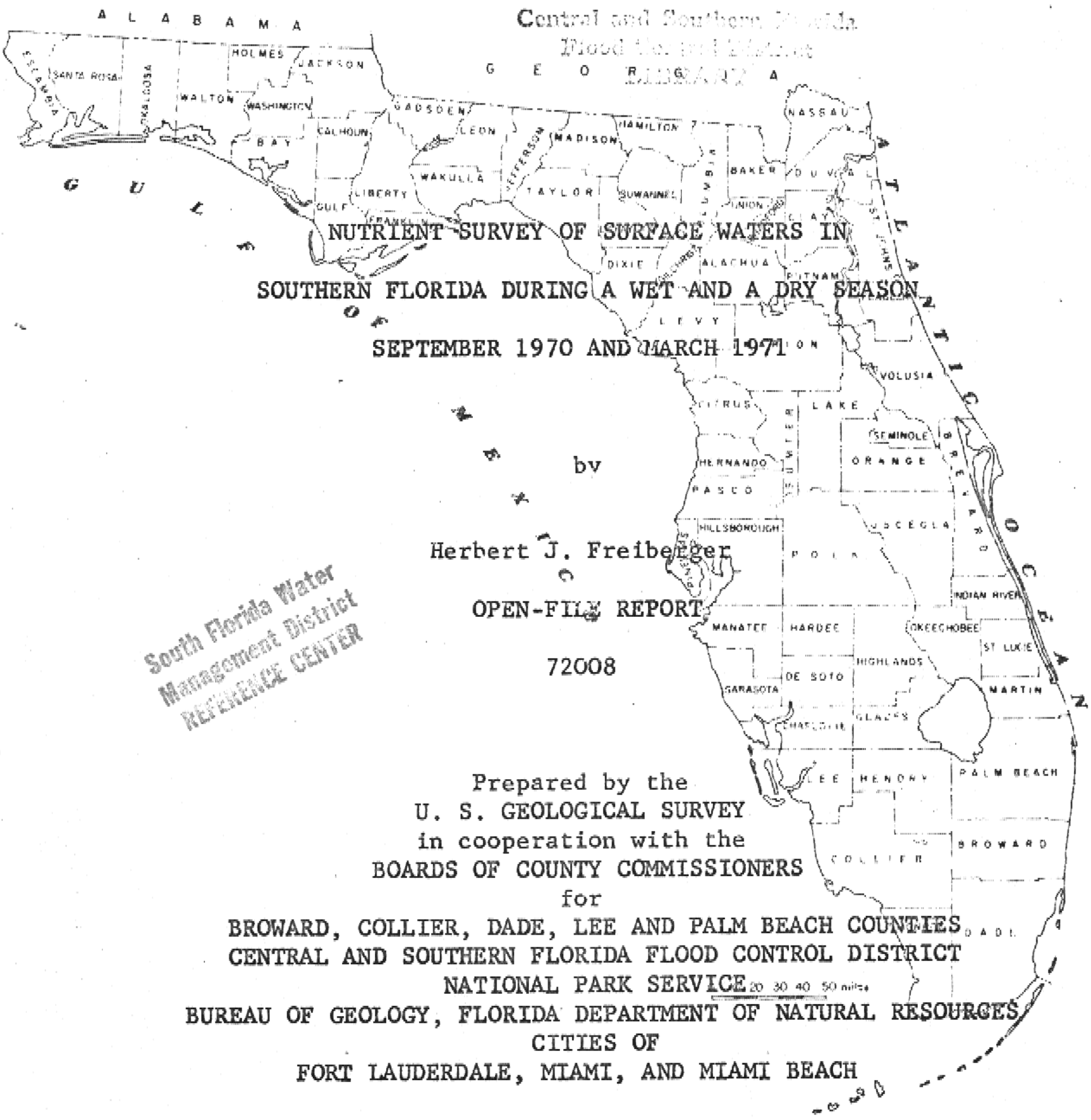
UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY



NUTRIENT SURVEY OF SURFACE WATERS IN SOUTHERN FLORIDA DURING A WET AND A DRY SEASON SEPTEMBER 1970 AND MARCH 1971

by

Herbert J. Freiberger

OPEN-FILE REPORT

72008

Prepared by the
U. S. GEOLOGICAL SURVEY
in cooperation with the
BOARDS OF COUNTY COMMISSIONERS
for
BROWARD, COLLIER, DADE, LEE AND PALM BEACH COUNTIES
CENTRAL AND SOUTHERN FLORIDA FLOOD CONTROL DISTRICT
NATIONAL PARK SERVICE
BUREAU OF GEOLOGY, FLORIDA DEPARTMENT OF NATURAL RESOURCES
CITIES OF
FORT LAUDERDALE, MIAMI, AND MIAMI BEACH

Tallahassee, Florida

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ABSTRACT

A mass nutrient survey of southern Florida surface waters was made in September 1970, during a period of generally high water, and again in March 1971, during a period of low water. Water samples were analyzed by automated chemical techniques for total ortho plus acid-hydrolyzable phosphorus (P-PO_4), ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N).

Phosphorus ($P-PO_4$) concentration averaged about 0.50 mg/l (milligram per liter) during the wet season; the average concentration was slightly higher during the dry season. At many sites sampled during the wet and dry seasons, less than 0.01 mg/l of phosphorus was found. At one site in Broward County near a point of sewage outfall, the concentration was 45 mg/l during the dry season. Ammonia was the most prevalent form of nitrogen detected. Concentrations of NH_3-N ranged from less than 0.01 to 14 mg/l in the wet season and from less than 0.01 to 25 mg/l in the dry season. Ammonia nitrogen concentrations averaged about 0.55 mg/l in the wet season and about 0.50 mg/l in the dry season. Throughout the study area, nitrite and nitrate concentrations were generally low in both wet and dry seasons. Nitrite ranged from less than 0.01 to 0.70 mg/l NO_2-N during the wet season and slightly lower in the dry season. Most nitrate concentrations were below 0.20 mg/l NO_3-N during the wet and dry seasons.

INTRODUCTION

The occurrence and distribution of the major inorganic chemical nutrients nitrogen (N) and phosphorus (P) were measured in surface waters of southern Florida in September 1970, during the wet season, and in March 1971, during the dry season.

The nutrient surveys had analytical support from the U. S. Geological Survey mobile laboratory designed to analyze water samples rapidly in the field for concentrations of nitrogen and phosphorus.

Results of the two surveys provided the following information:

1. Synoptic values for N and P concentrations in most of southern Florida's waters during a wet and a dry season.

2. Background data on nutrient concentrations to supplement available data.

3. A base of N and P data to aid State officials in establishing water-quality standards.

4. A base for determining trends.

5. A bank of comprehensive data obtained from analyses made on "fresh" samples before decomposition altered distribution of the nutrient species.

State and local water-management officials in southern Florida are aware of problems related to nutrient-rich waters. The reported data should assist them. A reduction of nutrients would help decrease the growth of algae and aquatic plants. When dissolved nutrients become plentiful, a heavy growth of plants often occurs. Heavy plant growths in canals and rivers curtail boating and other recreational activities and the eventual decay of these plants often causes undesirable odors, adverse esthetic conditions, and clogging of water-plant filtration systems.

ACKNOWLEDGMENTS

The nutrient surveys in Broward County were made by the U. S. Geological Survey in cooperation with the Broward County Pollution Control Board and the Central and Southern Florida Flood Control District. Surveys in Dade and Palm Beach counties were part of the individual cooperative programs with the counties. Samples for the surveys in Everglades National Park, Collier County, and Lee County were collected in cooperation with the National Park Service, Collier County, and Lee County. The nutrient surveys in Big Cypress Swamp and at many other sites in southern Florida were supported by and were a part of the semi annual sampling of waters of the State in cooperation with the Bureau of Geology, Florida Department of Natural Resources.

The author thanks Herman Feltz of the U. S. Geological Survey, for technical guidance and assistance in report preparation.

SAMPLING

Samples for the study were collected by several teams working without interruption through 24 hours. Field personnel were transported by automobile, light truck, motor boat, air boat, and helicopter. The areal coverage and number of sampling sites assigned each team, were chosen to allow ample time for on-site field measurements of selected water properties while assuring rapid delivery of samples to the mobile laboratory.

Water properties measured in the field were temperature, electrical conductivity, pH, dissolved oxygen and alkalinity. These properties were determined each time the water was sampled at a site in order to enhance the data interpretation, particularly with respect to the occurrence and distribution of the nitrogen forms. These data, along with field data collected in future nutrient surveys, will help in delineating trends.

Unfiltered samples for nutrient analyses were collected in sterilized high-density polyethylene bottles rinsed with the water to be sampled. Addition of preservatives was not considered necessary, inasmuch as analysis was not delayed; the average elapsed time from collection of a sample to completion of analysis was less than 6 hours.

ANALYTICAL SUPPORT

A 21-foot trailer, custom built for housing the mobile laboratory, and fitted with automated wet chemical analyzers was centrally located in the study area. Quick delivery and rapid analysis helped to assure little or no sample deterioration and reliable species differentiation.

The four channel Auto Analyzer[1/] system analyzed 30 samples per hour and measured the concentrations of ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), nitrate nitrogen (NO_3-N), and total ortho plus acid hydrolyzable phosphorus (P-PO_4) simultaneously. The physical arrangement consisted of two single-channel analyzers in parallel feeding signals to a dual pen recorder.

1 Mention of a proprietary product is for identification only, and does not constitute endorsement by the U. S. Geological Survey.

NUTRIENT SOURCES

Nitrogen and phosphorus enter water in southern Florida from numerous sources. Among the more significant are the atmosphere and municipal and agricultural wastes. Detergents, fertilizers, rural and urban runoff and drainage, precipitation, and animal wastes provide the basic sources of nutrients.

In the densely populated southeastern counties of Dade, Broward, and Palm Beach, the greatest source of nutrients is sewage-treatment plants. Septic tanks also contribute. Domestic waste waters contain high concentrations of nitrogen and phosphorus compounds, only a part of which is removed by waste treatment. The remaining part is discharged into rivers or canals, where it often stimulates plant growth and causes noxious odors.

Agriculture is a major source of nutrients, most of which originate from animal wastes and fertilizers. Fertilization of private lawns and gardens also contributes to the nutrient load of streams. In the Lake Okeechobee area, much land is used for sugar cane growing, cattle raising, and truck farming. Homestead and Immokalee are other large truck farming areas. Nitrogen and phosphorus fertilizers are heavily used in these areas, and, thus are significant suppliers of nutrients to soils. Not all the nitrogen supplied is used by plants; some is leached or eroded from soils, and some eventually is transported to waterways during runoff. Phosphorus, unlike nitrogen, is not lost from soils rapidly. Therefore, less phosphorus than nitrogen is likely to be freed to streams from fertilizers.

Most common detergents include phosphorus as a prime constituent. The use of synthetic detergents has increased the load of phosphorus in domestic waste water. The amount of detergent-based phosphorus in domestic waste water reportedly equals or exceeds the amount from all other sources (Task Group 2610 P Report, 1967). On the basis of figures for 1958, the detergent contribution to waste water in the United States was 2.1 pounds of phosphorus (6.4 pounds as PO_4) per capita (Task Group 2610 P Report, 1967). This figure projected to 1970 would probably be conservative, owing to increased per capita use of synthetic detergents since 1958. The combined 1970 population of Dade, Broward, and Palm Beach Counties is greater than 2 million. If the annual per capita use were 6.4 pounds as PO_4, the contribution of phosphorus from detergents would be well in excess of 12 million pounds as PO_4 per year from these three counties alone.

Rural runoff and urban drainage contribute a sizeable amount of phosphorus and nitrogen compounds to streams. In rural areas that are highly cultivated and fertilized, nutrient loads are generally significant during runoff. In urban as well as rural areas, storm runoff generally increases the nutrient load carried by a stream but generally decreases the total concentration of nutrients through dilution.

Animal waste is another source of nutrients in southern Florida. In Everglades National Park, nutrients are noticeably high during periods of low water, when animals and many nesting migratory birds tend to concentrate there.

SIGNIFICANCE OF NUTRIENTS

Nutrients are essential to the growth of plants. However, when the nutrient supply in water becomes abundant, growth of plants and algae can be overstimulated. Many problems involving domestic-water supply and waste-water treatment are the direct result of the interference of algae and plants with normal operations. Water treatment, also, is complicated when the water to be treated contains phosphorus.

Phosphorus and nitrogen compounds occur in water in several forms. The most common ionized form of phosphorus in water is orthophosphate (predominately as HPO_4^{-2} and $H_2PO_4^{-}$). It is the only form derived from natural sources and the type most readily assimilated by plants. The nitrogen compounds of primary concern in water are the ammonium (NH_4^{+}), nitrite (NO_2^{-}), and nitrate (NO_3^{-}) ions.

Nutrients can be detrimental to the operation of sewage-disposal plants. The nutrients often stimulate growth of algae, which can, in turn, produce noxious tastes and odors and clog filter systems. Undesirable growths interfere with coagulation and flocculation and the lime soda ash process of water softening used by many water-treatment plants. Soluble nutrients may also accelerate eutrophication of lakes.

Ammonia nitrogen in water generally originates from decomposition of nitrogenous organic matter. It exists in natural water predominately as the ammonium ion NH_4^+. At high pH values it is converted to NH_3, which can escape to the atmosphere as a gas. Ammonia nitrogen is usually the initial compound in the complex nitrogen chain and may eventually oxidize to nitrite and nitrate. Ammonia nitrogen causes problems in water-supply treatment processes. When it reacts with chlorine, the resulting compound is much less efficient as a disinfectant than free chlorine. Ammonia by itself, expels noxious odors. Substantial concentrations of ammonia in waters indicate recent pollution. In unpolluted rivers, the concentration of ammonia is low, generally less than 0.2 mg/l NH_3 - N (McKee and Wolf 1963).

Although the ammonia nitrogen in natural or polluted waters is usually not harmful to human beings, it can be toxic to fish and other aquatic life at high concentrations if dissolved oxygen is low and if the pH is high enough to produce NH_3. Some forms of algae that thrive on high nitrate concentrations are harmed when nitrogen is present in the form of ammonia. Lethal concentrations of ammonia vary, depending on the individual form of algae.

Nitrite in water is generally formed by bacterial action on ammonia and organic nitrogen. Nitrite, an unstable compound, oxidizes rapidly to form nitrate; thus it is not usually found in significant concentrations in water. Like ammonia, nitrite is often an indicator of pollution.

Nitrate normally does not occur in high concentrations in natural surface waters, as it is readily available for consumption by plants. It may be present in high concentrations at sewage outfalls. High nitrate concentration in the drinking or formula water of infants has been found to be an indirect cause of methemoglobinemia. The nitrate, when ingested by the infant, is converted to nitrite. The nitrite ion then oxidizes hemoglobin to methemoglobin and causes cyanosis. It has been recommended that waters containing more than 10 mg/l of nitrate nitrogen not be used in preparation of formula for babies (McKee and Wolf 1963).

Organically bound nitrogen and phosphorus are significant nutrient sources in highly vegetated areas, such as the swamps, marshes, and conservation areas within the study area; however, an assessment of the entire nutrient budget is beyond the scope of this report.

RESULTS

Nutrients were measured in water samples collected from each site in the area of investigation shown in figure 1, as follows:

Determinations included total ortho plus acid hydrolyzable phosphorus (P-PO_4), ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_2-N), and nitrate nitrogen (NO_3-N). Results of the analysis of each of the nitrogen species are reported in terms of nitrogen, allowing for direct comparison of relative concentrations. The midday or near midday concentrations of the four constituents are plotted on maps (figs. 2-5).

The distribution of phosphorus during wet and dry periods is shown in figure 2 and indicates concentrations in water of southern Florida vary according to geographical areas.

The first geographical area, which is virtually uninhabited by man, includes Everglades National Park, the Big Cypress watershed, the water conservation areas, and undeveloped areas south of Lake Okeechobee and north of Everglades Parkway. During the wet season, phosphorus concentrations in this area were very low, averaging about 0.01 mg/l P-PO_4. Phosphorus was detected at only 10 percent of the sites sampled. During the dry season, the concentrations averaged about 0.07 mg/l, including five sites where concentrations ranged between 0.18 and 0.67 mg/l P-PO_4. At these sites, which are deep ponds at points where the surrounding shallow water had dried up, the increase in phosphorus content was attributed to the increase in waste from fish and aquatic animals concentrating there.

Figure 1.--Map of southern Florida showing study area and location of sampling sites.

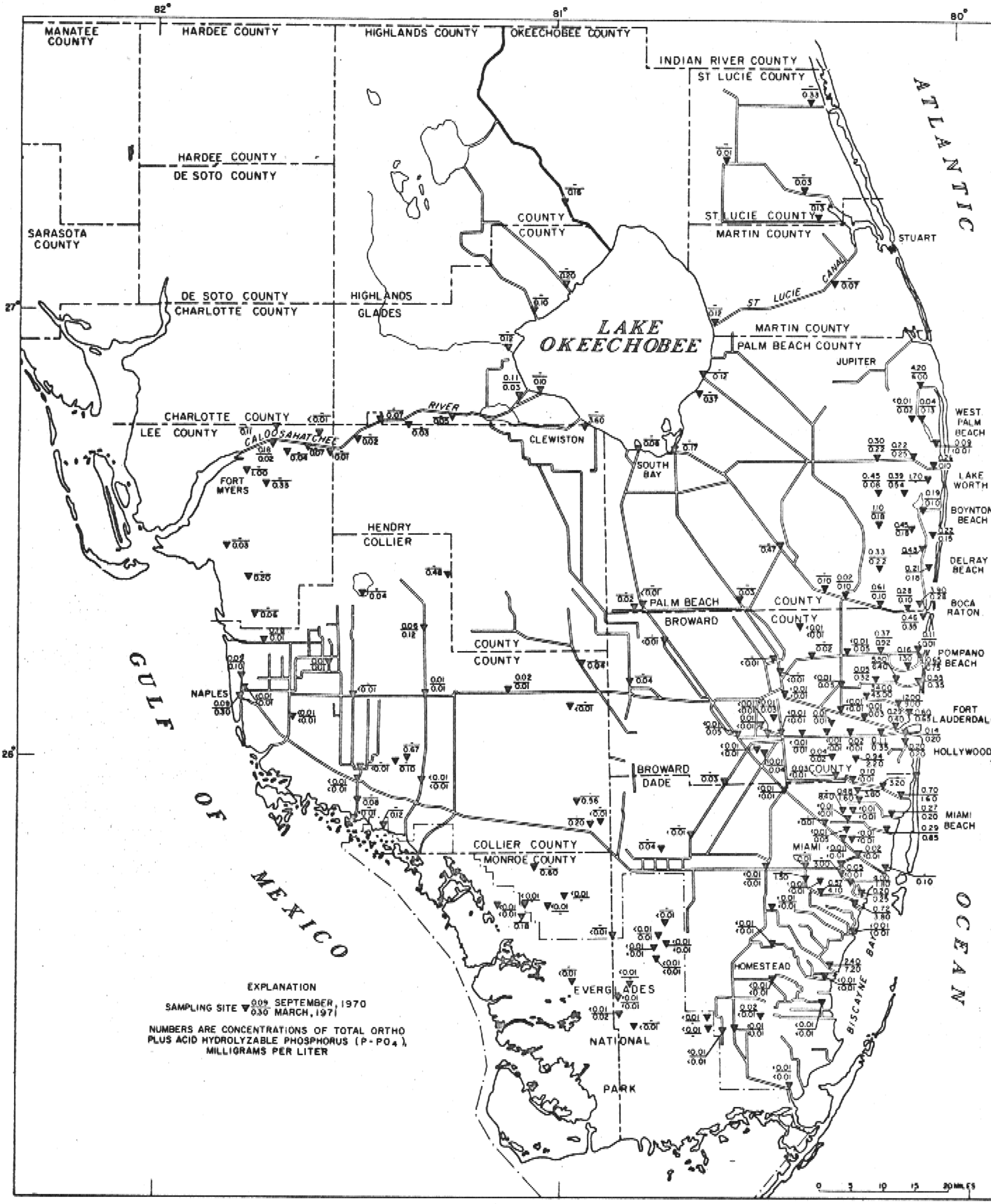

Figure 2.--Map of southern Florida showing areal concentrations of total ortho plus acid hydrolyzable phosphorus (P -PO4) in water in September 1970 and March 1971.

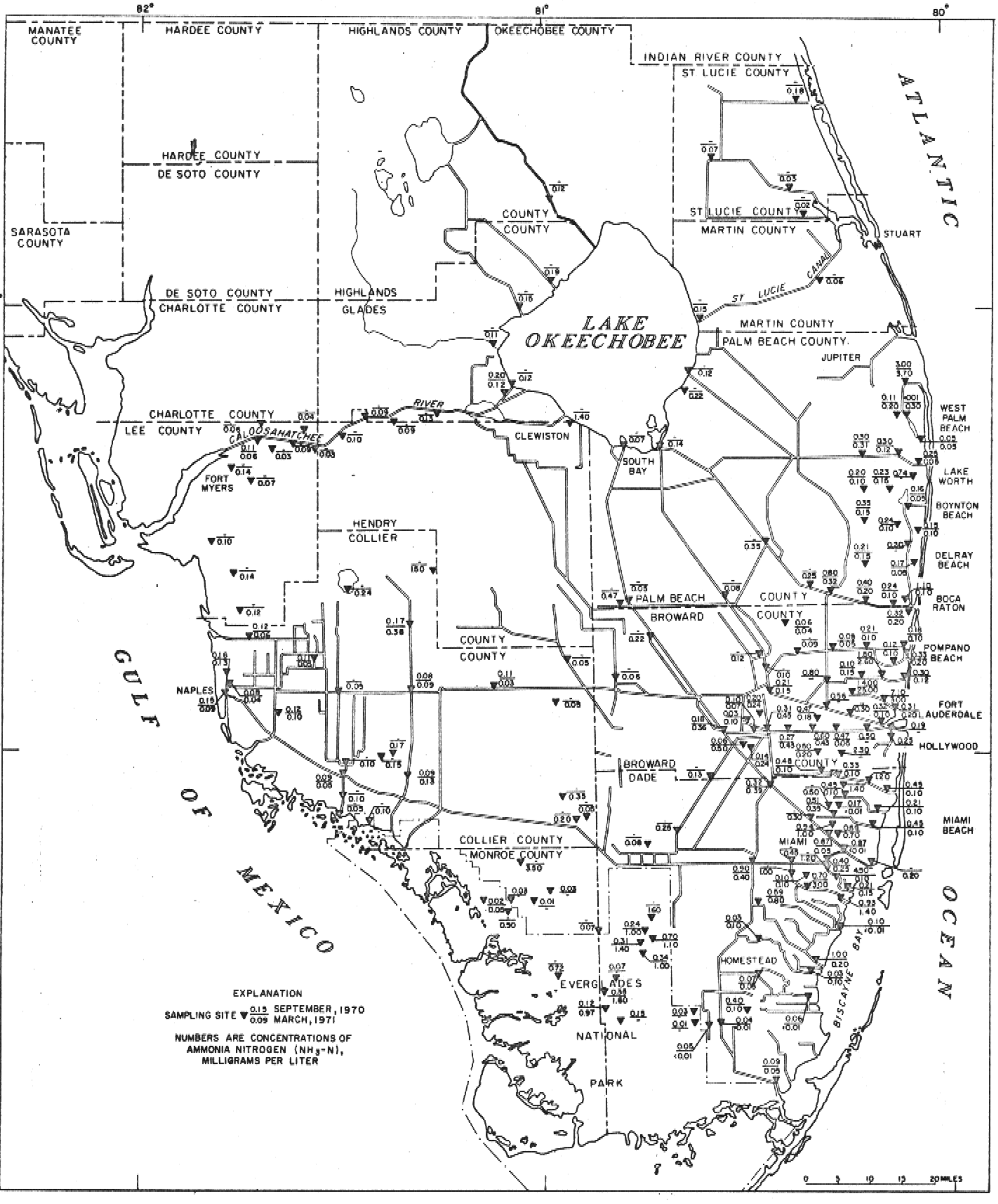

Figure 3.--Map of southern Florida showing areal concentrations of ammonia nitrogen (NH_3-N) in water in September 1970 and March 1971.

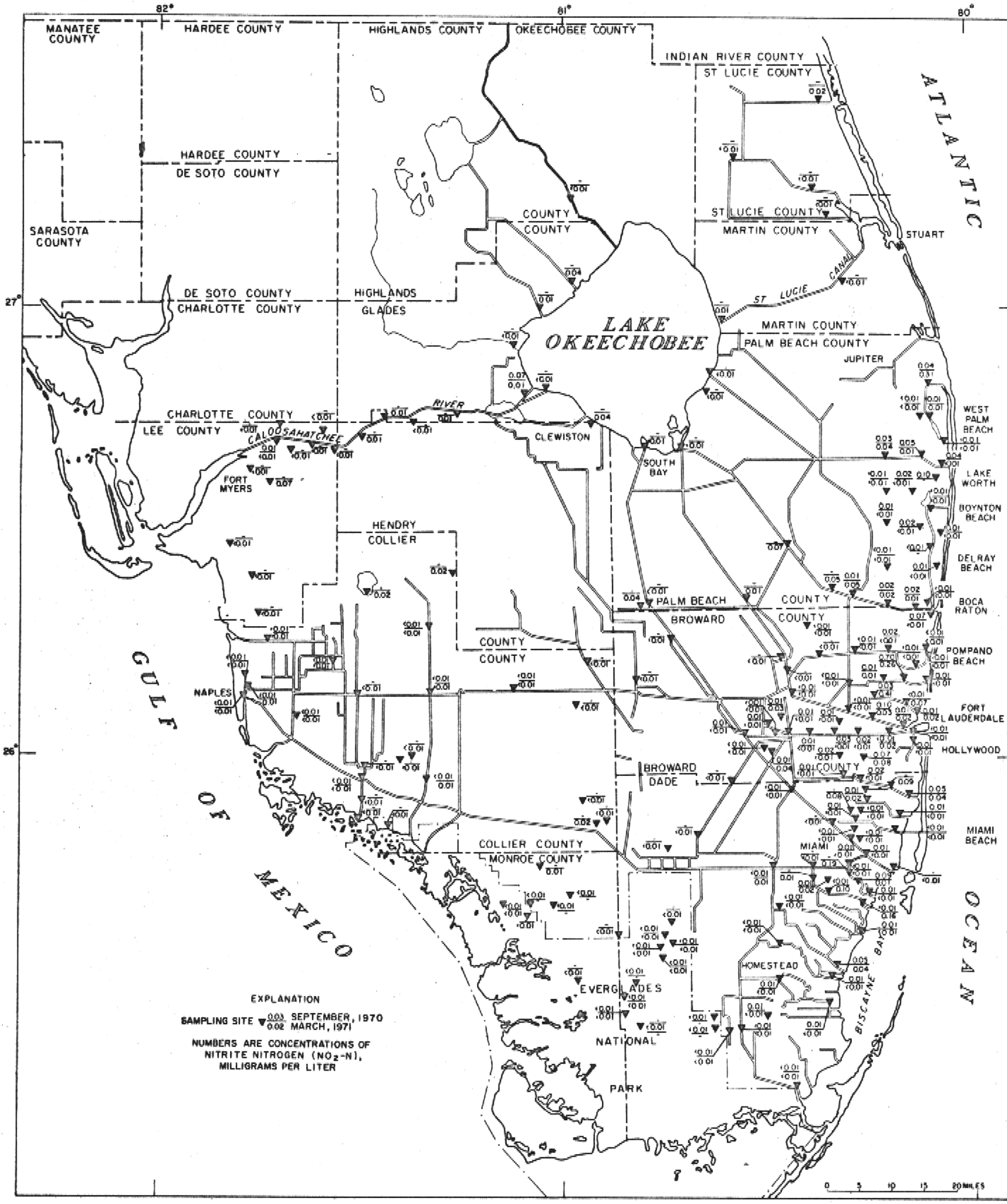

Figure 4.--Map of southern Florida showing areal concentrations of nitrite nitrogen (NO_2-N) in water in September 1970 and March 1971.

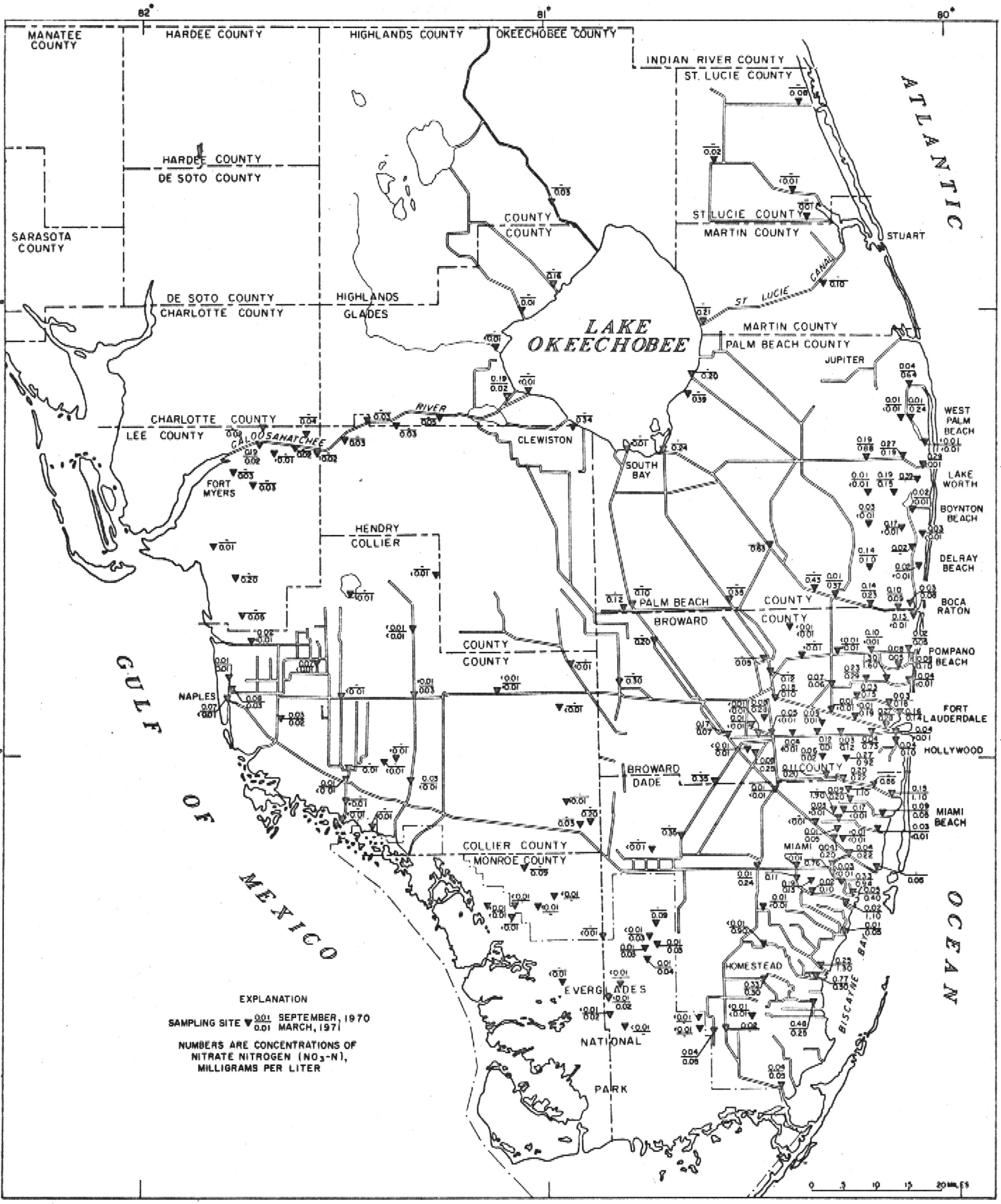

Figure 5.--Map of southern Florida showing areal concentrations of nitrate nitrogen (NO_3-N) in water in September 1970 and March 1971.

The second geographical area is east of Everglades National Park and the water conservation areas, but west of the urban areas along the Atlantic coast. This area showed an increase in average phosphorus concentrations compared with the first area described. Average phosphorus concentrations were 0.17 mg/l in the wet season and 0.22 mg/l P-PO_4 in the dry season. Phosphorus concentrations were low in western Dade County, where at 95 percent of the sites sampled no phosphorus was detected during either the wet or dry season. Farther north in central Broward and Palm Beach Counties, areas where sparse urban development has taken place along with much agricultural activity, phosphorus concentrations averaged 0.25 mg/l during the wet season and slightly less in the dry season. Concentrations ranged from less than 0.01 mg/l at many sites to 2.2 mg/l P-PO_4 at a site in Broward County. The higher concentrations in Palm Beach County are probably due to the long-term agricultural operations in the Lake Worth drainage district.

Concentrations of phosphorus at the sites sampled around Lake Okeechobee, along the Caloosahatchee River, and in the Fort Myers and Naples area averaged nearly the same during the dry season as those in central Broward and Palm Beach Counties. During the wet season, most of these sites were not sampled.

The third geographical area includes all the heavily populated communities along the Atlantic coast. Within these communities, phosphorus concentrations in water during the wet season averaged 1.6 mg/l and ranged from less than 0.01 mg/l at many sites to 34 mg/l P-PO_4 at Plantation Canal near Fort Lauderdale. In the dry period, the average concentration of phosphorus was about 2.0 mg/l. Water in many canals contained less than 0.01 mg/l phosphorus, and water from Plantation Canal near Fort Lauderdale contained 45 mg/l. Average phosphorus concentrations in the wet and dry seasons in the third geographical area are highly influenced by high phosphorus concentrations in Plantation Canal and Middle River Canal in Broward County. The wet and dry season averages for this area are 0.65 and 0.95 mg/l P-PO_4, respectively, if these two high values are excluded. High concentrations of phosphorus in water from these urbanized areas were attributed to the combined effect of sewage outfalls and agricultural wastes. Phosphorus concentrations in water were generally higher during the dry season. This was most likely due to less water available in the canal system for dilution.

Ammonia concentrations in water in southern Florida for the high and low water samplings are shown in figure 3. The data reveal that the most prevalent form of nitrogen measured during the reconnaissance was ammonia.

During the wet season, ammonia concentrations in southern Florida waterways averaged 0.55 mg/l and ranged from less than 0.01 to 14 mg/l NH_3-N. In the dry season, ammonia concentrations averaged 0.50 mg/l and ranged from less than 0.01 to 25 mg/l. Most concentrations of ammonia, in both the wet and dry seasons, were within a range of 0.10 to 0.50 mg/l NH_3-N. In Dade, Broward and Palm Beach Counties, during the wet season, some water near sewage-treatment outfalls contained ammonia in concentrations well in excess of the average range in the study area; canals in Dade and Broward Counties had ammonia as high as 4.5 and 14 mg/l, respectively. In the dry season, ammonia in waters in Dade, Broward, and Palm Beach Counties was more prevalent near points of sewage outfall than in the wet season; however, on the average, ammonia at most sample sites in these counties decreased slightly during the dry season.

In Everglades National Park, an area largely unaffected by human development, ammonia concentrations during the wet season were comparable with the average range over south Florida during the wet season. In the dry season, the average ammonia concentration in the Everglades was 1.3 mg/l NH_3-N. The relatively high ammonia concentrations in the Everglades during the dry season is probably caused by animals, water-fowl, and other biota.

Ammonia in other areas uninhabited by man, specifically the Big Cypress watershed and the water conservation areas, generally averaged 0.15 mg/l NH_3-N during the dry season. Samples were not collected at most of these sites during the wet season.

In the Naples, Fort Myers, and Lake Okeechobee areas ammonia concentrations averaged 0.10 mg/l NH_3-N during the dry season. Concentrations of ammonia in water in these areas ranged from 0.02 to 1.4 mg/l NH_3-N during the dry season. There were too few wet season samples available for comparison.

The concentration of nitrite nitrogen (fig. 4) was negligible except at a few sampling sites in water throughout southern Florida in both the wet and dry seasons. The highest concentration of nitrite recorded at these sites was 0.70 mg/l NO_2-N in Middle River Canal near Fort Lauderdale.

Concentrations of nitrate nitrogen in southern Florida are shown in figure 5. Nitrate was low in most water in both the wet and dry seasons. Concentrations of nitrate nitrogen averaged 0.10 mg/l in the wet season and 0.15 mg/l NO_3-N in the dry season. The highest concentration recorded, 1.9 mg/l, was in a sample from a canal in northern Dade County during the dry season. During both seasons, the concentration of nitrate at most of the sites sampled was below 0.20 mg/l NO_3-N.

PLANS FOR ADDITIONAL SAMPLING

Sampling for nutrient content of southern Florida waters started in 1969 and will continue indefinitely. Inorganic nutrient samplings, supplemented by organic nutrient samplings will be made at least twice annually, during the wet and dry seasons.

The reported data provide a base upon which to plan for more meaningful sampling. The data also aid in determining which parameters should be monitored in the future and at what frequency. Continued nutrient sampling of water throughout south Florida will help to provide a better knowledge of the occurrence and distribution of nutrients in the water and also will help to guide any remedial measures needed.

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