry, pg. 144, 301A. Mercury by cold vapor method, all others with use of graphite furnance.

Nutrients: Technicon AutoAnalyzer, pp. 616-628, 604, 605, 606, according to method developed by Grasshof.

RESULTS AND DISCUSSION

Salinities ranged from 31 to 38 °/oo during the study. Lowest values were from Largo Sound station; highest values were from offshore stations (Table 3).

Seawater temperatures ranged from 19.4 to 32.8 C. Lowest and highest temperatures came from the inshore stations (Table 3).

Water column pH ranged from 7.9 to 8.3 (Table 3). The pH meter malfunctioned during the June 1986 sampling, hence no data was acquired. Solar illumination.

The quanta cm^2 sec^{-1} 2 m above the sea surface ranged from 30.1 to 167.7 (Table 4). Highest values occurred close to midday. The sky was often cloudy during portions of the sampling days, thus reducing the solar radiation. The irradance meter malfunctioned during the final sampling, hence there is no information on irradiance during that period. The quanta cm^2 sec^{-1} at the seafloor at stations ranged from 2.6 to 108.7 (Table 4). Percentage of surface illumination impinging on the seafloor ranged from

5.3 to 74.7% (Table 4). Grecian Rocks station consistantly had the greatest percentage of light passing through the water column (49.9 to 74.7%).

Sediments

Grain Size Analysis

Seven particle size classes were listed for all stations, ranging from <0.05 mm (silt) to >2 mm (gravel) in diameter. In general, at all stations, a high percentage of sediment particles fell in the middle size ranges of 0.1 to 1 mm diameter throughout the sampling period. Samples with higher percentages of gravel-size particles originated from nearshore stations and were most often associated with dredged access channels leading to onshore developments. The largest percentage of silt (47.94%) occurred in a sample from a recently dredged access channel at the entrance to the Port Bougainville development canal; the second largest (43.26%) originated from the station at the Valois development where fill material from dredge spoil onshore continually erodes into adjacent waters.

Coliform Counts

Colonies/10g wet sediment ranged in numbers from <5 at several of stations to 16700 at the Rodriguez Key station in December 1985. High values (above 1000) were also found at the Broad Creek, Ocean Reef, Carysfort Yacht Club, Largo Sound, Hidden Harbor, and Basin Hill Shoals stations in July 1985. These stations are associated with developments and/or intensive boating activities. Rodriguez Key is a boating anchorage and lies a short distance offshore from the town of Key Largo, therefor falls into the same category as the other stations.

Detergents

Detergents ranged from 0.05 at Mosquito Banks to 1.48 ugMBAS/g wet sediment at the nearshore station in Largo Sound. Both the Largo Sound and Garden Cove samples contained amounts above 1.0 in June 1986; along with the Broad Creek, Ocean Reef, and other nearshore stations they ranged above .1 in every sample. There appears to be a gradual increase in a number of nearshore stations over the two year sampling period. Values for station 8 (Garden Cove) rose from .52 in July 1985 to 1.27 in June 1986, for station 9 at Largo Sound from .37 to 1.32, for Ocean Reef from .22 to .74 in February 1986. Throughout 1985, values did not reach 1.0; in February 1986, one sample exceeded 1.0, in June 1986 four samples (two replicates) exceeded 1.0.

Kjeldahl Nitrogen

This is the sum of organic and ammonia nitrogen. Values ranged from 160 ug/g at Turtle Rocks in July 1985 to 13170 at Garden Cove in February 1986. Sediments from stations located near developed areas onshore consistently showed higher values than offshore stations. Garden Cove, which shows consistently high values, is a shallow cove with a mangrove shoreline and some heavily used access channels leading to commercial and residential developments. Largo Sound, another station with high values, is an enclosed body of water connected to the ocean through a series of mangrove creeks. It is shallow, and surrounded on three sides by mangroves and a developed shore on the fourth side.

Total Phosphate Phosphorus

Values ranged from 11ug/g in June 1986 in Largo Sound to 230 ug/g at

the deep reef station in February 1986. Other high values were 212 at Ocean Reef north in December 1985 and 228 at Hidden Harbor in June 1986. Since phosphates are not naturally abundant in the marine environment, sources may be fertilizers and detergents. The high value at the deep reef station did not appear in December 1986. Additional data are required to determine whether some discharge may occur at the site (Simmons, personal communication) and affect phosphate contents of the sediments.

Total Organic Carbon

The samples contained from 9 to 148 mg/g dry sediment of organic carbon. Samples with the highest TOC were associated with channels close to developments. They were also in close proximity to mangrove swamps.

Oils and Greases

Values ranged from .2 ug/g dry sediment at Grecian Rocks in December 1986 to 6.58 at South Sound Creek east on the same date. The value for Grecian Rocks in February 1986 was 3.86, however, and for South Sound Creek east it was .73 (.76) for the replicate. On the whole, sediments from all stations contained fairly high amounts of these contaminants, but values fluctuated throughout the study period.

Trace Metals

Among the parameters listed, arsenic, cadmium, copper, mercury, and lead are of special interest because of their toxicity to marine life (National Academy of Sciences, 1972). Arsenic ranged from <.1 ppm in over 50% of samples in December 1986 which included both inshore and offshore

stations, to 9.9 ppm in February 1986 in Garden Cove, and 8.8 ppm in Largo Sound. The highest levels occurred in samples from nearshore stations. February 1986 values were the highest overall during the study period. Arsenic is used in paints and insecticides among many industrial uses. It tends to be accumulated by marine organisms. Cadmium levels were below .5 ppm in all sediments, ranging from <.05 at many stations in December, 1985 to .32 in Largo Sound in February 1986. In the majority of samples concentrations were well below .1 ppm, which is of significance since the compound is highly toxic to marine life. Copper ranged from <1 ppm at Broad Creek to 20 ppm at Garden Cove in February 1986. Values at stations located in the vicinity of large developments tended to be higher which can be explained by the extensive use of copper as an antifouling agent in marinas and bottom paints. Mercury levels ranged from <.05 at many stations in February, 1986 to .2 at Garden Cove and Largo Sound in June 1986. The level of mercury was low throughout the study period with the exception of the high values mentioned. Mercury is highly toxic to marine organisms. Since it is used in agriculture and in the plastics and paper industries, to name some, it may enter the marine environment through runoff and outfalls. Lead content of samples ranged from <0.2 at several stations in February 1986 at 8 ppm at the Harrison development in July 1985. Lead levels in the samples from inshore stations exceeded levels found in offshore stations considerably. Natural concentrations of lead are extremely low in the marine environment. Much of it is introduced through urban runoff where the source is the internal combustion engine. Boats and marinas are another important factor in lead pollution of the marine environment.

Hydrocarbons

The three sources of hydrocarbons in the marine environment are biogenic (produced by marine or terrestrial organisms), pyrogenic (produced by fires or combustion), and petrogenic (produced by petroleum products). The groups exhibit characteristic patterns which make their identification possible (Corcoran, 1983 and pers. comm.). A widely accepted method for separating biogenic and petrogenic hydrocarbons is to separate them into aliphatic and aromatic fractions. Table 5 lists the characteristics useful in interpreting aliphatic chromatograms. An extensive discussion of criteria is given in a report by Corcoran (1983).

Pesticides, Pthalates, and PCBs

Pesticides and pthalates found in the sediments and their detection limits are listed in Table 6. Although both pesticides and phthalates occurred in low amounts, none of the stations were free of the contaminants for the entire study period. Concentrations were higher at inshore stations, as expected; however, some comparatively high values of certain compounds occurred in outer reef stations. For instance, Heptachlor in samples from Carysfort Reef and Turtle Rocks were 2.62 and 2.29 ng/g, respectively, in December 1985. Values for this compound throughout the study period for all stations ranged from <0.002 ng/g to 32.8 in July 1985 in Largo Sound. Also in July 1985, Dieldrin was 11.64 ng/g and Endrin 15.14 ng/g at the deep reef station. Of interest is the continued presence in the samples of banned pesticides such as DDT throughout the study period, and its occurrence at offshore stations. A number of contaminants appeared at Ocean Reef north in fairly high amounts in December of 1985:

Lindane 41.60; Heptachlor 2.84; Aldrin 33.13; o,p DDE 1.62; Endosulfan I 8.64; pp' DDE 18.75; Dieldrin 13.88; Endrin 28.93; and Endosulfan II 4.33. These amounts are from the same sample. Sublethal effects of pesticides and LC50s are investigated by the EPA and continuously updated. Most pesticides are found to be more harmful than previously assumed (EPA, pers. comm.). In a case such as the station above where many contaminants occur in the sediment simultaneously, a synergistic effect may occur, enhancing toxicity to marine organisms. Fast degrading chemicals pose a lesser threat to aquatic life than the stable ones. The latter are of serious concern since they may become concentrated in body tissues, or persist in the environment, exposing organisms to their toxic qualities (Turk et al., 1972).

The PCBs Aroclor 1248/1254 were detected in all sediment samples collected in February, 1986. Concentrations ranged from a low of 40.98, 58.88 ppb at Grecian Rocks to a high of 321.36, 135.64 ppb at Broad Creek. High concentrations were also detected at Ocean Reef (267.80, 249.83 ppb), Carysfort Yacht Club (261.53, 192.80 ppb), and Largo Sound (286.60, 194.49 ppb). The Carysfort Reef station sediments contained concentrations of 184.46, 140.49 ppb. Stations at the deep reef station also exceeded 100 ppb.

The Aroclor chromatograms peaks were superimposed on pesticide signatures and therefore masked sediment pesticide and pthalate values during the February sample analysis. To eliminate the possibility of contamination, the laboratory cleaned and recalibrated their equipment and made a second evaluation of the samples. Similar results were obtained

(Corcoran, pers. comm.).

Pthalates occurred in comparatively high concentrations in the July 1985 samples. They were found throughout the sampling sites during all sampling dates with the exception of the February 1986 samples, when the Aroclor apparently masked their signatures on the chromatograms.

Tissue

Trace Metal Concentrations

1 July 1985

Nearshore stations

Aluminum ranged from 31 ppm in T. testudinum to 990 ppm in Ascidia nigrans; arsenic concentrations ranged from 0.5 ppm in T. testudinum to 3.9 ppm in Halimeda sp.; cadmium levels were all <3 ppm; copper levels ranged from 6 to 33 ppm in T. testudinum; iron concentrations ranged 28 ppm in Siderastrea radians to 2790 ppm in the sponge Spheciospongia vesparia; mercury was found to be below <0.1 ppm in all cases; and lead concentrations were always <10 ppm.

Offshore stations

Aluminum concentrations ranged from 42 ppmm in T. testudinum to 620 ppm in a tunicate (not identified); arsenic levels ranged from <0.5 ppm T. testudinum to 4.8 ppm in Acropora cervicornis; cadmium concentrations were <3 ppm in all cases; copper levels ranged from 7 ppm in T. testudinum to 110 ppm in Halimeda sp.; iron concentrations ranged from 16 ppm in A. cervicornis to 480 ppm in T. testudinum; mercury levels ranged from <0.1

ppm in several organisms to 0.2 ppm in Halimeda sp.; and lead levels were always <10 ppm.

December 1985

Nearshore stations

Aluminum values expressed high variability, levels ranged from 100 ppm in P. porites to 9000 ppm in T. testudinum; arsenic concentrations ranged from 0.2 ppm in P. porites to 19.3 ppm in T. testudinum; cadmium levels were <0.3 in most samples, the highest value was 1.3 ppm in S. vesparia; copper concentrations ranged from 1.1 ppm 23 ppm in two S. vesparia; iron levels ranged from 18 ppm in Halimeda sp. to 4800 in S. vesparia; lead levels ranged from <1 ppm in many samples to 1.5 ppm in Halimeda sp.; mercury levels were <0.05 ppm in all cases.

Offshore stations

Aluminum concentrations ranged from 60 ppm in M. annularis to 2800 ppm in T. testudinum; arsenic levels ranged from <0.2 ppm in several samples to 3.7 ppm in T. testudinum; cadmium concentrations were all <0.3 ppm; copper levels ranged from <4 ppm in several samples to 12 ppm in T. testudinum; lead concentrations ranged from <1 ppm in most samples to 1.3 ppm in M. annularis; all mercury levels were <0.05 ppm.

February 1986 sampling.

Nearshore stations

Aluminum concentrations ranged from 299 ppm to 2850 ppm in T. testudinum; arsenic levels ranged from <0.5 ppm in P. porites to 6.7 ppm in

T. testudinum; cadmium concentrations ranged from <.2 ppm in Halimeda sp. to 0.4 ppm in T. testudinum; copper levels ranged from 4 ppm in T. testudinum to 21 ppm in Halimeda sp.; iron concentrations ranged from 6 ppm in Halimeda sp. to 385 ppm in T. testudinum; mercury levels were always <0.1 ppm; and lead concentrations were always <1.0 ppm.

Offshore stations

Aluminum levels ranged from 85 ppm in M. annularis to 6000 ppm in T. testudinum; arsenic concentrations ranged from <0.5 ppm in A. cervicornis to 7.2 ppm in T. testudinum; cadmium concentrations ranged from <0.3 ppm in many samples to 0.7 ppm in the sponge Haliclona sp.; copper concentrations ranged from 5 ppm in M. annularis to 12 ppm in two samples of P. porites; iron levels ranged from 11 ppm in A. cervicornis to 100 ppm in T. testudinum; mercury concentrations were <0.1 ppm in all cases; and lead concentrations were <1.0 ppm in all cases.

June 1986 sampling.

Nearshore stations

Aluminum concentrations ranged from <100 ppm in T. testudinum to 460 ppm in Halimeda sp.; arsenic levels ranged from <1 ppm in P. porites to 6.6 ppm in T. testudinum; cadmium concentrations ranged from <0.2 ppm in Halimeda sp. to .35 ppm in T. testudinum; copper ranged from 3 ppm in Halimeda to 13 ppm in T. testudinum; iron levels ranged from 15 ppm in Halimeda to 4400 ppm in S. vesparia; mercury concentrations ranged from <0.1 ppm in most samples to 0.1 in S. vesparia; and lead levels were <1.0 ppm in all samples.

Offshore stations

Aluminum concentrations ranged from <100 ppm in M. annularis to 350 ppm in T. testudinum; arsenic levels ranged from <1 in several samples to 2.9 ppm in T. testudinum; cadmium concentrations ranged from <0.2 ppm in most samples to 0.25 ppm in T. testudinum; copper levels ranged from 2 ppm in T. testudinum to 9.5 ppm in M. annularis; iron concentrations ranged from 10 ppm in P. porites to 130 ppm in T. testudinum; mercury levels were <0.1 in all samples; and lead concentrations were <1.0 ppm in all samples.

Inshore stations with higher concentrations of trace metals in organisms were Garden Cove (5), Broad Creek (1), and South Sound Creek east (11). These are located in areas with disturbance activities or where the tidal flow transports materials from areas where disturbance does occur. The offshore stations with higher trace metal concentrations included Mosquito Bank (20), Basin Hill Shoal (17), and Grecian Rocks (14). These are areas in close proximity to navigation lanes or receive intense user activity.

Organisms that appear to concentrate certain trace metals include the filter feeders, especially the sponges and tunicates. The seagrass T. testudinum also seems to concentrate these metals under some circumstances. There is a great deal of temporal and spatial variability. Most replicate samples expressed similar concentrations of trace metals.

Tissue pesticide and pthalate compounds.

Pesticide compounds were found in parts per billion concentrations in dried organism tissues. Concentrations ranged from not detected (ND) to 84.20 ng/gm (ppb). Pthalates (plastic agents) were detected in tissues in

concentrations ranging from .04 to 24.52 ug/gm (ppm). The PCBs were detected in levels ranging from 137.83 to 780.58 ng/gm (ppb). Eighteen different pesticide compounds were detected in organism tissues. Stations that consistently had relatively higher concentrations of pesticides were station 17 (Basin Hill Shoals), 20 (Mosquito Bank), 1 (Broad Creek), and 3 (south Ocean Reef channel). Stations with relatively higher pthalates and PCB concentrations included 9 (Largo Sound), 14 (Grecian Rocks), 1 (Broad Creek), and 17 (Basin Hill Shoals).

Nearly the entire spectrum of organisms sampled contained pesticides in their tissues (Table 7). Algae, Plants, suspension feeders, and filter feeders were included, indicating that the compounds are persistent in the environment. Species with relatively higher levels of concentration included Thalassia testudinum, Halimeda spp., and Porites porites.

An unusual situation occurred during the February 1986 sampling. In the sediment analysis, the PCB Aroclor 1248 was found to be present in all samples, in tissue samples, Aroclor 1254 occurred in a number of the organisms from offshore stations 13, 14, 15, 17, 19, and 20. In samples containing Aroclor 1254, pesticide compounds were not detected, but were found in other tissue samples from the same station that did not contain Aroclor 1254. This situation will require further examination to evaluate what happened.

Table 7 reports the highest concentrations found during respective samplings. Detection limits are stated following each chemical (DL). Specific organism concentration and station data are found in the appendix tables. Other hydrocarbons detected during the program are also listed in the appendix tables.

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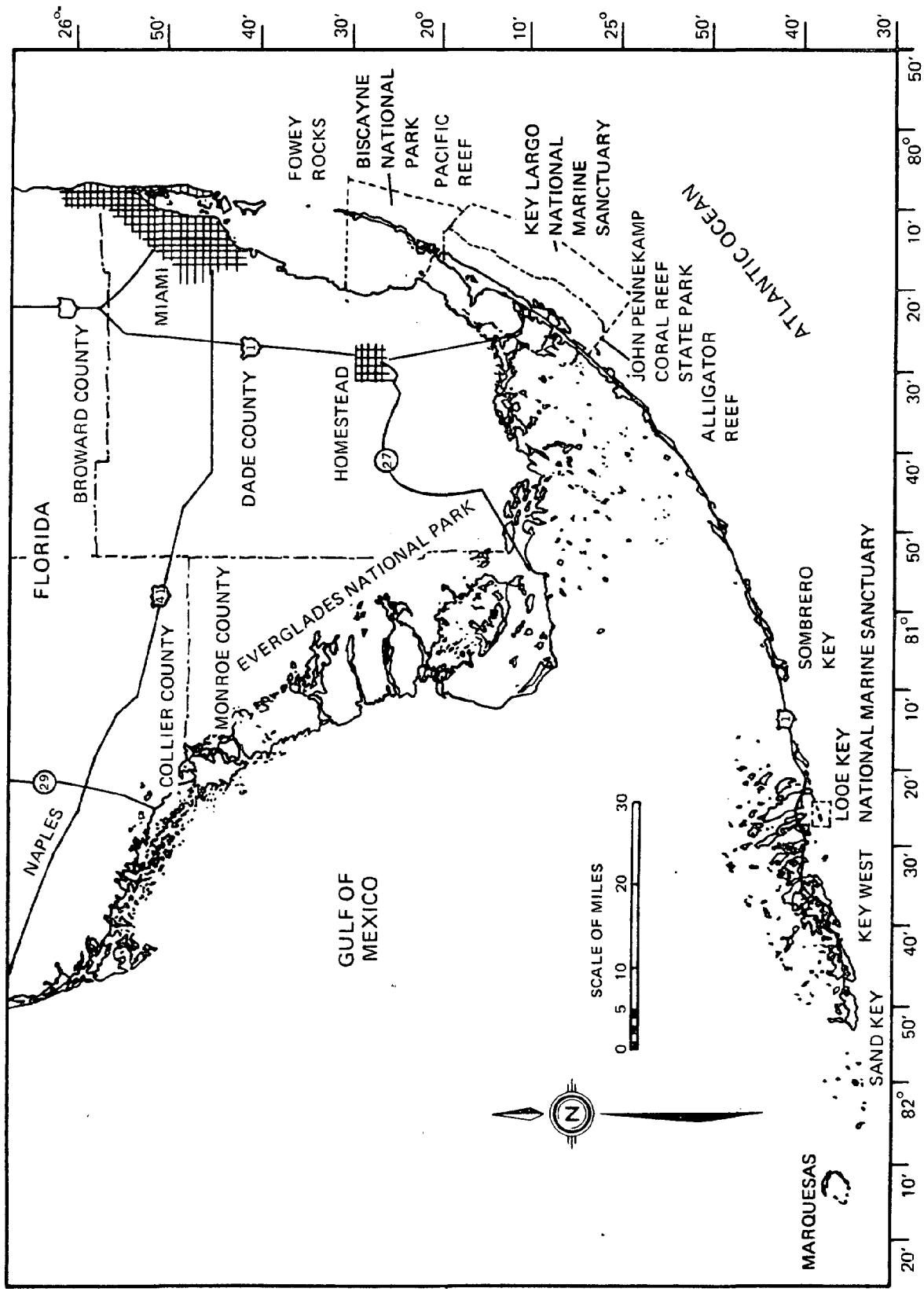

Figure 1. Tropical coral reef communities off south Florida.

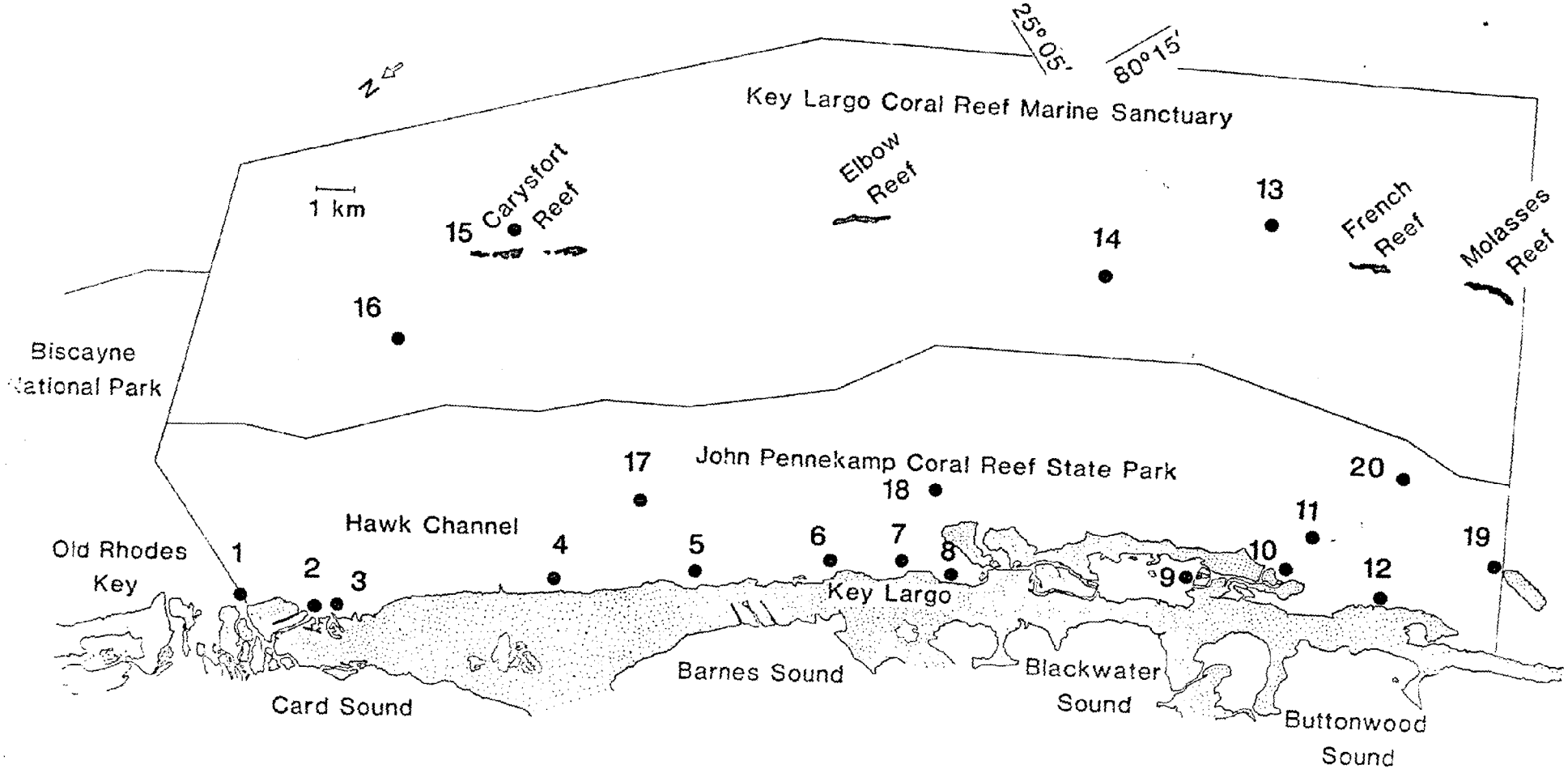

Figure 2. Sampling stations

Table 1. Organisms collected at sampling stations

Station Number	Organisms
1	*Thalassia testudinum*, *Halimeda* spp., *Speciospongia vesparia*.
2	*T. testudinum*, *Halimeda* spp.
3	*T. testudinum*, *Halimeda* spp.
4	*T. testudinum*, *Halimeda* spp.
5	*T. testudinum*, *Halimeda* spp.
6	*T. testudinum*, *Halimeda* spp.
7	*T. testudinum*, *Halimeda* spp.
8	*T. testudinum*, *Halimeda* spp.
9	*T. testudinum*, *Halimeda* spp.
10	*T. testudinum*, *Halimeda* spp.
11	*T. testudinum*, *S. vesparia*
12	*T. testudinum*, *Halimeda* spp.
13	*Montastraea annularis*, *Haliclona* sp.
14	*Acropora palmata*, *Acropora cervicornis*, *Porites porites*
15	*M. annularis*, *P. porites*, *A. palmata*
16	*T. testudinum*, *Diploria clivosa*, *A. cervicornis*, *Gorgonia ventalina*
17	*T. testudinum*, *M. annularis*, *P. porites*, *Halimeda* spp.
18	*T. testudinum*, *Halimeda* spp.
19	*T. testudinum*, *P. porites*, *Halimeda*
20	*T. testudinum*, *P. porites*, *M. annularis*, *Halimeda* spp.

Table 2. Gas chromatograph operating conditions.

Descriptor	Column 1	Column 2
Column Type	SE-30	SE-30
Column length (m)	30	30
Column velocity (cm/sec)	41.7	41.4
Detector gases		
H_2 (cc/min)	30	30
Air (SCHF)	1.0	1.0
Injection timer (sec)	30.5	30.5
Detector temperature (°C)	300	300
Injection port temperature (°C)	300	300
Temperature Program		
Initial temperature 100°C		
Final temperature 300°C		
Program rate 8°C/min		
Initial hold 0 min		
Final hold 5 min		

Table 3. Field station data

Station	Lat. Long.	Date	Time	Depth (m)	Tide	Temp (C)	Sal. (ppt)	pH
1	2520.4	071085	1135-1201	0.9	low	30.8	31	8.1
1	8015.0	120385	1116-1205	0.9	rising	25.5	35	8.1
1		022586	1140-1240	0.9	falling	22.7	36	8.0
1		061186	1421-1452	0.9	high	32.5	38	-
2	2518.9	071085	1231-1247	0.8	low	32	32	8.0
2	8016.1	120385	1220-1256	0.8	high	26.0	35	8.0
2	Station deleted following December sampling							
3	2518.6	071085	1308-1324	1.4	rising	32.8	32	7.9
3	8016.4	020385	1220-1256	1.4	high	26.0	35	8.1
3		022586	1302-1348	1.4	falling	23.2	34	7.8
3		061186	1324-1410	1.4	high	32.0	38	-
4	2515.2	071085	1340-1355	1.2	rising	32.0	32	8.0
4	8018.4	120385	1420-1447	1.2	falling	26.8	36	8.1
4		022586	1527-1600	1.2	low	23.0	36	8.0
4		061186	1234-1304	1.2	high	31.0	38	-
5	2512.2	071085	1444-1450	0.9	high	32.6	33	8.0
5	8018.9	120385	1500-1540	0.9	falling	26.2	36	8.1
5	Station deleted following December sampling							
6	2514.1	071085	1515-1530	1.0	high	32.0	34	8.2
6	8019.0	120385	1410-1440	1.0	falling	25.9	34	8.1
6		022686	1030-1118	1.0	falling	19.4	35	8.1
6		061186	1022-1101	1.0	rising	30.8	38	-
7	2511.7	071085	1540-1604	0.6	high	32.2	33	8.1
7	8021.3	120385	1252-1310	0.6	high	25.7	34	8.0
7	Station deleted following December sampling							
8	2510.4	071085	1621-1630	1.5	high	32.0	34	8.0
8	8021.8	120385	1145-1220	1.5	rising	25.6	33	7.9
8		022686	1138-1203	1.5	falling	20.0	35	8.0
8		061186	1732-1807	1.5	falling	34.0	38	-
9	2507.6	071085	1645-1708	0.7	high	31.4	34	7.9
9	8023.9	120385	1039-1111	1.2	rising	25.0	31	8.0
9		022686	1225-1252	0.7	falling	20.1	31	8.1
9		061086	1635-1712	0.7	falling	31.5	37	-
10	2506.0	071085	1722-1738	1.5	high	30.6	34	8.1
10	8024.6	120585	1428-1450	1.5	high	26.0	33	8.1
10		022686	1347-1429	0.6	low	19.6	35	8.1
10		061086	1510-1551	0.6	falling	31.5	38	-
11	2505.9	071085	1738-1747	2.5	high	31.0	34	8.0
11	8025.2	120585	1358-1416	2.5	high	26.0	34	8.0
11	Station deleted following December sampling							
12	2504.9	071085	1759-1815	1.6	high	31.8	34	7.9
12	8026.2	120585	1140-1158	1.6	rising	25.8	34	8.0
12		022686	1500-1521	1.6	low	22.2	35	8.2
12		061086	1414-1437	1.6	falling	32.2	38	-
13	2503.0	071185	1040-1115	28.9	falling	30.5	32	8.1
13	8021.1	120485	1027-1040	28.9	rising	22.4	35	-
13		022786	1138-1215	28.9	high	22.9	36	8.2
13		161286	1055-1125	28.9	rising	29.5	38	-

Table 3. Field station data (Continued)

Station Lat. Long.	Date	Time	Depth (m)	Tide	Temp (C)	Sal. (ppt)	pH
14 2506.7	071185	1155-1215	1.8	falling	30.8	32	8.1
14 8019.3	120485	1110-1204	1.8	rising	23.2	34	8.0
14	022786	1250-1350	1.8	falling	21.8	36	8.2
14	061286	1150-1306	1.8	high	29.5	38	-
15 2517.0	071185	1305-1330	13.7	low	30.3	33	8.1
15 8024.4	120485	1430-1530	13.7	falling	26.0	34	8.0
15	022786	1425-1510	13.7	low	22.3	36	8.2
15	061186	1544-1632	13.7	falling	31.0	38	-
16 2520.6	071185	1420-1440	2.7	low	31.1	34	8.0
16 8013.0	120485	1605-1640	2.7	falling	26.0	33	8.0
16 Station deleted following December sampling							
17 2512.9	071185	1455-1520	2.5	rising	31.1	33	8.1
17 8017.9	120485	1710-1730	2.5	falling	25.5	32	8.0
17	022786	1538-1615	2.5	low	21.6	36	8.3
17	061186	1126-1210	2.5	high	30.2	38	-
18 2509.3	071185	1545-1610	3.4	rising	31.1	32	8.1
18 8021.2	120585	0925-0950	3.4	rising	25.0	34	8.1
18 Station deleted following December sampling							
19 2503.1	071185	1730-1745	0.9	high	30.6	33	8.1
19 8026.4	120585	1100-1128	0.9	rising	25.5	33	8.1
19	022686	1540-1645	0.9	rising	22.2	35	8.2
19	061086	1318-1347	0.9	falling	32.0	38	-
20 2504.4	071185	1810-1850	2.2	high	31.2	32	8.2
20 8023.0	120585	1227-1249	2.2	rising	26.2	34	8.1
20	022786	1715-1745	2.2	low	21.3	34	8.2
20	061086	1501-1537	2.2	falling	32.5	38	-

Table 4. Solar illumination

Station	Date	Time	Depth (m)	Sky cover	Irradiation (quanta cm^2 sec^{-1} Surface	Depth	%
1	071085	1135-1210	0.9	clear	160.9	108.7	67.6
1	120385	1116-1205	0.9	overcast	80.2	58.2	72.4
1	022586	1140-1240	0.9	overcast	59.5	23.6	39.7
2	071085	1231-1247	0.8	clear	158.4	89.4	56.4
2	120385	1220-1256	0.8	overcast	56.8	2.6	4.6
2	Station deleted following December sampling						
3	071085	1308-1324	1.4	clear	166.0	79.8	48.1
3	120385	1309-1350	1.4	overcast	150.5	39.7	26.4
3	022586	1302-1348	1.4	clear	154.2	41.8	27.1
4	071085	1340-1355	1.2	hazy	117.6	39.5	33.6
4	120385	1420-1447	1.2	part. cld.	143.7	47.2	32.9
4	022586	1527-1600	1.2	part. cld.	136.8	46.5	34.0
5	071085	1444-1450	0.9	hazy	129.6	47.2	36.4
5	120385	1500-1540	0.9	part. cld.	64.4	3.7	5.8
5	Station deleted following December sampling						
6	071085	1515-1530	1.0	hazy	71.4	36.8	51.1
6	120385	1410-1440	1.0	instrument problem			
6	022686	1030-1118	1.0	part. cld.	138.4	76.4	55.2
7	071085	1540-1604	0.6	overcast	49.1	24.6	50.1
7	120385	1252-1310	0.6	instrument problem			
7	Station deleted following December sampling						
8	071085	1621-1630	1.5	overcast	30.1	6.2	20.6
8	120385	1145-1220	1.5	instrument problem			
8	022686	1138-1203	1.5	clear	145.8	17.7	12.1
9	071085	1645-1708	0.7	overcast	38.5	7.1	18.4
9	120385	1039-1111	1.2	instrument problem			
9	022686	1225-1252	0.7	part. cld.	147.6	58.8	39.8
10	071085	1738-1747	2.5	clear	144.4	19.1	13.2
10	120585	1428-1450	1.5	overcast	35.0	11.4	32.6
10	022686	1347-1429	1.5	part. cld.	147.8	19.1	12.9
11	071085	1738-1747	2.5	clear	144.4	19.1	13.2
11	120585	1358-1416	2.5	part. cld.	167.7	11.5	6.9
11	Station deleted following December sampling						
12	071085	1759-1815	1.6	clear	121.2	28.4	23.4
12	120585	1140-1158	1.6	part. cld.	8.1	8.1	10.7
12	022686	1500-1521	1.6	part. cld.	145.0	20.8	14.3
13	071185	1040-1115	15.2	hazy	121.5	24.7	20.3
13	120485	1027-1040	15.2	instrument problem			
13	022786	1138-1215	15.2	instrument problem			
14	071185	1155-1215	1.8	hazy	104.2	77.8	74.7
14	120485	1110-1204	1.8	overcast	33.4	16.5	49.4
14	022786	1250-1350	1.8	clear	145.4	101.6	69.9
15	071185	1305-1330	5.8	hazy	125.5	45.0	35.9
15	120485	1430-1530	instrument problem				
15	022786	1425-1510	5.8	part. cld.	140.0	40.3	28.8
16	071185	1420-1440	2.7	hazy	117.0	34.0	29.1
16	120485	1605-1630	instrument problem				
16	Station deleted following December sampling						

Table 4. Solar illumination (Continued)

Station	Date	Time	Depth (m)	Sky cover	Irradiation (quanta cm^2 sec^{-1} Surface	Depth	%
17	071185	1455-1520	2.5	hazy	115.3	62.1	53.9
17	120485	1710-1730	2.5	dusk			
17	022786	1538-1615	2.5	clear	137.0	36.0	27.3
18	071185	1545-1610	3.4	overcast	71.2	22.5	31.6
18	120585	0925-0950	3.4	overcast	35.4	3.1	8.8
18	Station deleted following December sampling						
19	071185	1730-1745	0.9	overcast	54.0	90.0	60.0
19	120585	1100-1128	0.9	part. cld.	162.4	8.6	5.3
19	022686	1540-1645	0.9	part. cld.	112.4	56.4	50.2
20	071185	1810-1850	2.2	overcast	48.4	13.3	27.5
20	120585	1227-1249	2.2	part. cld.	61.5	15.4	25.0
20	022786	1715-1745	2.2	part. cld.	87.0	8.5	9.8

Note, the instrument was non-functional during the June 1986 sampling.

Table 5. Criteria for distinguishing petrogenic from biogenic hydrocarbons (from Corcoran, 1983).

CRITERION	PETROGENIC	BIOGENIC
1) Homologous Series	Wide boiling range (C_1 to C_{60}) Several series	Narrow boiling range (C_{15} to C_{35}) Few series (2 or 3)
2) Odd-carbon predominance	Absent (CPI 1)	Usually present over a narrow range (C_{15}, C_{17} and/or C_{19} often prominent
3) Unresolved Complex Mixture (UCM)	Present, often dominant	Absent or barely detectable
4) Isoprenoid distribution	Appreciable pristane (C_{19}), phytane (C_{20}), C_{16}, C_{18}	Pristane often abundant, no others detected
5) Pristane/Phytane ratio	1.5 to 2.5	100 or greater
6) Resolved/Unresolved Complex Mixture (Res/UCM)	1 but not zero	Infinite
7) Total hydrocarbon as carbon/ total organic matter (HCC/TOM)	Larger ratio	Smaller ratio

Table 6. Pesticides and phthalates in sediments collected in 1985 and 1986 and detection limits for pesticides and pthalates (labelled as N.D.)

PESTICIDES (ng/gm)	
	0.004
Lindane	0.002
Heptachlor	0.004
Aldrin	0.004
o,p DDE	0.004
Heptachlor epoxide	0.004
Endosulfan I	0.014
p,p DDE	0.004
Dieldrin	0.002
o,p DDD	0.011
Endrin	0.006
o,p DDT	0.002
p,p DDD	0.011
Mirex	0.001
p,p DDT	0.012
Endosulfan II	0.004
Methoxychlor	0.002
alpha chlordane	0.002
Endosulfan sulphate	0.01
PTHALATES (ug/gm)	
Diethyl pthalate	0.01
Dibutyl pthalate	0.01
Butyl benzyl pthalate	0.01
Diethyl hexyl pthalate	0.01

Table 7. Pesticide Compounds

Date	Concentration (ng/gm, ppb)	Organism	Station
	LINDANE (DL = .004 ng/gm, ppb)		
July 85	.095	P. porites	4
December 85	30.88	T. testudinum	11
February 86	12.87	T. testudinum	17
June 86	9.62	T. testudinum	1
	HEPTACHLOR (DL = .002 ng/gm, ppb)		
July 85	0.70	T. testudinum	14
December 85	84.20	Haliclona sp.	13
February 86	20.23	T. testudinum	4
June 86	38.60	T. testudinum	4
	ALDRIN (DL = .004 ng/gm, ppb)		
July 85	ND		
December 85	26.96	P. porites	1
February 86	27.62	T. testudinum	17
June 86	38.10	Halimeda sp.	8
	O, P DDE (DL = .004 ng/gm, ppb)		
July 85	0.42	T. testudinum	5
December 85	26.33	P. porites	1
February 86	21.04	Halimeda sp.	20
June 86	30.38	Halimeda sp.	3
	HEPTACHLOR EPOXIDE (DL = .004 ng/gm, ppb)		
July 85	0.12	Halimeda sp.	10
December 85	15.45	S. vesparia	18
February 86	31.46	T. testudinum	17
June 86	3.01	T. testudinum	17
	ENDOSULFAN I (DL = .014 ng/gm, ppb)		
July 85	ND		
December 85	29.59	P. porites	1
February 86	20.76	Haliclona sp.	13
June 86	24.89	T. testudinum	12
	P,P DDE (DL = .004 ng/gm, pbb)		
July 85	0.30	T. testudinum	16
December 85	17.05	P. porites	20
February 86	20.23	T. testudinum	17
June 86	13.53	Halimeda	3

Table 7. Pesticide Compounds (Continued)

Date	Concentration (ng/gm, ppb)	Organism	Station
		DIELDRIN (DL = .002 ng/gm,ppb)	
July 85	1.04	T. testudinum	20
December 85	15.01	A. cervicornis	14
February 86	20.13	A. palmata	14
June 86	32.34	T. testudinum	4
		O,P DDD (DL = .011 ng/gm,ppb)	
July 85	0.06	P. porites	4
December 85	15.69	T. testudinum	9
February 86	40.72	T. testudinum	17
June 86	0.91	T. testudinum	3
		ENDRIN (DL = .006 ng/gm,ppb)	
July 85	0.23	T. testudinum	2
December 85	20.69	P. porites	1
February 86	20.58	T. testudinum	17
June 86	21.24	T. testudinum	8
		O,P DDT (DL = .002 ng/gm, ppb)	
July 85	0.49	T. testudinum	5
December 85	46.22	Halimeda sp.	9
February 86	28.96	T. testudinum	17
June 86	29.66	T. testudinum	1
		P',P DDD (DL = .011 ng/gm, ppb)	
July 85	0.02	S. radians	4
December 85	ND		
February 86	14.28	A. palmata	14
June 86	ND		
		ENDOSULFAN II (DL = .004 ng/gm, ppb)	
July 85	0.03	S. vesparia	18
December 85	14.13	P. porites	20
February 86	ND		
June 86	20.21	Halimeda sp.	4
		P', P DDT (DL = .012 ng/gm, ppb)	
July 85	0.17	T. testudinum	1
December 85	20.70	P. porites	20
February 86	6.47	T. testudinum	9
June 86	4.91	Halimeda sp.	17

Table 7. Pesticide Compounds (Continued)

Date	Concentration (ng/gm, ppb)	Organism	Station
	MIREX (DL = .001 ng/gm, ppb)		
July 85	0.02	T. testudinum	11
December 85	22.05	P. porites	20
February 86	15.74	Halimeda	19
June 86	36.42	Halimeda	3
	METHOXYCHLOR (DL = .002 ng/gm, ppb)		
July 85	0.31	Halimeda sp.	12
December 85	16.45	P. porites	1
February 86	9.22	T. testudinum	14
June 86	21.84	Halimeda sp.	3
	ALPHA CHLORDANE (DL = .002 ng/gm, ppb)		
July 85	ND		
December 85	ND		
February 86	ND		
June 86	40.53	Halimeda sp.	20
	ENDOSULFAN SULFATE (DL = .01 ng/gm, ppb)		
July 85	ND		
December 85	ND		
February 86	ND		
June 86	2.18	Halimeda sp.	20
	AROCLOR 1254 (DL not given)		
July 85	ND		
December 85	ND		
February 86	780.58	A. palmata	15
June 86	ND		
	PTHALATES AND PCB COMPOUNDS		
	DIETHYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	24.52	G. ventalina	17
December 85	0.55	T. testudinum	14
February 86	21.23	T. testudinum	6
June 86	14.62	T. testudinum	9
	DIBUTYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	6.82	T. testudinum	20
December 85	0.28	Halimeda sp.	9
February 86	2.54	T. testudinum	14
June 86	7.31	T. testudinum	17

Table 7. Pesticide Compounds (Continued)

Date	Concentration (ng/gm, ppb)	Organism	Station
	BUTYL BENZYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	5.99	T. testudinum	10
December 85	0.04	Halimeda sp.	1,12
February 86	0.14	T. testudinum	14
June 86	0.76	T. testudinum	9
	DIETHYL HEXYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	3.20	Halimeda sp.	7
December 85	1.40	T. testudinum	2
February 86	3.01	T. testudinum	1
June 86	2.49	T. testudinum	9
	DIETHYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	24.52	G. ventalina	17
December 85	0.55	T. testudinum	14
February 86	21.23	T. testudinum	6
June 86	14.62	T. testudinum	9
	DIBUTYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	6.82	T. testudinum	20
December 85	0.28	Halimeda sp.	9
February 86	2.54	T. testudinum	14
June 86	7.31	T. testudinum	17
	BUTYL BENZYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	5.99	T. testudinum	10
December 85	0.04	Halimeda sp.	1,12
February 86	0.14	T. testudinum	14
June 86	0.76	T. testudinum	9
	DIETHYL HEXYL PTHALATE (DL = .01 ug/gm, ppm)		
July 85	3.20	Halimeda sp.	7
December 85	1.40	T. testudinum	2
February 86	3.01	T. testudinum	1
June 86	2.49	T. testudinum	9
	AROCLOR 1254 (DL not given) (Concentration given in ng/gm, ppb)		
July 85	ND		
December 85	ND		
February 86	780.58	A. palmata	15
June 86	ND		