Assessment of Water-Quality Monitoring and a Proposed Water-Quality Monitoring Network for the Mosquito Lagoon Basin, East-Central Florida

By Sharon E. Kroening

Prepared in cooperation with the
National Park Service

Scientific Investigations Report 2007-5238

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia: 2008

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:

World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Kroening, S.E., 2008, Assessment of Water-Quality Monitoring and a Proposed Water-Quality Monitoring Network for the Mosquito Lagoon Basin, East-Central Florida: U.S. Geological Survey Scientific Investigations Report 2007-5238, 53 p.

Contents

Figures

Tables

Conversion Factors, Acronyms, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
acre (ac)	4,047	square meter
square mile (mi^2)	2.590	square kilometer
	Application rate	
pounds per acre (lb/ac)/yr	1.121	kilograms per hectare
	Mass	
ounce, avoirdupois (oz)	28.35	gram
pound, avoirdupois (lb)	0.4536	kilogram
ton, short (2,000 lb)	0.9072	megagram
ton, long (2,240 lb)	1.016	megagram
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

Acronyms

CANA	Canaveral National Seashore
CAZ	Conditionally Approved Zone
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
NASA	National Aeronautics and Space Administration
NAPD/MDN	National Atmospheric Deposition Program/Mercury Deposition Network
NAPD/NTN	National Atmospheric Deposition Program/National Trends Network
NPS	National Park Service
OSDS	onsite-sewage disposal system
PCB	polychlorinated biphenyl
SJRWMD	St. Johns River Water Management District
USGS	U.S. Geological Survey
VOC	volatile organic compound

Other Abbreviated Units

CFU/100 ml	colony forming units per 100 milliliters
$(gal/ft^2)/hr$	gallon per square foot per hour
mg/kg	milligram per kilogram
µg/L	microgram per liter
mg/L	milligram per liter
MPN/100 ml	most probable number per 100 milliliters
ng/L	nanograms per liter
ppt	parts per thousand
Pt-Co units	platinum-cobalt units

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
$°F=(1.8×°C)+32$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29); horizontal coordinate information (latitude-longitude) is referenced to the North American Datum of 1927 (NAD 27).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Assessment of Water-Quality Monitoring and a Proposed Water-Quality Monitoring Network for the Mosquito Lagoon Basin, East-Central Florida

By Sharon E. Kroening

Abstract

Surface- and ground-water quality data from the Mosquito Lagoon Basin were compiled and analyzed to: (1) describe historical and current monitoring in the basin, (2) summarize surface- and ground-water quality conditions with an emphasis on identifying areas that require additional monitoring, and (3) develop a water-quality monitoring network to meet the goals of Canaveral National Seashore (a National Park) and to fill gaps in current monitoring. Water-quality data were compiled from the U.S. Environmental Protection Agency's STORET system, the U.S. Geological Survey's National Water Information System, or from the agency which collected the data. Most water-quality monitoring focused on assessing conditions in Mosquito Lagoon. Significant spatial and/or seasonal variations in water-quality constituents in the lagoon were quantified for pH values, fecal coliform bacteria counts, and concentrations of dissolved oxygen, total nitrogen, total phosphorus, chlorophyll-*a*, and total suspended solids. Trace element, pesticide, and ground-water-quality data were more limited. Organochlorine insecticides were the major class of pesticides analyzed. A surface- and ground-water-quality monitoring network was designed for the Mosquito Lagoon Basin which emphasizes: (1) analysis of compounds indicative of human activities, including pesticides and other trace organic compounds present in domestic and industrial waste; (2) greater data collection in the southern part of Mosquito Lagoon where spatial variations in water-quality constituents were quantified; and (3) additional ground-water-quality data collection in the surficial aquifer system and Upper Floridan aquifer. Surface-water-quality data collected as part of this network would include a fixed-station monitoring network of eight sites in the southern part of the basin, including a canal draining Oak Hill. Ground-water quality monitoring should be done routinely at about 20 wells in the surficial aquifer system and Upper Floridan aquifer, distributed between developed and undeveloped parts of the basin. Water samples collected should be analyzed for a wide range of constituents, including physical properties, nutrients, suspended sediment, and constituents associated with increased urban development such as pesticides, other trace organic compounds associated with domestic and industrial waste, and trace elements.

Introduction

Mosquito Lagoon is located in eastern Volusia and Brevard Counties, Florida (fig. 1), and is the northernmost estuary in the Indian River Lagoon system, which has the highest species diversity of any estuary in North America (Sigua and others, 2000). The ecological importance of Mosquito Lagoon, in particular, has been demonstrated by designations given to this estuary—an estuary of National Significance through the National Estuary Program (U.S. Environmental Protection Agency, 2006) and an Outstanding Florida Water and Aquatic Preserve (Walters and others, 2001).

The Canaveral National Seashore (CANA) lies within the southern two-thirds of the Mosquito Lagoon Basin (fig. 1) and is managed by the National Park Service (NPS). This seashore was established by Federal Legislation in 1975 to "preserve and protect the outstanding natural, scenic, scientific, ecologic, and historic values of certain lands, shoreline, and waters of the State of Florida, and to provide for the public outdoor recreation use and enjoyment of the same" (U.S. Congress, 1975).

The NPS strives to maintain the natural quality of surface and ground waters under its jurisdiction in accordance with all applicable Federal, State, and local laws and regulations (Walters and others, 2001). Two high priority goals for CANA are: (1) to compile and analyze water-quality data from the Mosquito Lagoon Basin to reveal water bodies for which monitoring is adequate for NPS needs and those for which more monitoring is needed, and (2) to develop a coordinated water-quality monitoring network (Walters and others, 2001). Water-quality data are needed by the NPS to: (1) manage waters within CANA to maintain the highest level of biological diversity for ecosystem integrity, (2) acquire sufficient knowledge about water quality to effectively participate in State and local water management planning, (3) seek the highest level of protection for CANA under State water-quality standards, (4) acquire appropriate baseline information to adequately understand and manage water resources, and (5) provide a framework of reference to evaluate future water-quality changes that may occur.

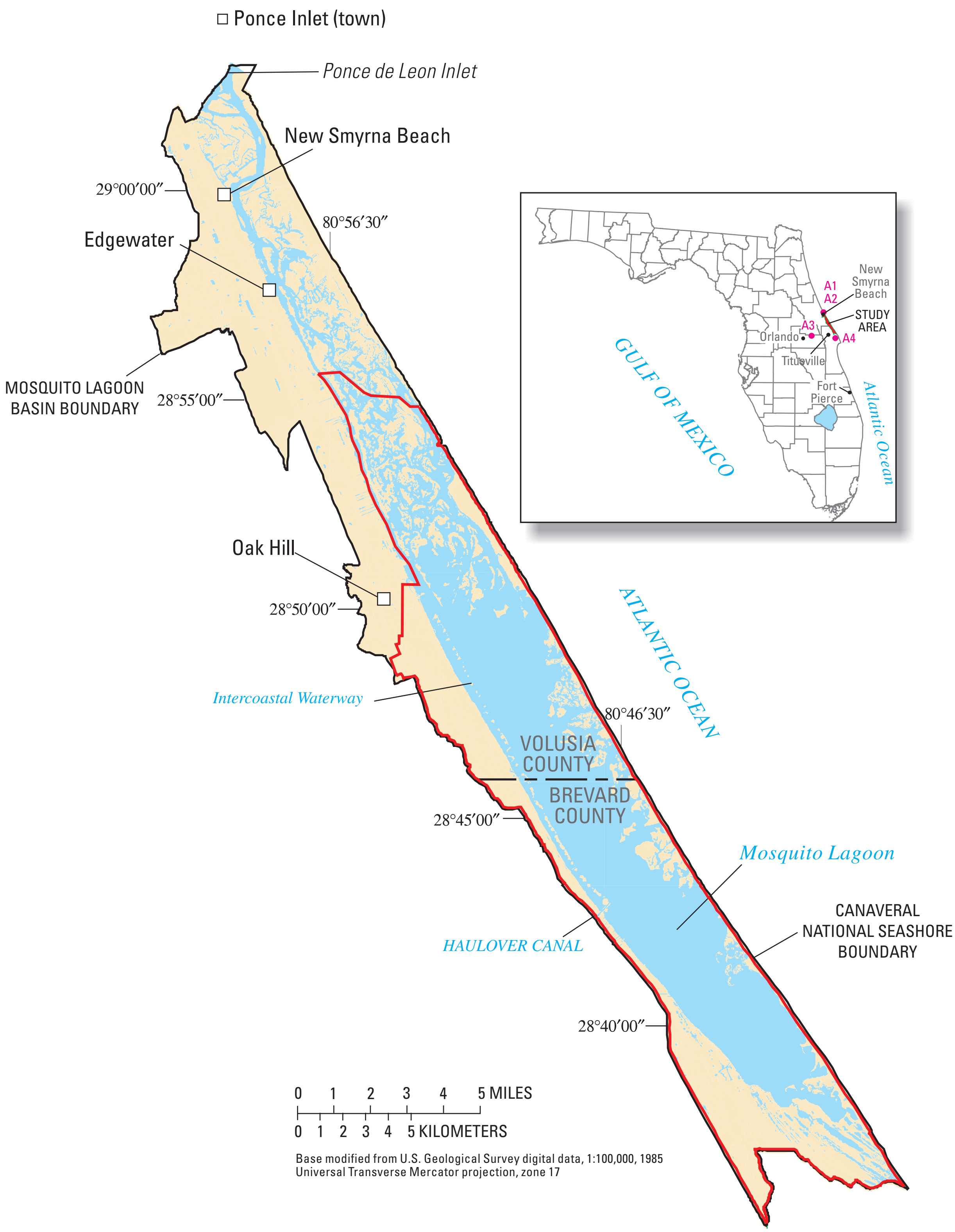

Figure 1. Location of the Mosquito Lagoon Basin in east-central Florida.

In 2004, the U.S. Geological Survey (USGS), in cooperation with the NPS, initiated a study to: (1) compile and analyze water-quality data from the Mosquito Lagoon Basin, with an emphasis on identifying areas that need additional monitoring; and (2) design a surface- and ground-water-quality monitoring network for CANA. Water-quality data, which were collected and analyzed by numerous Federal, State, and local agencies from 1954 to 2003, were summarized and further data needs were identified in this report.

Purpose and Scope

The purposes of this report are to: (1) describe historical and current monitoring in the Mosquito Lagoon Basin, (2) summarize surface- and ground-water quality conditions based on retrospective data, with an emphasis on identifying areas which need additional monitoring or warrant modifications of the existing monitoring programs, and (3) present a water-quality monitoring network developed to meet CANA's goals. The decisions made and rationale used in determining the locations and prioritization of sites in the water-quality monitoring network, sampling frequency, properties for testing, and appropriate quality assurance and quality control are presented. This report includes summaries of data collected by Federal, State, and local agencies and a private agency.

Physical Setting

The Mosquito Lagoon Basin encompasses 124 mi^2 in east-central Florida (fig. 1). The estuary, Mosquito Lagoon, comprises a large percentage of the basin—46 percent of the total area. The climate is classified as humid subtropical, and the basin typically receives from 48 to 56 in. of rainfall each year (Walters and others, 2001). About 65 percent of the annual rainfall occurs between May and October, generally from localized convective storms.

Mosquito Lagoon is the major surface-water feature in the basin. This estuary is classified as a coastal lagoon (Kjerfve and Magill, 1989), and is about 37 mi long and 3 mi wide at its widest expanse. The lagoon is shallow, with an average depth of 4 ft (Steward and others, 2003), and is deepest along the Intracoastal Waterway, which was dredged to a depth of 12 ft in 1952 (Walter and others, 2001). The lagoon's only connection to the Atlantic Ocean is the Ponce de Leon inlet, which is located at the northern end. Mosquito Lagoon also is connected to the Indian River Lagoon to the west by Haulover Canal, which was constructed in 1887 to improve navigation through the Indian River Lagoon system (Walters and others, 2001). Numerous natural and spoil islands, forming many constricting channels, are located in the northern 15 mi of the lagoon.

Surface-water drainage into Mosquito Lagoon and tidal exchange between the estuary and the Atlantic Ocean are limited. There are no major streams that discharge into the lagoon. Freshwater inflow primarily is from direct surface runoff, ground-water inflow, and discharge from numerous small canals (Steward and others, 1994). Treated wastewater has been discharged into Mosquito Lagoon from facilities in New Smyrna Beach and Edgewater. The discharge of treated wastewater from these facilities was reduced in the late 1990s. Currently (2006), about 70 percent of the treated wastewater from the New Smyrna Beach facility and about 80 percent of the treated wastewater from the Edgewater facility are disposed through reuse distribution systems (Utilities Commission of New Smyrna Beach, 2006; City of Edgewater, 2006). Reuse distribution systems provide treated wastewater to irrigate lawns or crops. Mosquito Lagoon generally exchanges water with the Atlantic Ocean through the Ponce de Leon Inlet two times each day due to the semi-diurnal tides (Walter and others, 2001). The excursion distance of ocean water into the lagoon, however, only extends to a point between Edgewater and Oak Hill due to the large number of islands in the northern part of the estuary, the estuary's shallow depth, and its long, narrow shape (Walters and others, 2001). Wind-driven currents are considered to be the only substantial force capable of circulating water through Mosquito Lagoon (Steward and others, 1994; Walters and others, 2001; Sigua and Tweedale, 2004).

Seagrass and other submerged aquatic vegetation in Mosquito Lagoon are important for the health of the estuarine ecosystem. Seagrass beds serve as nursery habitats for fish and benthic invertebrates and act as sediment traps by slowing down currents and by removing smaller particulates from suspension in the water column (Zieman, 1982; Virnstein and others, 1983). Seagrass coverage in the Indian River Lagoon system, including Mosquito Lagoon, is routinely monitored by the St. Johns River Water Management District (SJRWMD). In 1999, there were about 16,400 acres of seagrasses in Mosquito Lagoon. Seagrass coverage has decreased about 20 percent in Mosquito Lagoon since 1943 (Steward and others, 2003). Most of this decrease has occurred in the northern part of the estuary. In 1999, there were 51 acres of seagrass in the northernmost transect of Mosquito Lagoon (Steward and others, 2003). This change represents a 94 percent loss since 1943. Reductions in seagrass coverage have been less in the southern part of the estuary. In 1999, about 13,000 acres of seagrasses were measured in this part of Mosquito Lagoon, representing about a 20 percent reduction in coverage since 1943 (Steward and others, 2003).

About 15 percent of the annual harvest of commercial fish and shellfish in the United States comes from the Indian River Lagoon system, including Mosquito Lagoon (Walters and others, 2001). From 1987 to 1997, the number of commercial shellfish harvesting permits more than doubled from 45 to 99, and 12 clam-farming operations were in place as of 2000 (Walters and others, 2001). This increase in commercial harvesting and in aquaculture was attributed by Walters and others (2001) to the 1994 State law which banned gill-net use in the Indian River Lagoon system. Commercial shellfish harvesting is allowed within CANA under a provision of the Park's enabling legislation which states that harvesting will be permitted in accordance with State law. Park visitors also harvest shellfish; however, the amount of recreational fishing in Mosquito Lagoon has not been adequately monitored (Walters and others, 2001).

Shellfish can concentrate bacteria and viruses that are present in the water up to 100 times, thus posing a potential health risk to humans, who may consume these organisms either raw or partially cooked. Typhoid, hepatitis, and salmonellosis are some of the diseases that may be transmitted to humans through shellfish consumption. To protect consumers from shellfish-related illnesses, the National Shellfish Sanitation Program has set bacteriological standards for shellfish-growing waters. The geometric mean of fecal coliform must be less than 14 MPN/100 mL, and not more than 10 percent of water samples can exceed a level of 43 MPN/100 mL in areas where shellfish are harvested and directly marketed to the public.

The State of Florida regulates areas where shellfish are grown and harvested to protect consumers from shellfish-related illnesses. Shellfish harvesting areas within Mosquito Lagoon were classified by the State of Florida in 2000 as Approved, Conditionally Approved, Conditionally Restricted, or Prohibited (fig. 2). Approved shellfish harvesting areas usually are open to shellfish harvesting at all times and only temporarily closed under extraordinary circumstances, such as red tides, hurricanes, or sewage spills. Conditionally approved areas are periodically closed to shellfish harvesting based on the likelihood of contamination events. Controlled purification of shellfish is allowed in conditionally restricted areas by special permit. Shellfishing activities in conditionally restricted areas may be temporarily suspended based on pollution events. Most of the southern one-third of the lagoon was classified as approved. Conditionally restricted and prohibited areas are located in the northern part. Conditionally approved areas were further classified as Conditionally Approved Zone 1 (CAZ1) and Conditionally Approved Zone 2 (CAZ2).

Areas classified as CAZ1 are closed when the 2-day cumulative rainfall at the wastewater treatment facility in Edgewater exceeds 1.15 in., and areas classified as CAZ2 are closed when the 2-day cumulative rainfall exceeds 4.03 in. These rainfall limits were calculated based on regression equations developed by the State of Florida, which relate fecal coliform levels to rainfall amounts. Shellfish harvesting areas are reopened when fecal coliform bacteria levels in the water are within water-quality standards and bacteria levels in the shellfish have returned to background levels (Browning, 2000).

Two principal aquifer systems, the surficial aquifer system and the Floridan aquifer system, underlie the Mosquito Lagoon Basin. The surficial aquifer system is the uppermost water-bearing unit, and consists of sand, shell beds, silt, clay, and indurated shell or coquina of Pliocene to Quaternary age. The Floridan aquifer system consists of limestone and dolomite rocks of Eocene and Miocene age and is the primary source of potable water in the basin (Toth, 1988). A confining unit composed of clays of Miocene age separates the surficial aquifer system from the Floridan aquifer system (Toth, 1988). The depth to the top of the Floridan aquifer system ranges from about 100 to 200 ft below NGVD 1929 within the basin (Toth, 1988) and is deeper toward the south. The Floridan aquifer system is further subdivided into two highly transmissive zones, the Upper Floridan aquifer and Lower Floridan aquifer, which are separated by a less permeable middle semiconfining unit. The Mosquito Lagoon Basin is considered to be a discharge area for the Floridan aquifer system (Toth, 1988) because the confining unit between the surficial aquifer system and Floridan aquifer system is thin or absent in the basin (Toth, 1988). This increases the likelihood for vertical leakage or movement of water from the Floridan aquifer system to the surficial aquifer system and ultimately to the Mosquito Lagoon Basin.

Three soil orders—entisols, histosols, and spodosols—generally overlie the surficial aquifer system within the Mosquito Lagoon Basin (fig. 3). Entisols are mineral soils with little or no soil profile development, histosols are organic soils that develop in a water-saturated environment, and spodosols are mineral soils that have a subsurface horizon with an accumulation of organic matter and oxides of aluminum, with or without iron oxides. Entisols generally are concentrated on the barrier islands and along the western shore of the Mosquito Lagoon Basin. Histosols generally are concentrated on the natural and constructed islands in the northern part of the Mosquito Lagoon Basin and also are present on parts of the shoreline. Spodosols generally are in the western part of the basin. The drainage characteristics of the soil orders covering the basin have been classified by the U.S. Department of Agriculture (1991). The entisol soils generally are classified as well to excessively drained. In contrast, the spodosols and histosols soils are classified as poorly to very-poorly drained.

Several studies have quantified the amount of ground water discharging into Mosquito Lagoon and neighboring areas. The amount of ground water discharged into the lagoon was estimated using a ground-water flow model (Tibbals, 1990) and seepage meters (Belanger and others, 1997). There was a large discrepancy between the results reported from those studies. Tibbals (1990) reported that 2.2 ft^3/s of water discharged from the Floridan aquifer system into Mosquito Lagoon. Belanger and others (1997) reported that ground-water flow into Mosquito Lagoon ranged from about 0.01 to 0.04 $(gal/ft^2)/hr$, which corresponds to discharges from 750 to 3,000 ft^3/s. Similar discrepancies between measured and simulated ground-water discharges into the Indian River Lagoon were reported by Lee (1977), Belanger and Walker (1990), and Pandit and El-Khazen (1990). The rate and sources of ground-water discharge to the Indian River Lagoon system were further studied using various techniques to resolve the difference between reported ground-water discharge rates (Martin and others, 2002; Martin and others, 2004; and Cable and others, 2004). Results from these studies indicated that about 1 to 5 percent of the water seeping into the Indian River Lagoon from the sediments originated from the ground-water system, and most of the water seeping into the Indian River Lagoon likely was water that had recirculated into the sediments.

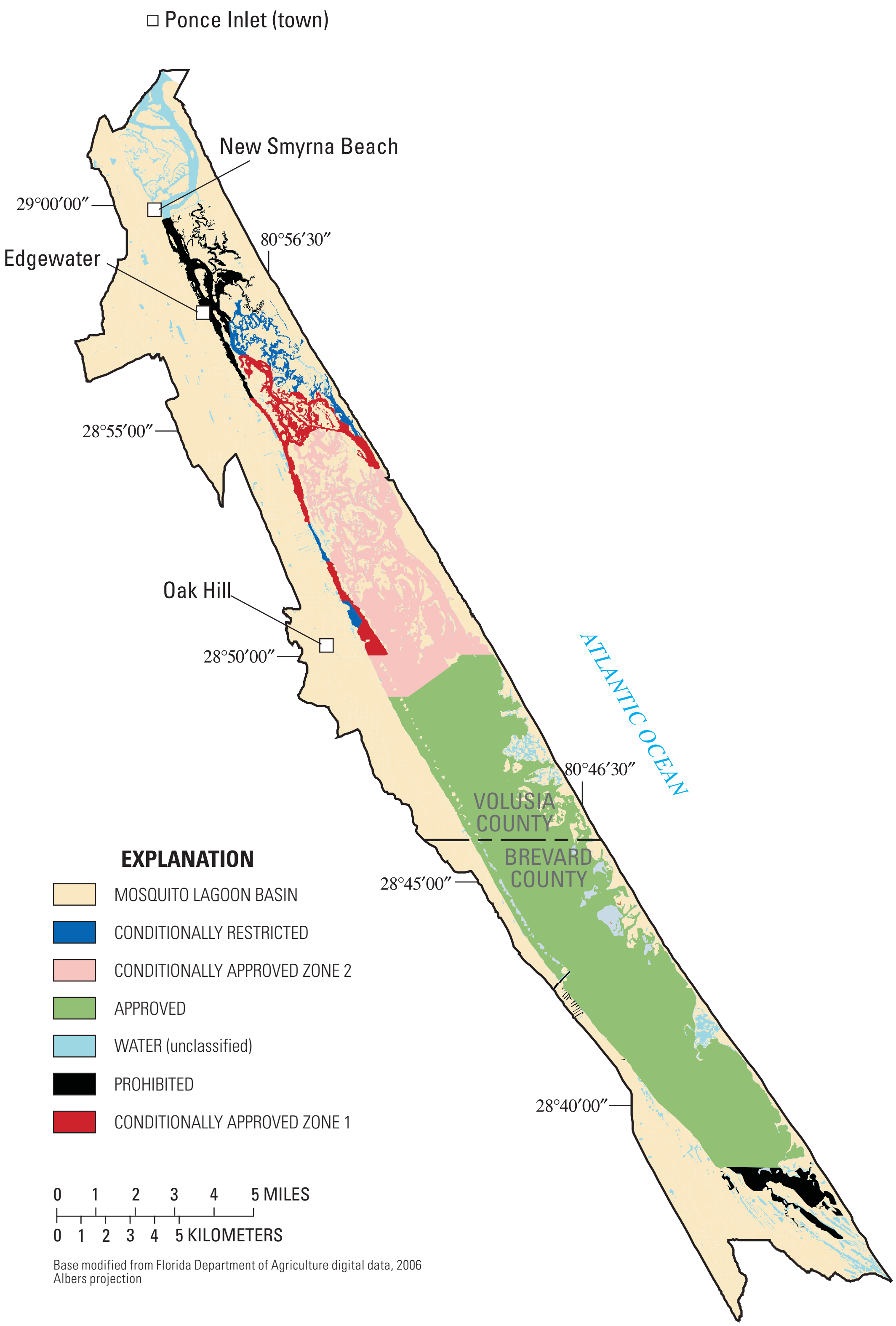

Figure 2. Classified shell fishing areas in the Mosquito Lagoon Basin (Jackie Harrell, Florida Department of Agriculture and Consumer Services, written commun., 2006).

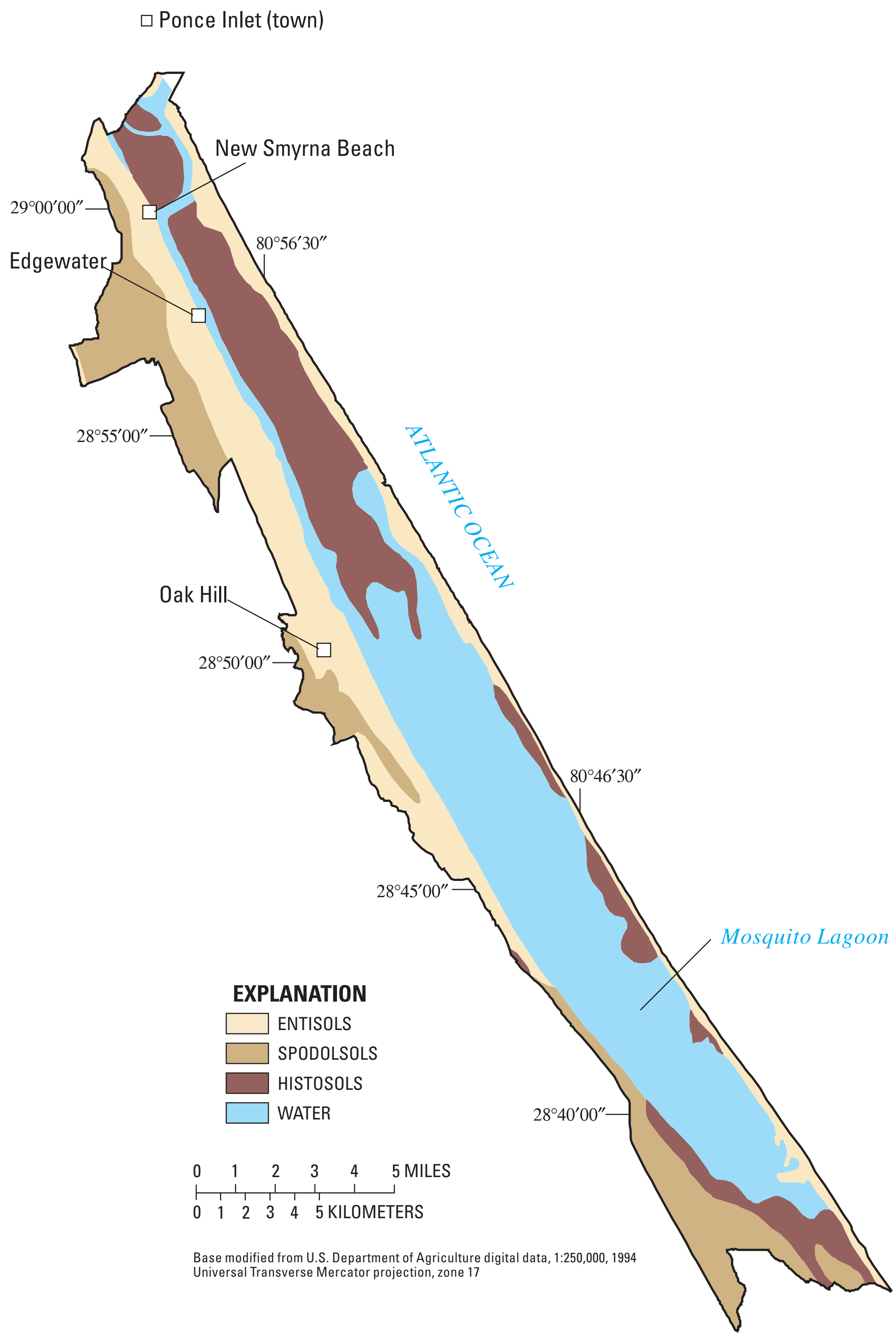

Figure 3. Generalized soil orders in the Mosquito Lagoon Basin.

In 2000, wetlands, nonforested upland areas, forested upland areas, and urban areas comprised about 95 percent of the Mosquito Lagoon Basin's land surface (fig. 4). Wetlands covered 42 percent of the terrestrial parts of the basin, and generally were located on the barrier islands, on islands in the northern part of the basin, and in the southern part of the basin. Forested and nonforested uplands and urban areas encompassed about 31 and 22 percent of the terrestrial parts of the basin, respectively. Upland areas generally were located along the western shore of the basin, and urban land use was concentrated in the cities of New Smyrna Beach, Edgewater, and Oak Hill, and along the northern barrier islands.

The human population of the Mosquito Lagoon Basin has increased over time. From 1990 to 2004, the populations of the largest four towns (New Smyrna Beach, Edgewater, Oak Hill, and Ponce Inlet) increased an average of about 36 percent (table 1). The populations of Oak Hill and Ponce Inlet have increased at the greatest rates—about 50 percent in each town.

Many residences in the Mosquito Lagoon Basin rely on onsite-sewage disposal systems (OSDS) for domestic wastewater treatment and disposal. Most of New Smyrna Beach, Edgewater, and the communities on the barrier islands use centralized sewerage systems for wastewater treatment (Walters and others, 2001; Steward and others, 2003); however, all areas south of Edgewater (fig. 4) rely on OSDS for wastewater treatment. The Oak Hill area was identified as having the largest number of OSDS in the basin (Browning, 2000). Most of these systems were reported by Browning (2000) as being installed near the water table in soils severely limited for disposal of domestic waste in drainfields. Twenty-four areas in the Mosquito Lagoon Basin from New Smyrna Beach to Oak Hill were evaluated by the Volusia County Health Department (1999) to determine whether the communities should be placed on a centralized sewerage system. About 65 percent of these areas were recommended for placement on a centralized sewerage system, and six of the areas were strongly recommended for placement.

Methods

Water-quality data compiled for this report were obtained from the U.S. Environmental Protection Agency's STORET data system, USGS National Water Information System, or from other organizations collecting the data. The STORET system was used to obtain data from the Florida Department of Environmental Protection (FDEP), Brevard County, and Volusia County Environmental Health Laboratory (hereinafter referred to as Volusia County). All other data were obtained from the Florida Department of Agriculture and Consumer Services (FDACS), Indian River Lagoon Water Quality Monitoring Network, National Atmospheric Deposition Program/National Trends Network (NADP/NTN), National Atmospheric Deposition Program/Mercury Deposition Network (NADP/MDN), Marine Resources Council of East-Central Florida (Marine Resources Council), and National Aeronautics and Space Administration (NASA).

Data were analyzed to describe recent conditions in the Mosquito Lagoon Basin, when sufficient data were available. Most surface-water-quality data analysis focused on the 1999-2003 period, except for the pesticide, polychlorinated biphenyl (PCB), and trace element data, because this period represents recent conditions in the basin, and the most information on method reporting or detection limits was available for this period. Information on method reporting or detection limits is necessary to properly interpret censored (below the reporting or detection limit) water-quality data (Helsel and Cohn, 1988; Helsel, 1990, 2005a, 2005b). Pesticide, PCB, and trace element data in surface water generally were not reported from 1999 to 2003, so the entire period of record was analyzed for these data which primarily were collected in the early 1990s. The data on ground-water quality, pesticide, PCB, and trace element concentrations in surface water were more limited compared to the other analytes. Ground-water-quality data were collected periodically from 1954 to 2002.

Data from two sources were recensored using the lowest quantification limit each agency denoted in its data prior to statistical analysis. Some of these data required recensoring because machine readings, indicated by small negative values or extremely small positive values, were reported. Some investigators analyze machine readings, such as those using basic statistical techniques; however, newer statistical techniques have been developed to analyze data near method reporting limits (Helsel, 2005b).

It was unclear whether data from some sources were censored at a method detection or quantification limit because selected concentrations were reported only as "less than the value given." For this reason, censoring limits will not be differentiated as "method detection limits" or "practical quantification limits" throughout the rest of this report.

Censoring limits associated with selected surface-water-quality constituents are listed in table 2. Reporting limits associated with data obtained from NASA varied in some instances by a factor of 10 or more due to the analytical method or laboratory used to analyze the water samples. The Marine Resources Council only reported physical property values that were not censored. Reporting limits associated with fecal coliform, trace element, and trace organics data are discussed later in this report. It was beyond the scope of this study to assess the accuracy of the reporting limits used by each agency.

The presence of censored water-quality data was expected to have little effect on interpretations of the chlorophyll-*a*, major ion, total organic plus ammonia nitrogen, and total suspended solids data because only a small percentage (less than 16 percent) of these data were less than the censoring limits, and less than 25 percent of the values were within twice the censoring limit. Several analytes, such as ammonia nitrogen, nitrate nitrogen, orthophosphate, total phosphorus, and water color, had a larger percentage of censored values. About 40 to 50 percent of these values were less than the censoring limit.

Data were analyzed using several statistical and graphical techniques. Constituent concentrations were described using summary statistics. The minimum and maximum values were substantially outside the typical range for some constituents.

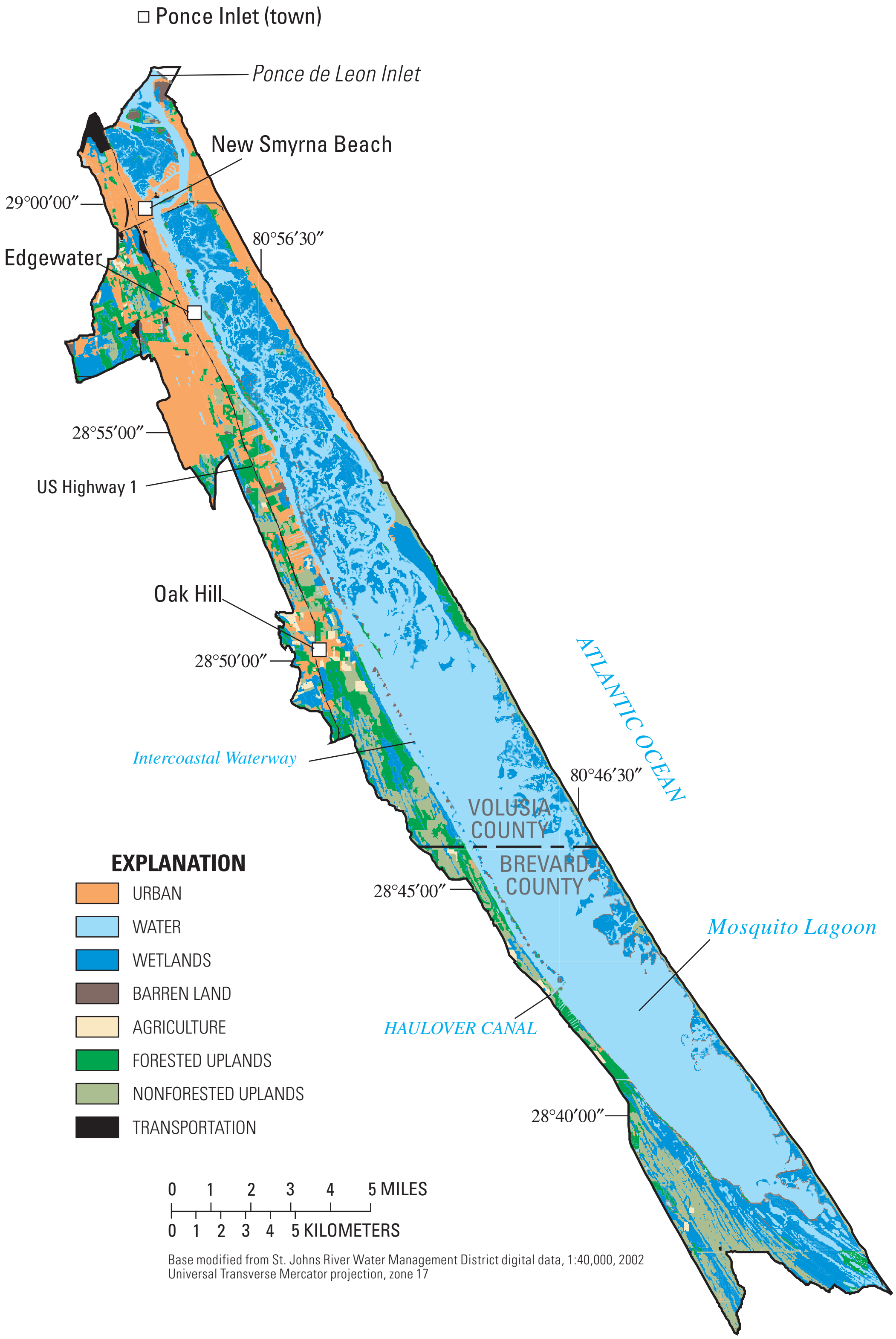

Figure 4. Generalized land use and land cover in the Mosquito Lagoon Basin, 2000.

The 10th, 90th, and 99th percentile values were reported at times in addition to the minimum and maximum for selected surface-water constituents to aid the reader in understanding the typical ranges in reported constituent values. These outlying values may have been in error. It was impossible, given the timeframe of this study, to investigate the causes for each outlying value in detail. Summary statistics with censored water-quality data were computed according to Helsel and Cohn (1988). The predominant ground-water type was graphed using trilinear diagrams. Spatial and seasonal variations in water-quality constituent values among sites were graphed using boxplots. Four periods (January-March, April-June, July-September, and October-December) were used to analyze seasonal variations in surface-water-quality data because a quarterly sampling frequency was the most common sampling frequency among the networks. The multiple-stage Kruskal-Wallis test (Helsel and Hirsch, 2002) was used to identify significant spatial and seasonal variations in surface-water-quality constituent values. The Wilcoxon rank-sum test (Helsel and Hirsch, 2002) was used to identify significant differences in constituent concentrations between the surficial aquifer system and Upper Floridan aquifer.

Acknowledgments

The author acknowledges John Stiner from the National Park Service for supporting this study. The author also acknowledges assistance from Wendy Tweedale of the St. Johns River Water Management District for providing water-quality data and information on method detection limits. Additionally, the author wishes to thank Gerald Rosebery from the Marine Resources Council for providing water-quality data from the Indian River LagoonWatch Program, and William Browning of the Florida Department of Agriculture and Consumer Services for providing bacteria data from Mosquito Lagoon and reports summarizing shellfish harvesting area closure regulations.

Table 1. Population of areas in the Mosquito Lagoon Basin in 1990, 2000, and 2004.

[Source of data: U.S. Census Bureau, 2005]

City or town	1990	2000	2004 (estimated)	Population increase from 1990-2000, percent
New Smyrna Beach	16,543	20,048	21,464	21.2
Edgewater	15,337	18,668	20,721	21.7
Oak Hill	917	1,378	1,454	50.3
Ponce Inlet	1,704	2,513	3,178	47.4
Total	34,501	42,607	46,817	35.7

Monitoring Efforts in the Mosquito Lagoon Basin

Data documenting the quality of surface waters, ground water, and the atmospheric deposition in the vicinity of the basin have been collected by a private agency (Marine Resources Council) and several Federal, State, and local agencies, including Brevard County, Florida Department of Agriculture and Consumer Services (FDACS), FDEP, NASA, National Park Service, SJRWMD, USGS, and Volusia County. Most monitoring focused on assessing water-quality conditions in Mosquito Lagoon, in terms of the number of sites monitored. About 190 surface-water, ground-water, and atmospheric deposition sites were monitored. About two-thirds of these sites were monitored to determine the surface-water quality of Mosquito Lagoon, and most of the remaining sites were used to determine ground-water quality. The quality of atmospheric deposition was monitored at four sites.

Surface-Water Quality Monitoring

Monitoring of water quality in Mosquito Lagoon began in 1970, with most data collection having occurred since the mid-1980s. The largest monitoring programs that were conducted to assess the water quality of Mosquito Lagoon, in terms of the total sites sampled and the period of record of data collection, were operated by the FDACS, SJRWMD, and Volusia County. Other agencies or organizations operate smaller networks compared to these or may collect data only on a periodic basis. A complete listing of the constituents monitored by these entities is given in table 3.

Table 2. Censoring limits for surface-water quality data compiled from selected agencies.

[IRLQWMN, Indian River Lagoon Water Quality Monitoring Network; NASA, National Aeronautics and Space Administration; constituents shown in milligrams per liter, except for chlorophyll-*a* which is shown in micrograms per liter and water color which is shown in platinum-cobalt units]

Constituent	IRLQWMN	NASA	Volusia County
Ammonia nitrogen	Not analyzed	0.02-0.2	0.015L
Chlorophyll-*a*	1	.5-1	1
Nitrite plus nitrate nitrogen	.01	.02	.01
Organic plus ammonia nitrogen	.1	.1-2.5[1]	.4
Total phosphorus	.01	.02-.1[2]	.01
Total suspended solids	5	4-10[2]	5
Water color	10	5	10

[1]One value censored at 2.5 mg/L.

[2]No censored data for this constituent.

Table 3. List of constituents monitored in water, bottom sediments, suspended sediments, and fish in Mosquito Lagoon.

Physical properties	Pesticides, pesticide degradates, and other trace organic compounds
Acidity, as $CaCO_3$	2,4,5-T
Alkalinity, as $CaCO_3$	2,4,5-TP
Dissolved oxygen	2,4-D
Oxidation reduction potential	4,4-DDD
pH	4,4-DDE
Salinity	4,4-DDT
Salinity, bottom	Aldrin
Secchi disk depth	Alpha hexachlorobenzene
Specific conductance	Beta hexachlorobenzene
Temperature, air	Chlordane
Temperature, water	Chlordane (technical mix & metabolites)
Total dissolved solids	DDT
True color	Delta benzene hexachloride
Turbidity	Dieldrin
Nutrients	Endosulfan
Ammonia as NH_3	Endosulfan I
Ammonia, unionized	Endosulfan II
Ammonia as nitrogen	Endosulfan sulfate
Organic plus ammonia nitrogen	Endrin
Nitrate nitrogen	Endrin aldehyde
Nitrite nitrogen	Gamma benzene hexachloride (lindane)
Organic nitrogen	Heptachlor
Orthophosphate	Heptachlor epoxide
Phosphate	Methoxychlor
Phosphorus	p,p′ DDD
Major inorganic constituents	p,p′ DDE
Calcium	PCB 1016
Chloride	PCB 1221
Fluoride	PCB 1232
Hardness (calcium, magnesium)	PCB 1242
Magnesium	PCB 1248
Potassium	PCB 1254
Silica	PCB 1260
Silicon	PCBS
Sodium	Phenolic compounds
Sulfate	Toxaphene
Biological properties	**Trace elements**
Chlorophyll-*a*	Aluminum
Chlorophyll-*b*	Antimony
Chlorophyll-*c*	Arsenic
Enterococcus group bacteria	Barium
Fecal coliform	Beryllium
Pheophytin *a*	Bismuth
Total coliform	Boron
Suspended solids	Cadmium
Fixed solids	Chromium
Nonvolatile suspended solids	Copper
Solids, volatile on ignition	Iron
Total residue (TSS+TDS)	Lead
Total suspended solids (TSS)	Manganese
Volatile suspended solids	Mercury
Biochemical/chemical oxygen demand	Molybdenum
Biochemical oxygen demand	Nickel
Biochemical oxygen demand, 11 days at 20 °C	Selenium
Biochemical oxygen demand, 12 days at 20 °C	Silver
Biochemical oxygen demand, 19 days at 20 °C	Thallium
Biochemical oxygen demand, 20 days at 20 °C	Tin
Biochemical oxygen demand, 25 days at 20 °C	Titanium
Biochemical oxygen demand, 28 days at 20 °C	Zinc
Biochemical Oxygen demand, 33 days at 20 °C	**Organic carbon/grease and oil**
Biochemical oxygen demand, 5 days at 20 °C	Organic carbon
Chemical oxygen demand	Grease and oil

The FDACS shellfish environmental assessment section has monitored sites in Mosquito Lagoon, primarily to determine bacteria levels. From 1995 to 2004, 43 sites were monitored. Water samples were analyzed to determine fecal coliform and enterococcus group bacteria counts, turbidity, and other physical properties (dissolved oxygen concentration, pH, salinity, and water temperature).

The SJRWMD monitored 24 sites in Mosquito Lagoon. Most of these sites (22) were sampled as part of the Indian River Lagoon Water Quality Monitoring Network—a coordinated effort between the SJRWMD, Volusia County, Brevard County, and NASA. This network has been coordinated by the SJRWMD since 1988 to: (1) characterize water quality in the Indian River Lagoon, (2) identify water-quality problem areas, (3) measure the effectiveness of management objectives and actions, (4) provide current information to reformulate management plans, and (5) provide accountability to the public by relating progress toward restoration and protection of the Indian River Lagoon (Sigua and others, 1996). Sites originally were sampled as part of this network to measure physical properties (water color, specific conductance, pH, salinity, dissolved oxygen, turbidity), nutrients (ammonia, nitrite plus nitrate nitrogen, phosphorus, organic plus ammonia nitrogen, and orthophosphate), chlorophyll-*a*, and suspended sediment in water. In 1996, this sampling network was modified to: (1) provide answers to specific questions related to the long-term management of seagrass and water quality in the Indian River Lagoon, (2) increase the statistical power of data collected, (3) increase the effectiveness of staff and laboratory resources, and (4) collect complimentary data for development of a hydrodynamic and water-quality model of the Indian River Lagoon system (Sigua and others, 1996). These modifications resulted in a substantial decrease in the number of fixed sampling sites (from 22 to 4) in Mosquito Lagoon, and analysis of additional water-quality constituents, including the inorganic and organic fractions of suspended solids in water.

Volusia County monitored water quality at 21 sites in Mosquito Lagoon from 1988 to 1999. Some of this monitoring was done in cooperation with the Indian River Lagoon Water Quality Monitoring Network, and the rest was done as part of an assessment of water bodies in the county. Physical properties (dissolved oxygen, pH, salinity, specific conductance, water color, and turbidity) were measured and water samples were analyzed for fecal indicator bacteria counts, nutrients (ammonia, nitrite plus nitrate nitrogen, organic plus ammonia nitrogen, orthophosphate, and phosphorus), chlorophyll-*a*, suspended sediment, and organic carbon. The sampling network for Volusia County was modified in 2000, with the number of sites sampled reduced to 13 and the sampling frequency reduced from monthly to quarterly.

Brevard County monitored two sites in Mosquito Lagoon from 1979 to 1995. Monitoring at these sites was done as part of the Indian River Lagoon Water Quality Monitoring Network from 1987 to 1995. The constituent groups monitored include physical properties (salinity, turbidity, pH, specific conductance, water temperature, and water color), chlorophyll-*a* and pheophytin-*a*, nutrients (organic plus ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, phosphorus, and orthophosphate), biochemical oxygen demand, and fecal coliform bacteria counts.

The FDEP periodically monitored 10 sites in Mosquito Lagoon from 1970 to 1998. Most of these sites were sampled to determine water-quality conditions and the quality of the bottom sediments. Major constituent groups that were analyzed included physical properties (alkalinity, dissolved oxygen concentration, pH, salinity, specific conductance, water color, and turbidity), nutrients (ammonia nitrogen, organic nitrogen, nitrate, nitrite, and orthophosphate), chlorophyll-*a*, fecal coliform bacteria, chloride, suspended solids, and trace elements (chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc).

The Marine Resources Council coordinated citizen volunteer sampling at 22 sites in Mosquito Lagoon from 1991 to 2003. Water samples were collected on a weekly basis to determine values of physical properties (dissolved oxygen concentration, pH, salinity, and water temperature). The purpose of this sampling program was to provide the regulating agencies with data of known quality to determine long-term and seasonal variations in constituent values. This program provides data from remote areas of the estuary, and augments the data collected by other agencies (Marine Resources Council of East Florida, 2003).

NASA monitored seven sites in Mosquito Lagoon from 1984 to 2002. One site was sampled as part of the Indian River Water Quality Monitoring Network from 1996-2003 and was previously sampled by Brevard County. At this site, physical properties (water color, specific conductance, pH, salinity, dissolved oxygen, turbidity) were measured and water samples were analyzed by the SJRWMD laboratory to determine concentrations of nutrients (nitrite plus nitrate nitrogen, total phosphorus, organic plus ammonia nitrogen, and orthophosphate), chlorophyll-*a*, organic carbon, pheophytin *a*, suspended sediment, and silica and fecal coliform counts in the water. The remaining six sites were sampled to assess the water quality of the southern part of Mosquito Lagoon. The length of monitoring varied among these sites. One site was sampled from 1984 to 2002, and five sites were sampled from 1991 to 1993. More constituents were measured at these sites compared to the site sampled as part of the Indian River Water Quality Monitoring Network. Physical properties (alkalinity, dissolved oxygen, pH, salinity, and turbidity) were measured and water samples were analyzed at several contract laboratories to determine concentrations of nutrients, chlorophyll-*a*, major ions, pesticides, suspended solids, trace elements, and fecal coliform bacteria counts.

The NPS monitored 19 sites in Mosquito Lagoon from 1991 to 1993 to determine the quality of the water, bottom sediment, and suspended sediments and constituents present in fish tissues. Physical properties (dissolved oxygen, oxidation-reduction potential, and water color) were measured and samples were analyzed to determine concentrations of nutrients, chlorophyll-*a*, major ions, pesticides and other trace organics, trace elements, and fecal coliform counts.

The USGS monitoring activities in Mosquito Lagoon were limited to measuring physical properties (dissolved oxygen concentration, pH, specific conductance, and water temperature) in Haulover Canal. Specific conductance and water temperature were continuously monitored at this location from 1998 to 2003. Short-term continuous monitoring of dissolved oxygen concentration was done in 1998-99.

As evidenced herein, most of the monitoring efforts of Mosquito Lagoon have focused on assessing conditions in the water column. Less than 6 percent of the sites monitored were sampled to assess contaminants in the fish inhabiting the water, pigments in the periphyton, or to determine the quality of the bottom sediments, dry deposition, or suspended sediments.

Ground-Water Quality Monitoring

The FDEP, SJRWMD, and USGS monitored 55 wells to determine ground-water quality in the Mosquito Lagoon Basin (figs. 5a-b). Fifty-three wells were located in the northern part of the basin, and two were located in the southern part. The USGS monitored ground-water quality from 1954 to 1987 in 43 wells, which ranged from 14 to 992 ft deep, where well depth was reported. Water samples were collected and analyzed to determine physical properties (acid neutralizing capacity, pH, specific conductance, turbidity, and water color), nutrients (ammonia, nitrite plus nitrate nitrogen, organic plus ammonia nitrogen, orthophosphate, and phosphorus), major ions (chloride, fluoride, magnesium, potassium, sodium, and sulfate), pesticides, trace elements, and volatile organic compounds. The SJRWMD monitored ground-water quality from 1987 to 2004 in 12 wells, which ranged from 30 to 998 ft deep. The water samples were collected and analyzed for physical properties (alkalinity, pH, and specific conductance), nutrients (ammonia, nitrite plus nitrate nitrogen, organic plus ammonia nitrogen, orthophosphate, and phosphorus), major ions (calcium, chloride, fluoride, magnesium, potassium, sodium, and sulfate), organic carbon, trace elements, and turbidity. The FDEP monitored ground-water quality in 1993 and 1996 in four wells. These wells also were sampled by the SJRWMD from 1987 to 2004. These wells ranged from 30 to 60 ft deep, and water samples were collected and analyzed for physical properties (dissolved oxygen, pH, and specific conductance), nutrients (ammonia, organic plus ammonia nitrogen, orthophosphate, and total phosphorus), major ions (calcium, chloride, fluoride, magnesium, potassium, sodium, and sulfate), organic carbon, and turbidity.

Atmospheric Deposition Monitoring

The quality of atmospheric deposition was monitored at four sites (A1 to A4) in the vicinity of the Mosquito Lagoon Basin (fig. 1) by the NADP/NTN, NADP/MDN, and SJRWMD from 1983 to 2007 (table 4). Data spanning the longest period of record (1983-2007) were available at site A4, which is about 10 mi south of Mosquito Lagoon. This site was sampled as part of the NADP/NTN. Wet deposition samples were collected weekly at this site (provided a sufficient volume of water was available) and analyzed to determine physical properties (pH and specific conductance) and concentrations of major ions (calcium, magnesium, sodium, potassium, chloride, and sulfate), nitrate, and ammonium. Data collection at the other three sites began in 2003. Sites A1 and A2, located in the northern part of the basin near the town of Ponce Inlet, were monitored by the Indian River Water Quality Monitoring Network. Site A1 was monitored in 2003, and site A2 was monitored from 2003 to 2007. Wet deposition samples generally were collected weekly at sites A1 and A2. Dry deposition samples generally were collected monthly at site A2. Samples from both sites were analyzed to determine physical properties (pH and specific conductance), alkalinity values, and concentrations of major ions (calcium, chloride, magnesium, potassium, sodium, and sulfate) and nutrients (ammonium nitrogen, nitrate nitrogen, total organic plus ammonia nitrogen, orthophosphate, and total phosphorus). Trace elements (aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, nickel, selenium, silver, strontium, and zinc) generally only were monitored at site A2. Site A3, located about 30 mi southwest of Mosquito Lagoon, was monitored by the NADP/MDN from 2003 to 2007 to determine the mercury concentration in wet deposition.

Table 4. Atmospheric deposition monitoring sites in the vicinity of the Mosquito Lagoon Basin, 1983-2007.

[Site locations are shown in figure 1. SJRWMD, St. Johns River Water Management District; NADP, National Atmospheric Deposition Program; MDN, Mercury Deposition Network; NTN, National Trends Network; USCG, U.S. Coast Guard]

Site identifier	Site description	Latitude	Longitude	Agency conducting monitoring
A1	Ponce Inlet USCG Station	29° 03′ 53″	80° 54′ 54″	SJRWMD
A2	Ponce Inlet USCG Station (northwest corner of property)	29° 03′ 55″	80° 54′ 58″	SJRWMD
A3	Orange County, Florida	28° 35′ 33″	81° 11′ 25″	NADP/MDN
A4	Kennedy Space Center	28° 32′ 34″	80° 38′ 38″	NADP/NTN

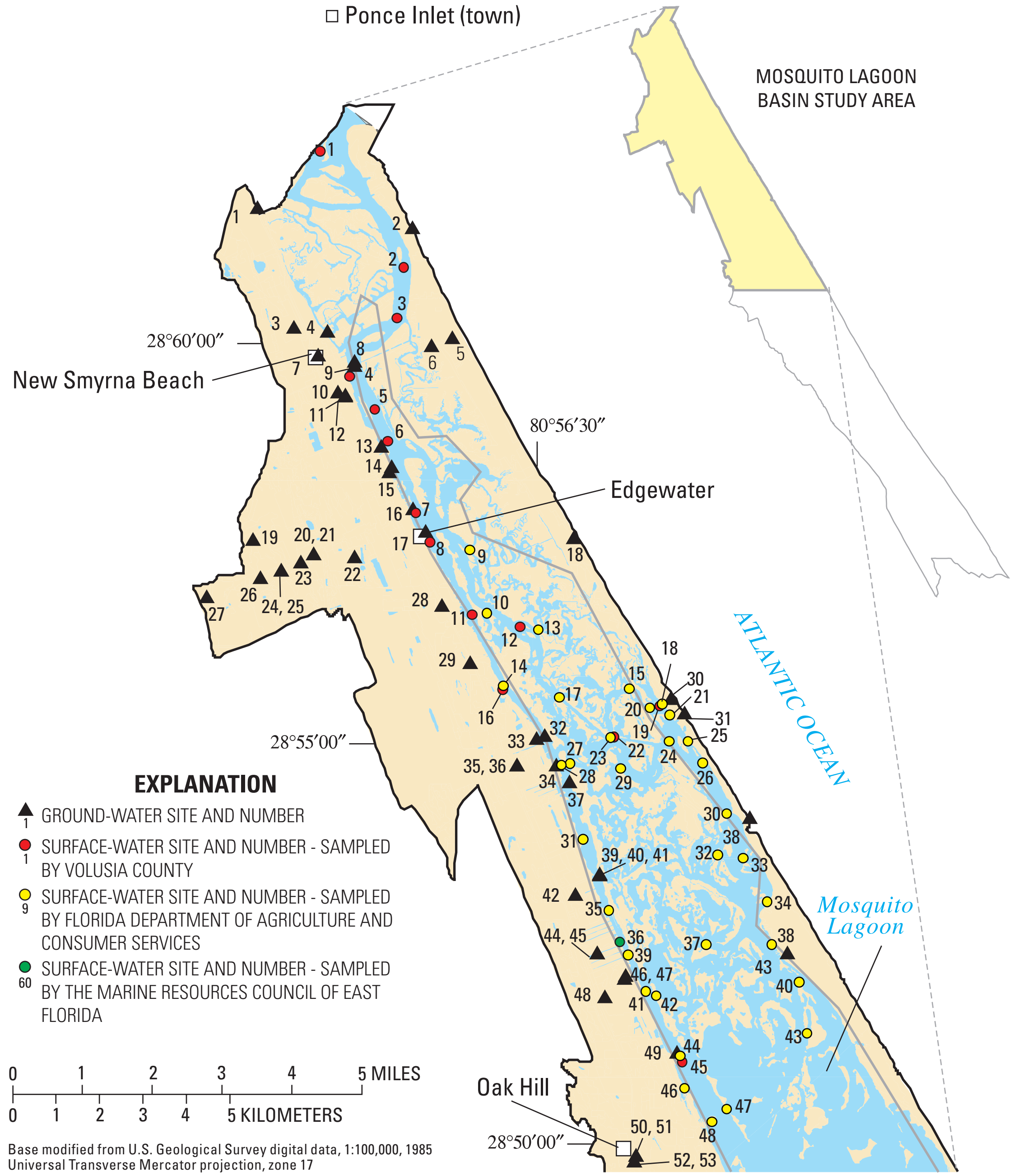

Figure 5a. Surface-water and ground-water sites sampled in the northern part of the Mosquito Lagoon Basin. Surface-water sites were sampled during 1999-2003. Ground water sites were sampled during 1954-2004.

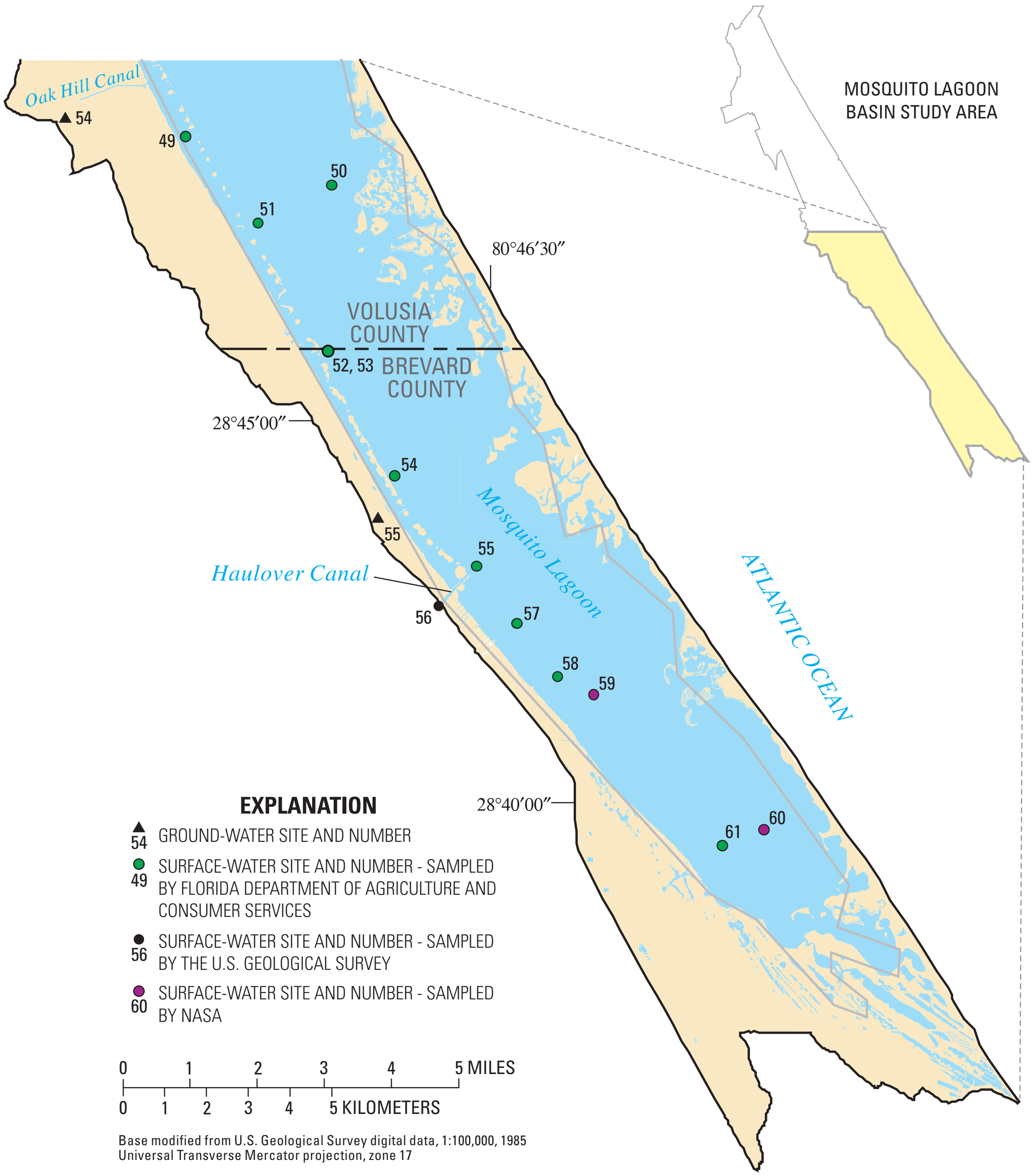

Figure 5b. Surface-water and ground-water sites sampled in the southern part of the Mosquito Lagoon Basin. Surface-water sites were sampled during 1999-2003. Ground water sites were sampled during 1954-2004.

Water-Quality and Atmospheric Deposition Conditions in the Mosquito Lagoon Basin

The subsequent sections describe surface- and ground-water quality conditions in the Mosquito Lagoon Basin. Also summarized herein is atmospheric deposition, which may be a substantial source of some contaminants to the Mosquito Lagoon Basin.

Surface-Water Quality

Water-quality conditions were assessed at 61 sites in Mosquito Lagoon from 1999 to 2003 (figs. 5a-b and table 5). The sites were monitored by the FDACS, Indian River Lagoon Water Quality Monitoring Network, Marine Resources Council, NASA, Volusia County, and the USGS. The major constituent groups that were measured include physical properties, fecal coliform and enterococcus group bacteria counts, and concentrations of nutrients and suspended solids. These constituent groups were not measured at all sites, and the total number of constituents measured at an individual site varied from about 5 to 45 constituents. The constituents measured at each site are listed in table 5. The surface-water data collection procedures used by the various agencies are described by Rantz (1982), Gately (1991), Steward and Higman (1991), U.S. Geological Survey (1997-2006), National Atmospheric Deposition Program (1999), and Marine Resources Council of East Florida (2004).

Knowledge of the quality of the data collected is important to properly interpret water-quality data, and documentation of the data quality often is conducted as part of water-quality assessments (Fitzgerald, 1997; Menheer and Brigham, 1997; Mueller, 1998; Martin and others, 1999). Most of the data used to determine water-quality conditions in Mosquito Lagoon from 1999-2003 were reported to be quality assured by the agency which collected the data (Gately, 1991; Sigua and others, 1996; Browning, 2000; Wagner and others, 2006; Marine Resources Council, 2007). The precision and bias of the data compiled were not reassessed due to the limited timeframe of the study.

Salinity, Dissolved Oxygen, and Water pH

Many estuarine resources are affected by the salinity of water, such as aquatic plants, benthic organisms, and fish (Alber and Flory, 2002; Pierson and others, 2002). Salinity values, dissolved oxygen, and water pH were measured at 61 sites in Mosquito Lagoon from 1999 to 2003 (figs. 5a-b and table 5). Most of these sites were located in the northern part of the lagoon, north of the town of Oak Hill. Reported salinity values in Mosquito Lagoon ranged from 0.4 to 47 ppt during this 5-year sampling period. The minimum reported value likely was an error since 99 percent of the reported values were greater than 22 ppt and a substantial amount of freshwater would be required to dilute Mosquito Lagoon water to less than 1 ppt salinity. Salinity values in Mosquito Lagoon had no statistically significant spatial variability. Spatial differences in salinity within the estuary were examined using only sites 2, 19, 45, and 59 (figs. 5a-b) due to the voluminous amount of data. These four sites were previously identified by Sigua and others (1996) as having differing water quality. There was no significant difference in salinity among these sites (p-value = 0.8186). Data from all 61 sites sampled from 1999 to 2003 were pooled to determine the general seasonal variation in concentrations in the lagoon. The seasonal distribution of salinity values may deviate from this general pattern in any given year due to differences in hydrologic conditions. In general, salinity values were significantly greater from April to June compared to all other times of the year and were significantly lower from October to December (fig. 6). The greater values from April to June likely were due to low precipitation combined with increased evaporation before the onset of the wet season. The lower values from October to December correspond to the end of the wet season in central Florida, and likely reflect dilution from increased precipitation.

Salinity variations resulting from Atlantic Ocean tides appeared to be small compared to the observed seasonal variations. Salinity data collected over a tidal cycle were available at sites 6, 19, 45, and 59 (figs. 5a-b and table 5). Tidal cycle data were collected once a month from January to June 1999. Data for the other physical properties discussed in this report were not available over a tidal cycle. Variations in salinity values associated with tides were examined at site 6, which was closest to the Ponce de Leon Inlet and where any tidal influence was expected to be the greatest. The maximum variation in salinity values associated with a tidal cycle ranged from 0.4 to 1.2 ppt, which was small compared to the general seasonal variations in values (fig. 6).

Dissolved oxygen concentrations varied spatially and seasonally in Mosquito Lagoon. Reported concentrations ranged from 1 to 14.8 mg/L; however, most concentrations (80 percent) ranged from 3.7 to 8.2 mg/L. About 15 percent of the reported concentrations were less than the 4.0-mg/L criterion set by the State of Florida for class II surface waters (Florida Department of Environmental Protection, 2004). Spatial variations in dissolved oxygen concentrations were tested with the same four sites used to assess spatial variations in salinity values, and data from all 61 sites sampled from 1999 to 2003 were pooled to determine the general seasonal variation. Dissolved oxygen concentrations were significantly greater at sites 2 and 59 compared to sites 19 and 45 (fig. 7). There also was a significant seasonal variation in concentrations. Concentrations were significantly greater from January to March and significantly lower from July to September, compared to other times of the year (fig. 8). These seasonal variations likely were due to variations in the solubility of oxygen in water (which is higher in cold water), because seasonal variations in concentrations corresponded with periods of low- and high-water temperatures in the lagoon.

Table 5. Surface-water sites in the Mosquito Lagoon Basin monitored by various Federal, State, and local agencies and a private agency from 1999-2003

[Site locations shown in figures 5a and 5b. FDACS, Florida Department of Agriculture and Consumer Services; ICWW, Intracoastal Waterway; NASA, National Aeronautics and Space Administration; SJRWMD, St. Johns River Water Management District; USGS, U.S. Geological Survey]

Site no.	Site description	Latitude	Longitude	Agency collecting data	Period of record	Approximate frequency of sample collection	Constituents/properties sampled and remarks
1	Ponce Inlet, center channel	28° 56′ 27″	80° 50′ 04″	Volusia County	1999-2003	Monthly (1999), quarterly (2000-01, 2003)	Ammonia nitrogen (only monitored from 2000-03), chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity
2	Mosquito Lagoon, at ICWW channel marker 26	29° 02′ 40″	80° 54′ 20″	SJRWMD, Volusia County	1988-2001, 2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity
3	Mosquito Lagoon, at ICWW channel marker 32	29° 02′ 02″	80° 54′ 26″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen, nitrite plus nitrate nitrogen, organic carbon, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, silica, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, volatile suspended solids, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
4	Mosquito Lagoon, south of south causeway, near stormwater	29° 01′ 18″	80° 55′ 07″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
5	Mosquito Lagoon, at ICWW channel marker 45	29° 00′ 53″	80° 54′ 45″	Marine Resources Council SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen, nitrite plus nitrate nitrogen, organic carbon, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, silica, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, volatile suspended solids, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values, and two to five samples were collected per month (1998-99).

Table 5. Surface-water sites in the Mosquito Lagoon Basin monitored by various Federal, State, and local agencies and a private agency from 1999-2003.—Continued

Site no.	Site description	Latitude	Longitude	Agency collecting data	Period of record	Approximate frequency of sample collection	Constituents/properties sampled and remarks
6	Mosquito Lagoon, south of ICWW channel marker 47	29° 00′ 29″	80° 54′ 34″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly, two times per month (1997-98), quarterly	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. Monthly sampling by the SJRWMD (1988-96, 1999-2003) and quarterly sampling by Volusia County (1999-2003). The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
7	Mosquito Lagoon, at ICWW channel marker 50	28° 59′ 35″	80° 54′ 10″	Marine Resources Council, SJRWMD, Volusia County,	1988-2003	Monthly (1988-99), quarterly (2000-03)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
8	Mosquito Lagoon, at ICWW channel marker 52	28° 59′ 13″	80° 53′ 58″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-03)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
9	Mouth of Potts Creek	28° 59′ 07″	80° 53′ 22″	FDACS	1998-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
10	Lease 727	28° 58′ 20″	80° 53′ 09″	FDACS	1988-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
11	Mosquito Lagoon, at ICWW CM 57	28° 58′ 18″	80° 53′ 22″	SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-03)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity
12	Mosquito Lagoon, just W. of Three Sisters Islands	28° 58′ 09″	80° 52′ 41″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, entercoccus group bacteria, fecal coliform group bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.

Table 5. Surface-water sites in the Mosquito Lagoon Basin monitored by various Federal, State, and local agencies and a private agency from 1999-2003.—Continued

Site no.	Site description	Latitude	Longitude	Agency collecting data	Period of record	Approximate frequency of sample collection	Constituents/properties sampled and remarks
13	East of Three Sisters Island	28° 58′ 07″	80° 52′ 25″	FDACS	1995-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
14	ICW marker 60	28° 57′ 24″	80° 52′ 55″	FDACS	1993-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
15	North area of Cedar Creek	28° 57′ 22″	80° 51′ 07″	FDACS	1988-2003	1-2 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
16	Mosquito Lagoon, at ICWW CM 60	28° 57′ 22″	80° 52′ 56″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
17	North end of Government Cut	28° 57′ 16″	80° 52′ 07″	FDACS	1990-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
18	North of station 62 at power lines	28° 57′ 11″	80° 50′ 39″	FDACS	1990-2004	1-2 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
19	Mosquito Lagoon, just E. of Cedar Island	28° 57′ 09″	80° 50′ 41″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly, two times per month (1997-98), quarterly	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, organic carbon, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, silica, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, volatile suspended solids, wind direction, wind velocity. Monthly sampling by the SJRWMD (1988-96, 1999-2003), and quarterly sampling by Volusia County (1999-2001, 2003). The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
20	Eastern mouth of Cedar Creek	28° 57′ 08″	80° 50′ 50″	FDACS	1990-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
21	Condissolved oxygenminiums north of J.B.'s	28° 57′ 02″	80° 50′ 32″	FDACS	1990-2004	1-2 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
22	Mosquito Lagoon, at Shipyard Canal and Cedar Creek	28° 56′ 46″	80° 51′ 20″	Marine Resources Council, SJRWMD, Volusia County	1988-2003	Monthly (1988-99), quarterly (2000-01, 2003)	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, fixed solids, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, pH, pheophytin-*a*, phosphorus, orthophosphate, salinity, secchi disk depth, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.

Table 5. Surface-water sites in the Mosquito Lagoon Basin monitored by various Federal, State, and local agencies and a private agency from 1999-2003.—Continued

Site no.	Site description	Latitude	Longitude	Agency collecting data	Period of record	Approximate frequency of sample collection	Constituents/properties sampled and remarks
23	Southern mouth of Cedar Creek and Government Cut	28° 56′ 46″	80° 51′ 22″	FDACS	1990-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
24	Turner's Flats, east of Government Cut	28° 56′ 43″	80° 50′ 33″	FDACS	1991-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
25	South of J.B.'s Restaurant	28° 56′ 43′	80° 50′ 17″	FDACS	1990-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
26	Last waterfront house south of J.B.'s	28° 56′ 27″	80° 50′ 04″	FDACS	1995-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
27	East of ICW marker 65, east side of island in Blue Hole Cut	28° 56′ 26″	80° 51′ 57″	FDACS	1995-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
28	ICW marker 65	28° 56′ 25″	80° 52′ 05″	FDACS	1992-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
29	Lease 1102	28° 56′ 22″	80° 50′ 42″	FDACS	1990-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
30	Turtle Mound, west shore	28° 55′ 48″	80° 49′ 44″	FDACS	1995-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
31	In ICW, at Boston Whaler plant	28° 55′ 29″	80° 51′ 47″	FDACS	1992-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
32	West side of leases 1121, 1124, 1125, 1126	28° 55′ 17″	80° 49′ 52″	FDACS	1990-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
33	Second cut southeast of Turtle Mound	28° 55′ 14″	80° 49′ 30″	FDACS	1990-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
34	Northeast docks in Eldora	28° 54′ 42″	80° 49′ 09″	FDACS	1990-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
35	ICW marker 71	28° 54′ 35″	80° 51′ 25″	FDACS	1995-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
36	MO8560, End of East Ariel Street, Oak Hill	28° 54′ 12″	80° 51′ 15″	Marine Resources Council	1999-2003	2-5 times per month	Dissolved oxygen, pH, salinity, secchi disk depth, water temperature
37	Lease 1085, Slippery Creek	28° 54′ 09″	80° 50′ 02″	FDACS	1990-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
38	Southernmost house in Eldora	28° 54′ 09″	80° 49′ 05″	FDACS	1995-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
39	In ICW, between markers 73 and 75	28° 54′ 02″	80° 51′ 08″	FDACS	1990-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
40	Castle Wind Cut, SE of Eldora	28° 53′ 41″ 28.8947	80° 48′ 42″ -80.81167	FDACS	1996-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity

Table 5. Surface-water sites in the Mosquito Lagoon Basin monitored by various Federal, State, and local agencies and a private agency from 1999-2003.—Continued

Site no.	Site description	Latitude	Longitude	Agency collecting data	Period of record	Approximate frequency of sample collection	Constituents/properties sampled and remarks
41	North of ICW marker 2, at south end of concrete bulkhead	28° 53′ 35″	80° 50′ 53″	FDACS	1995-2004	1-7 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
42	Between spoil islands, NE of ICW marker 2	28° 53′ 31″	80° 50′ 44″	FDACS	1990-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
43	Dead Mans Cove, SE of station 120	28° 53′ 02″	80° 48′ 35″	FDACS	1995-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
44	Southwest of ICW marker 7, Lopez lighthouse	28° 52′ 45″	80° 50′ 24″	FDACS	1995-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
45	Mosquito Lagoon at ICWW CM 7	28° 52′ 41″	80° 50′ 22″	Marine Resources Council, SJRWMD	1988-2003	Monthly	Ammonia nitrogen, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, enterococcus group bacteria, fecal coliform bacteria, organic plus ammonia nitrogen nitrogen, nitrite plus nitrate nitrogen, organic carbon, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, silica, specific conductance, water temperature, total coliform bacteria, total suspended solids, water color, turbidity, volatile suspended solids, wind direction, wind velocity. The Marine Resources Council sampled monthly (1991-92) to determine dissolved oxygen concentrations and salinity, secchi disk depth, pH, and water temperature values.
46	Dissolved oxygenuble outfall west of ICW marker 9	28° 52′ 21″	80° 50′ 20″	FDACS	1995-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
47	Between spoil islands, NE of ICW marker 10	28° 52′ 05″	80° 49′ 44″	FDACS	1995-2004	1-5 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
48	West of ICW marker 10, NW of high density leases	28° 51′ 56″	80° 49′ 57″	FDACS	1995-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
49	West of ICW marker 17, Mosquito Lagoon	28° 50′ 19″	80° 49′ 03″	FDACS	1995-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
50	ICW marker 29, Mosquito Lagoon	28° 49′ 40″	80° 46′ 52″	FDACS	1990-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
51	ICW marker 21, Mosquito Lagoon	28° 49′ 10″	80° 47′ 58″	FDACS	1995-2004	5-12 times per year	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
52		28° 47′ 30″	80° 46′ 56″	FDACS	1995-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
53	East of ICW marker 21, Mosquito Lagoon	28° 47′ 30″	80° 46′ 56″	FDACS	1990-2004	1-6 times per month	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
54		28° 45′ 52″	80° 45′ 57″	FDACS	1990-2004	2-14 times per year	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity

Table 5. Surface-water sites in the Mosquito Lagoon Basin monitored by various Federal, State, and local agencies and a private agency from 1999-2003.—Continued

Site no.	Site description	Latitude	Longitude	Agency collecting data	Period of record	Approximate frequency of sample collection	Constituents/properties sampled and remarks
55		28° 44′ 42″	80° 44′ 44″	FDACS	1990-2004	2-14 times per year	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
56	Haulover Canal	28° 44′ 10″	80° 45′ 18″	USGS	1995-2003	Daily	Discharge, water temperature, specific conductance, dissolved oxygen, wind speed, wind direction
57		28° 43′ 56″	80° 44′ 09″	FDACS	1990-2004	2-12 times per year	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
58		28° 43′ 14″	80° 43′ 32″	FDACS	1990-2004	2-12 times per year	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity
59	Midway between shores, south of Haulover Canal	28° 43′ 00″	80° 43′ 00″	Brevard County, NASA, SJRWMD	1987-2003	5-13 times per year	5-day biochemical oxygen demand, chlorophyll-*a*, chlorophyll-*b*, chlorophyll-*c*, dissolved oxygen, fecal coliform bacteria, organic plus ammonia nitrogen nitrogen, nitrate nitrogen, nitrite plus nitrate nitrogen, nitrite nitrogen, organic carbon, pH, pheophytin-*a*, total phosphorus, orthophosphate, salinity, secchi disk depth, silica, specific conductance, water temperature, total suspended solids, water color, turbidity, volatile suspended solids, wind direction, wind velocity
60		28° 41′ 14″	80° 40′ 29″	NASA	1984-2002	1-7 times per year	Aluminum, antimony, arsenic, beryllium, biochemical oxygen demand, bismuth, boron, cadmium, calcium, chemical oxygen demand, chloride, chlorophyll-*a*, chromium, copper, dissolved oxygen, grease and oil, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, ammonia nitrogen, organic plus ammonia nitrogen nitrogen, nitrate, nitrite plus nitrate nitrogen, nitrite, organic carbon, pH, total phosphorus, orthophosphate, potassium, salinity, silica, silver, sodium, specific conductance, sulfate, water temperature, total dissolved solids, total suspended solids, water color, turbidity, zinc[1]
61		28° 41′ 00″	80° 41′ 6″	FDACS	1996-2004	2-12 times per year	Dissolved oxygen, fecal coliform bacteria, pH, salinity, water temperature, turbidity, wind direction, wind velocity

[1]About 40 constituents were measured periodically at site 60. Fluoride was analyzed in 1984. Tin and titanium were analyzed in 1986. Barium was analyzed during 1984-86. About 30 trace organic compounds were analyzed during 1991-92, including 2,4,5-TP; 2,4-D; 4,4-DDD; 4,4-DDE; 4,4-DDT; aldrin; alkalinity; alpha benzene hexachloride; beta benzene hexachloride; chlordane; delta benzene hexachloride; dieldrin; endosulfan I; endosulfan II; endosulfan sulfate; endrin; endrin aldehyde; gamma benzene hexachloride (lindane); heptachlor; heptachlor epoxide; methoxychlor; PCB 1016; PCB 1221; PCB 1232; PCB 1242; PCB 1248; PCB 1254; PCB 1260; phenolic compounds; and toxaphene. Fecal coliform and total coliform bacteria were analyzed during 1991-93. Mercury and water color were analyzed during 1993-2002. Chloride was analyzed in 1984 and during 2000-02. Sodium was analyzed during 2000-02. Bismuth was analyzed in 2002.

The water in Mosquito Lagoon generally was slightly alkaline with reported pH values ranging from 6.7 to 9.0 at all 61 sites in 1999-2003. Of the reported values, 99 percent were greater than 7.2. Similar to other physical properties, water pH values also varied both spatially and seasonally in the lagoon. Spatial variations in water pH values were tested at the same four sites used to assess spatial variations in salinity values and dissolved oxygen concentrations, and data from all 61 sites sampled from 1999 to 2003 were pooled to determine the general seasonal variation. Water pH values were significantly greater at site 59 in the southern part of the lagoon compared to the others (fig. 9). Values were significantly greater from January to March compared to other times of the year (fig. 10).

Major Ions

Major ion (calcium, magnesium, sodium, potassium, sulfate, and chloride) concentrations were analyzed less frequently in Mosquito Lagoon compared to the physical properties. Sufficient data were available at one site in 2000-02 (fig. 5b and table 5, site 60) to determine the ion balance. Chloride and sodium dominated the ion balance in the water, as expected. Reported chloride concentrations at this site ranged from 15,000 to 23,000 mg/L in 2000-02, and sodium concentrations ranged from 500 to 14,000 mg/L. All but one of the reported sodium concentrations were greater than 8,000 mg/L, which suggested the minimum reported concentration of 500 mg/L may be an error.

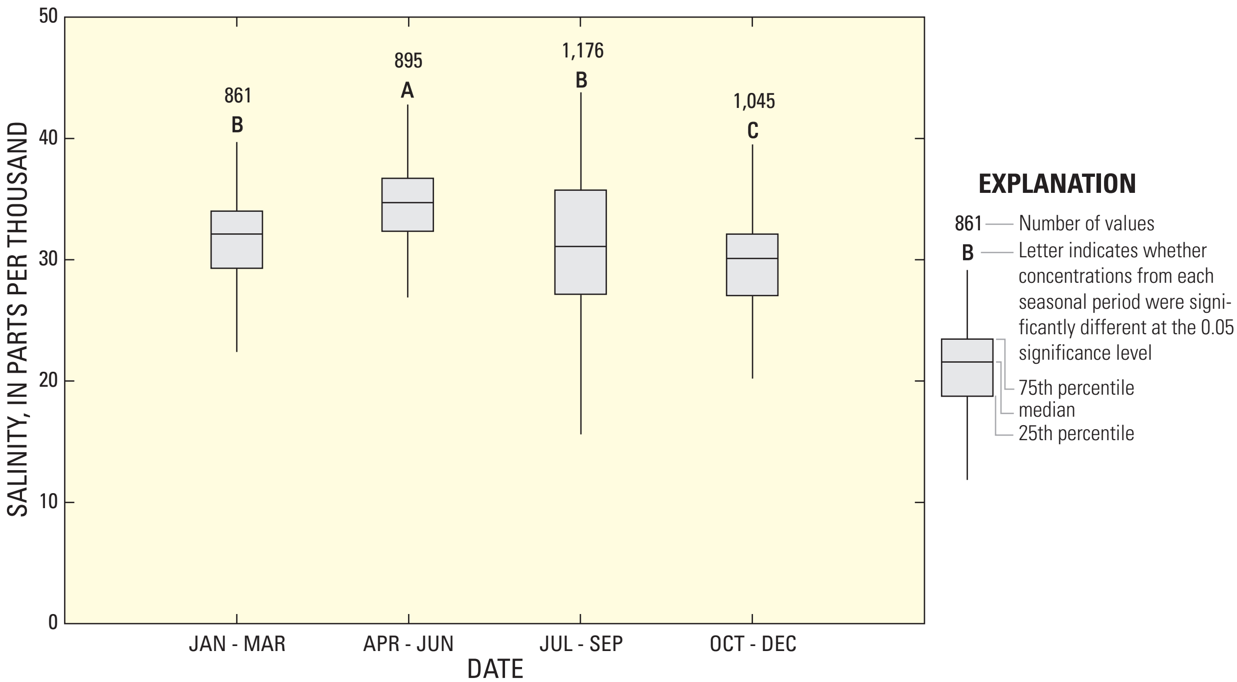

Figure 6. General seasonal distribution of salinity in Mosquito Lagoon, 1999-2003, based on 61 sampling sites. Median values with the same letter were not statistically different.

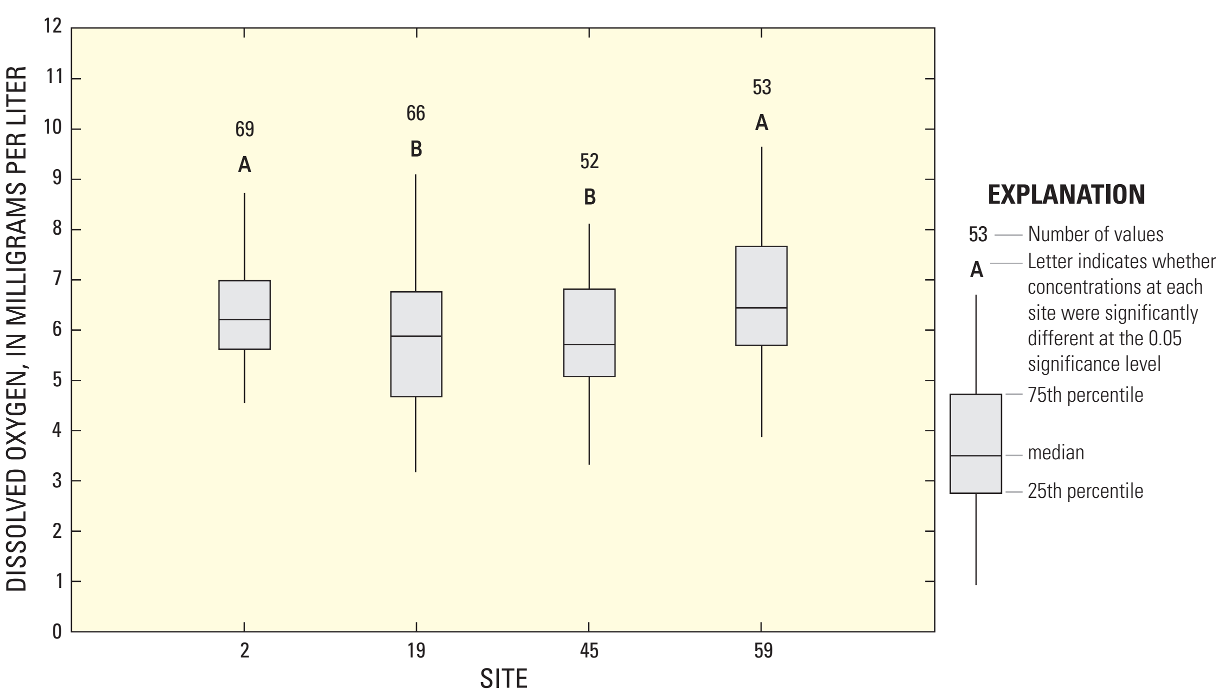

Figure 7. Dissolved oxygen concentrations at four surface-water sites in Mosquito Lagoon, 1999-2003. Median values with the same letter were not statistically different.

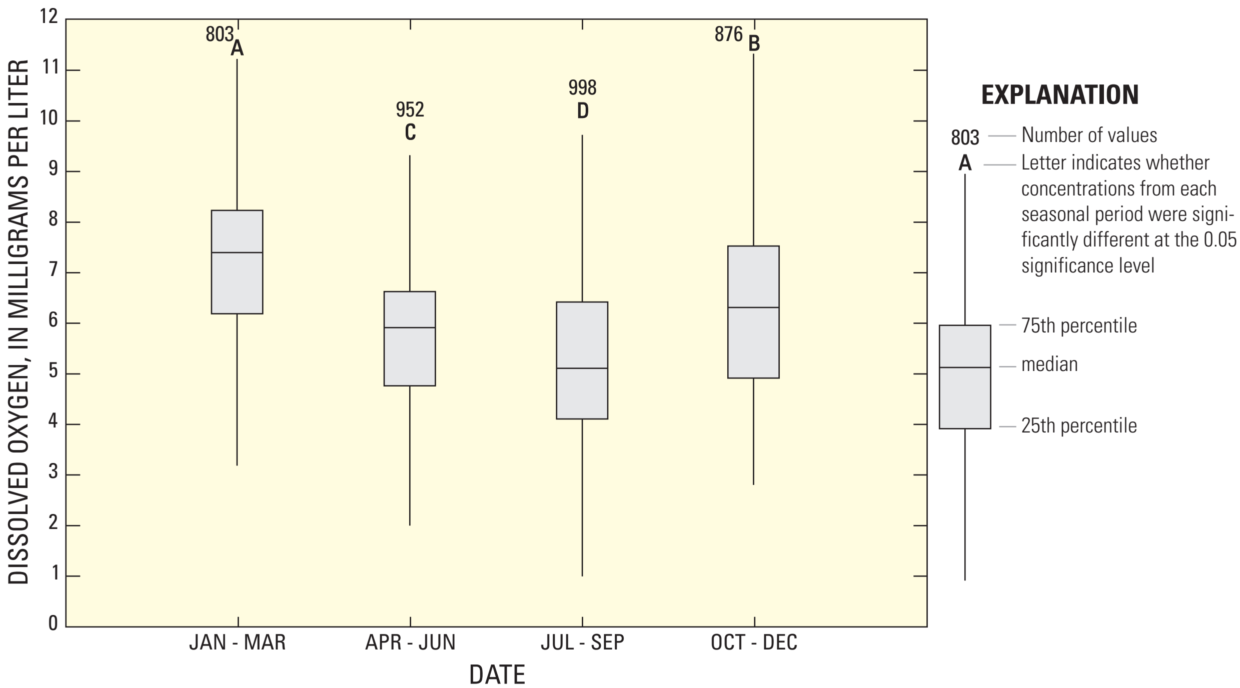

Figure 8. Generalized seasonal distribution of dissolved oxygen concentrations in Mosquito Lagoon, 1999-2003, based on 61 sampling sites. Median values with the same letter were not statistically different.

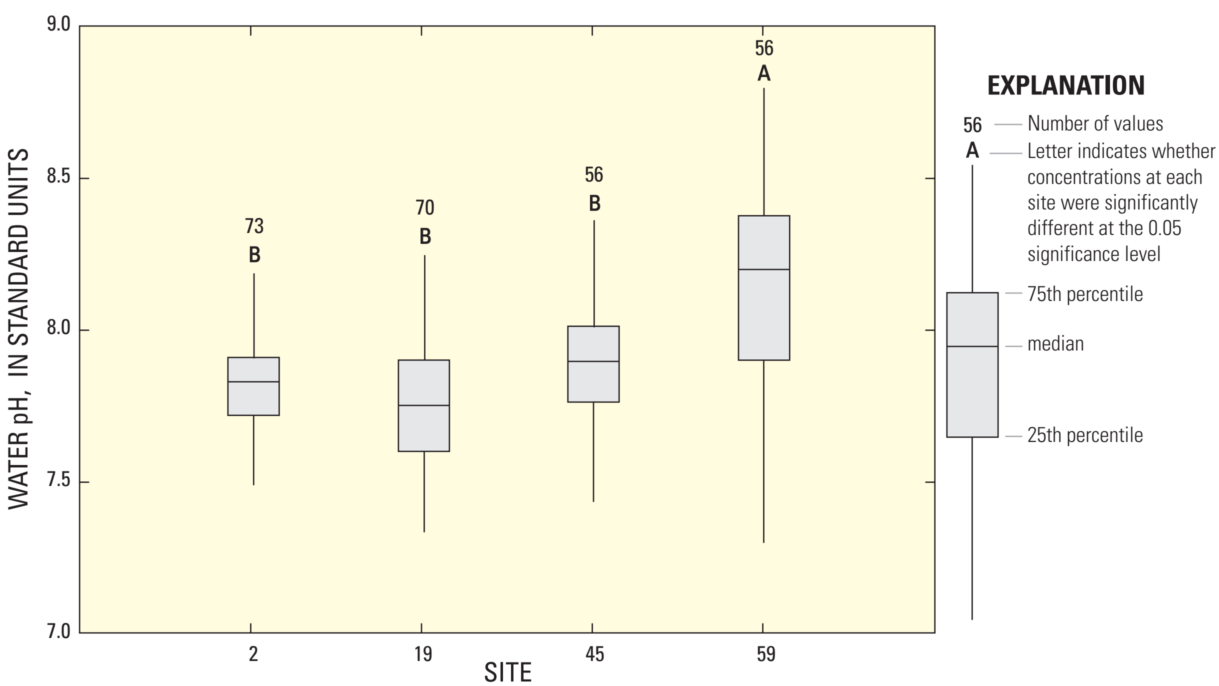

Figure 9. Water pH at four surface-water sites in Mosquito Lagoon, 1999-2003. Median values with the same letter were not statistically different.

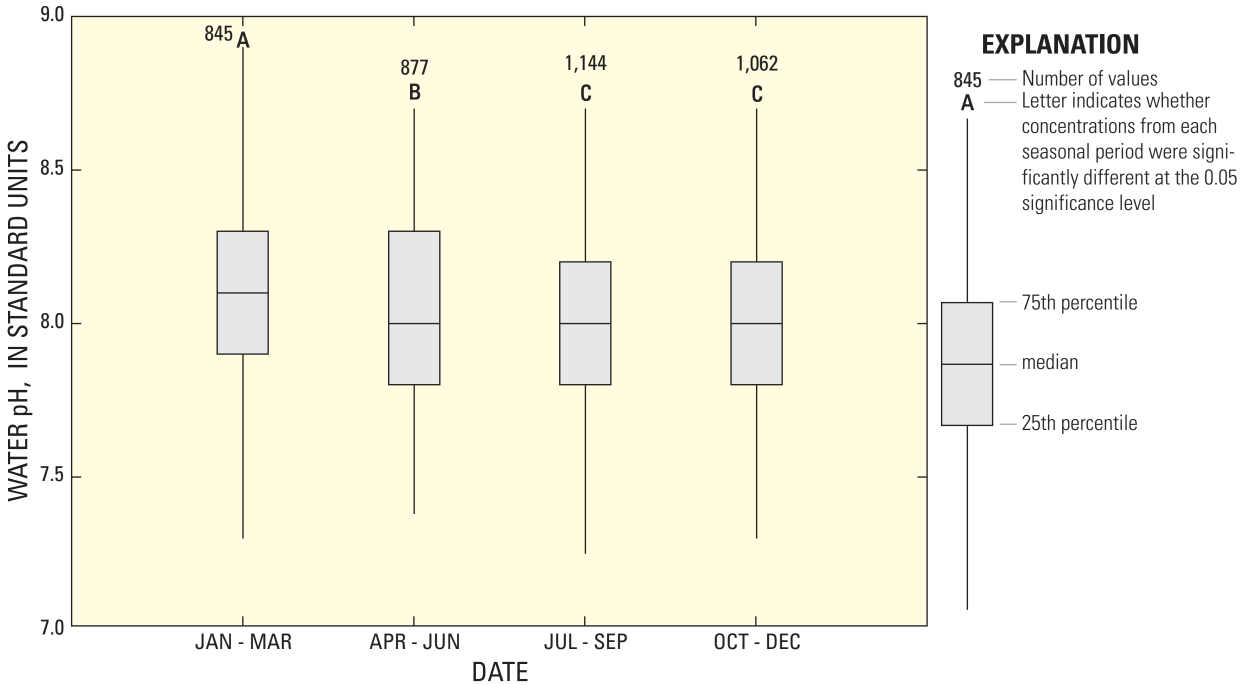

Figure 10. Generalized seasonal distribution of water pH in Mosquito Lagoon, 1999-2003, based on 61 sampling sites. Median values with the same letter were not statistically different.

The microbial reduction of sulfate is believed to be the primary mechanism by which inorganic mercury is converted to methylmercury in the environment (Gilmour and others, 1992). Methylmercury is more toxic to aquatic organisms than inorganic mercury, and may concentrate in aquatic organisms because it is eliminated from their bodies at a slower rate compared to inorganic mercury.

The limited data indicated that sulfate generally was present in the water from Mosquito Lagoon at concentrations greater than 1,000 mg/L which varied seasonally. Sulfate concentrations were reported at six sites in Mosquito Lagoon (fig. 11 and table 6, sites P2-P6 and P8) from 1984 to 2003. The most extensive data were available at site P8, which was sampled from 1984 to 2002. Data at sites P2 to P6 were more limited and extended from 1991 to 1993. The reported sulfate concentrations in Mosquito Lagoon ranged from 1,195 to 23,900 mg/L, and generally did not vary significantly among the sites. The maximum concentration was about 3 times greater than the second highest concentration, which suggests the maximum value of 23,900 mg/L may be an error. The interquartile range in sulfate concentrations was small (560 mg/L) compared to the range in values which suggested seasonal variations in concentrations were limited. Subsequent analyses of the data from 1991 to 93 showed concentrations were significantly lower from July to September compared to all other times of the year. The lower concentrations from July to September likely resulted from dilution with wet season precipitation.

Bacteria

Enterococci bacteria are the recommended indicator organism to determine the suitability of marine waters for recreation (U.S. Environmental Protection Agency, 1986). The U.S. Environmental Protection Agency (1986) recommends that enterococci counts should not exceed a geometric mean of 35 CFU/100 mL based on at least five samples collected over a 30-day period, or that the count of a single sample should not exceed 158 CFU/100 mL, in waters moderately used for recreation. Enterococci counts were typically monitored on a monthly basis at 13 sites (sites 1-8, 11, 12, 16, 19, and 22) sampled by Volusia County in the northern part of Mosquito Lagoon from 1999 to 2003 (fig. 5a). Entercocci bacteria were reported in 80 percent of the samples, and counts ranged from less than 5 to 1,685 CFU/100 mL. Ninety percent of the reported values, however, were equal to or less than 90 CFU/100 mL. There was no significant difference among sites (p-value=0.1120) or by season (p-value = 0.2255).

The occurrence and distribution of fecal coliform bacteria in Mosquito Lagoon were assessed using only data collected by the FDACS at sites 9-10, 13-15, 17-18, 20-21, 23-35, 37-44, 46-55, and 57-58 (figs. 5a-b and table 5) to avoid possibly weighting results in the northern part of the basin to data with higher reporting limits. Fecal coliform bacteria counts were measured at most sites sampled by the FDACS and Volusia County from 1999 to 2003 (figs. 5a-b and table 5). Fecal coliform bacteria counts by Volusia County were reported at a limit

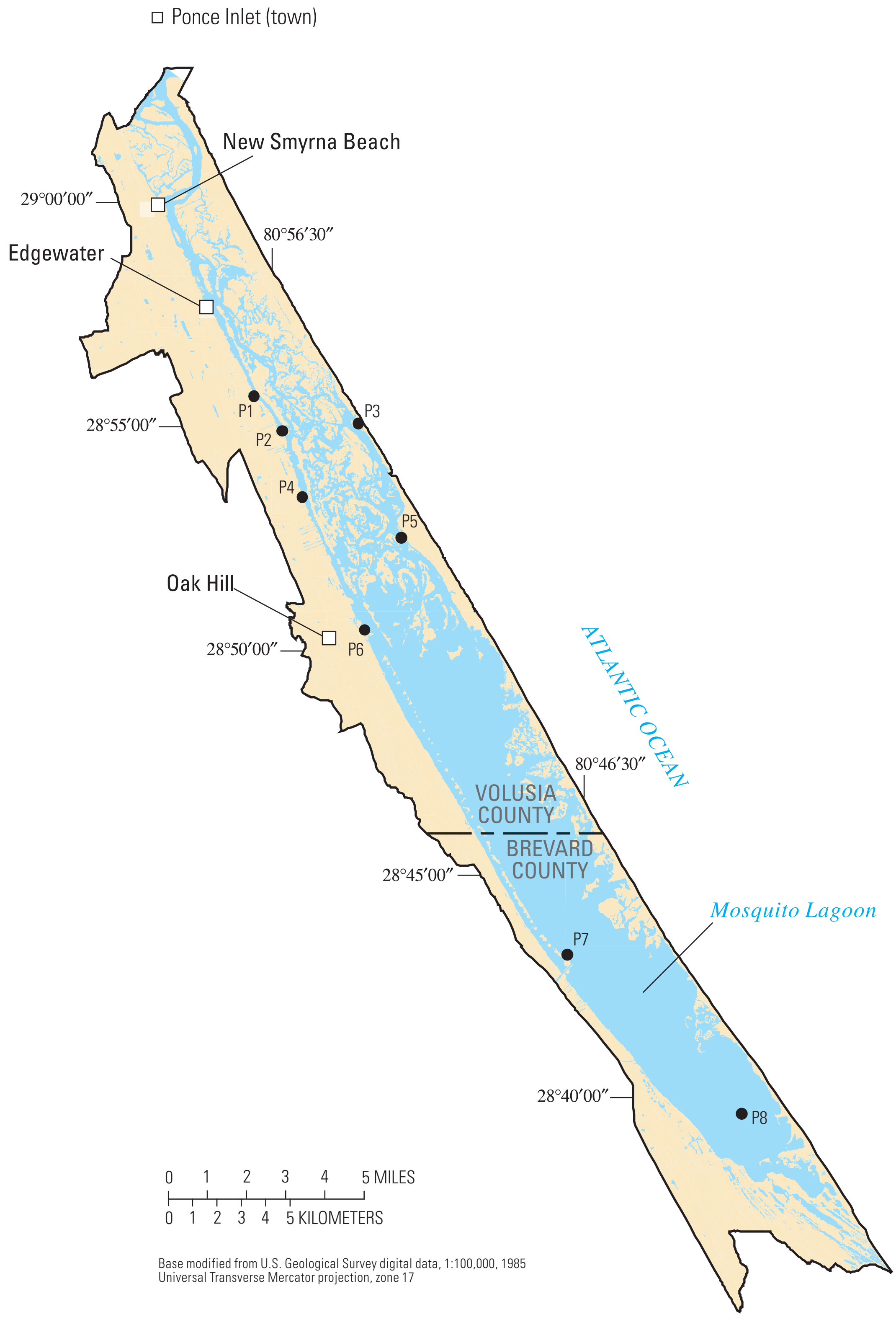

Figure 11. Location of selected sites in the Mosquito Lagoon Basin where major ion, pesticide, polychlorinated biphenyl, or trace element data were collected, 1978-2002. (Source of data, St. Johns River Water Management District, 2002.)

Table 6. Sites in the Mosquito Lagoon Basin with major ion, pesticide, polychlorinated biphenyl, or trace element data, 1978-2002.

[Sites listed with major ion data were those with sufficient information to determine the ion balance or describe sulfate concentrations; ICWW, Intracoastal Waterway; CM, channel marker; NASA, National Aeronautics and Space Administration; NPS, National Park Service; PCBS, polychlorinated biphenyls. Site locations shown in figure 11]

Site identifier	Description	Monitoring agency	Period of record	Data monitored	Latitude	Longitude
P1	Mosquito Lagoon near ICWW CM 60	FDEP	1984-2002	Trace elements	28° 57′ 21″	80° 52′ 53″
P2	Mosquito Lagoon at ICWW CM 13A	NASA, NPS	1991-93	Major ions, PCBs, and trace elements	28° 56′ 34″	80° 52′ 10″
			1991-92	Pesticides		
P3	Mosquito Lagoon	NASA, NPS	1991-93	Major ions, PCBs, and trace elements	28° 54′ 10″	80° 49′ 72″
			1991-92	Pesticides		
P4	Mosquito Lagoon	NASA, NPS	1991-93	Major ions, PCBs, and trace elements	28° 55′ 05″	80° 51′ 39″
			1991-92	Pesticides		
P5	Mosquito Lagoon	NASA, NPS	1991-93	Major ions, PCBs, and trace elements	28° 54′ 10″	80° 49′ 07″
			1991-92	Pesticides		
P6	Mosquito Lagoon	NASA, NPS	1991-93	Major ions, PCBs, and trace elements	28° 52′ 01″	80° 50′ 04″
			1991-92	Pesticides		
P7	Mosquito Lagoon at ICWW CM 41	FDEP	1978	Trace elements	28° 44′ 48″	80° 44′ 55″
P8	Mosquito Lagoon	NASA, NPS	1984-2002	Major ions and PCBs; see footnote 1	28° 41′ 14″	80° 40′ 29″

[1] Trace elements were monitored in 1984, 1986-95, 1997, 1999-2002. Pesticides were monitored from 1991-92. Sufficient data to determine the ion balance was collected at this site from 2000-2002.

of 5 colonies/100 mL, and counts by FDACS were reported at a lower limit (1 MPN/100 mL). Data with low reporting limits were preferable for analyses and interpretation because preliminary analyses of the data indicated that 70 percent of the fecal coliform counts were between 1 and 5 MPN/100 mL. Exclusion of data collected by Volusia County likely resulted in little loss of information because data from the FDACS represented about 90 percent of the fecal coliform bacteria data from 1999 to 2003. To determine seasonal variations, data collected from all sites sampled by the FDACS were pooled.

Fecal coliform bacteria counts in Mosquito Lagoon generally were less than 21 MPN/100 mL and varied seasonally and spatially among the areas classified for shellfishing. Bacteria counts ranged from 1 to 920 MPN/100 mL during 1999-2003. High counts did not occur frequently. Ninety percent of the reported counts were equal to or less than 21 MPN/100 mL. Bacteria counts were significantly greater from September to October and December to February compared to all other months, and counts were significantly lower from April to June compared to other times of the year. The period from September to October represents the end of the wet season. Higher bacteria counts during this period may have resulted from runoff from the land surface. The December to February period typically is drier compared to the September to October period. Higher bacteria counts during this period correspond to a period when total suspended solids concentrations typically are greater in Mosquito Lagoon, which suggests high bacteria counts may be associated with the resuspension of bottom materials. Some fecal bacteria survive longer in sediments compared to the water column (Howell and others, 1996), and high bacteria counts in a United Kingdom estuary have been attributed to the resuspension of bottom sediments (Obiri-Danso and Jones, 2000). Bacteria counts also were significantly greater in the areas of the lagoon classified as “conditionally restricted” compared to all other areas, and counts were significantly less in areas classified as “approved” (figs. 2, 12). No data were available from the FDACS in areas of the estuary classified as “prohibited.”

There were significant variations in fecal coliform bacteria counts among sites within areas classified as “conditionally restricted” and “conditionally approved,” and there were no significant variations in bacteria counts among sites in the “approved” areas (p-value = 0.054). Six sites (sites 9, 18, 21, 25, 39, and 46) were sampled by the FDACS in “conditionally restricted” areas (fig. 5a). Bacteria counts at these sites were significantly greater at site 18 compared to all other sites, except site 25, and bacteria counts were significantly less at site 46. Twenty-seven sites (fig. 5a, sites 10, 13-15, 17, 20, 23-24, 26-35, 37-38, 40-44, and 47-48) were sampled by the FDACS in the “conditionally approved” areas. Nineteen of these sites were located in CAZ1 areas, and the remaining sites were located within CAZ2. Bacteria counts among these sites generally were significantly greater at sites within CAZ1 compared to sites within CAZ2. Bacteria counts were greater at sites 10, 13, 14, 20, 27-28, 31, 35 and 41, which were located within CAZ1, compared to all other sites within the “conditionally approved” areas. These nine sites were located near “conditionally restricted” areas and along the Intracoastal Waterway. Bacteria counts were significantly lower at sites 30, 32-34, 37-38, 40, 43, and 47 compared to the other sites in “conditionally approved” areas. Most of these sites were located in CAZ2, except sites 30 and 47 which were located within CAZ1. Sites 30 and 47, however, were located near areas classified as CAZ2.

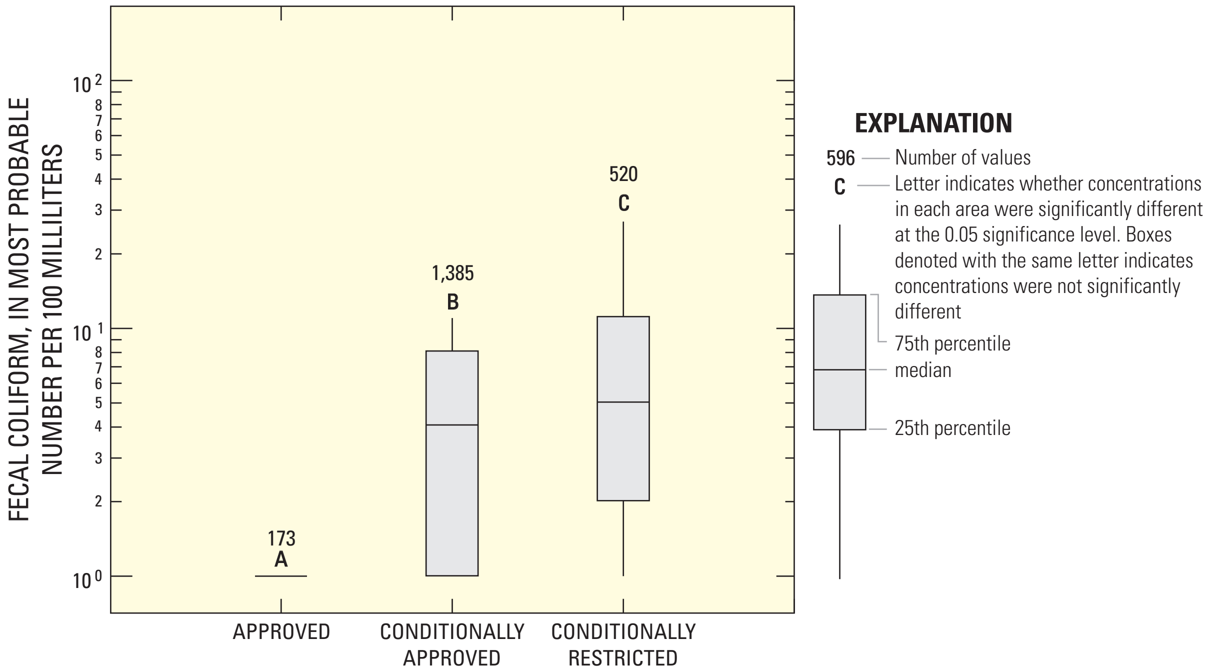

Figure 12. Fecal coliform counts in Mosquito Lagoon by shellfish harvesting areas classified by the Florida Department of Agriculture, 1999-2003. Median values with the same letter were not statistically different.

Nutrients

Nitrite plus nitrate nitrogen (hereinafter referred to as nitrate), organic plus ammonia nitrogen, total phosphorus, and orthophosphate concentrations were reported at 16 sites (figs. 5a-b, sites 1-8, 11, 12, 16, 19, 22, 45, 59, and 60) in Mosquito Lagoon from 1999-2003. Measurement of organic plus ammonia nitrogen, however, ceased at 12 of the 16 sites (figs. 5a-b, sites 1-5, 7, 8, 11, 12, 16, 22, and 60) in 2001 based on the compiled data. There were fewer data for ammonia nitrogen concentrations from 1999 to 2003 compared to the other nitrogen species. One site (fig. 5b, site 60) was sampled over the entire 5-year period to determine ammonia nitrogen concentrations, and 13 sites (fig. 5a, sites 1-8, 11, 12, 16, 19, and 22) were sampled in 2003 to determine ammonia nitrogen concentrations.

Most of the nitrogen in Mosquito Lagoon was in the form of organic nitrogen from 1999 to 2003. Sources of organic nitrogen include organic materials eroded from the land surface and transported to the estuary, such as plant detritus and animal wastes, or the production of algae and other aquatic plants in the lagoon. Reported nitrate and ammonia nitrogen concentrations generally were near method reporting limits. Nitrate nitrogen concentrations ranged from less than 0.01 to 2.8 mg/L; however, 90 percent of the reported values were less than 0.02 mg/L. Ammonia nitrogen concentrations ranged from less than 0.01 to 0.11 mg/L, and 90 percent of the values were less than 0.05 mg/L. Organic plus ammonia nitrogen concentrations generally were greater than the other nitrogen species, and ranged from less than 0.56 to 38 mg/L; however, 90 percent of the concentrations were less than 1.43 mg/L. Organic plus ammonia nitrogen concentrations were significantly lower near the Ponce de Leon Inlet (site 1) compared to the other sites (fig. 13), and were significantly greater at sites in the southern part of the lagoon (figs. 5a and 13). Lower concentrations near the Ponce de Leon Inlet may result from the dilution by the Atlantic Ocean water, and higher concentrations in the southern part of the lagoon may be related to the resuspension of organic matter associated with the bottom sediments. There was a significant seasonal variation in organic plus ammonia nitrogen concentrations in Mosquito Lagoon, with concentrations being significantly greater from July to September (the wet season) compared to other times of the year (fig. 14). Increased concentrations from July to September correspond to the periods when total suspended solids and chlorophyll-*a* concentrations are elevated in the lagoon, which suggest seasonal variations in organic plus ammonia nitrogen concentrations may be related to the resuspension of organic materials associated with bottom sediments or plant material associated with algal blooms.

Total phosphorus concentrations in Mosquito Lagoon generally were low. Concentrations ranged from less than 0.04 to 0.55 mg/L, and 90 percent of the concentrations were less than 0.08 mg/L. Concentrations were significantly greater near the Ponce de Leon Inlet (site 1) in comparison to the other sites, and concentrations at site 59 were significantly lower than the other sites (fig. 15). Greater concentrations near the Ponce de Leon Inlet may result from an undocumented source of contamination, such as OSDS leachate, or possibly the suspended sediments near the Ponce de Leon Inlet have a greater phosphorus content compared to the rest of the estuary. There was no significant difference in reported total phosphorus concentrations from the remaining sites in the lagoon. The data also showed a significant seasonal variation in concentrations. Concentrations were significantly greater from April to December than from January to March (fig. 16). These seasonal variations may be caused by runoff from the land surface or the dieoff of drift algae in the lagoon which contributes recycled nutrients to the water column (Badylak and Phlips, 2004).

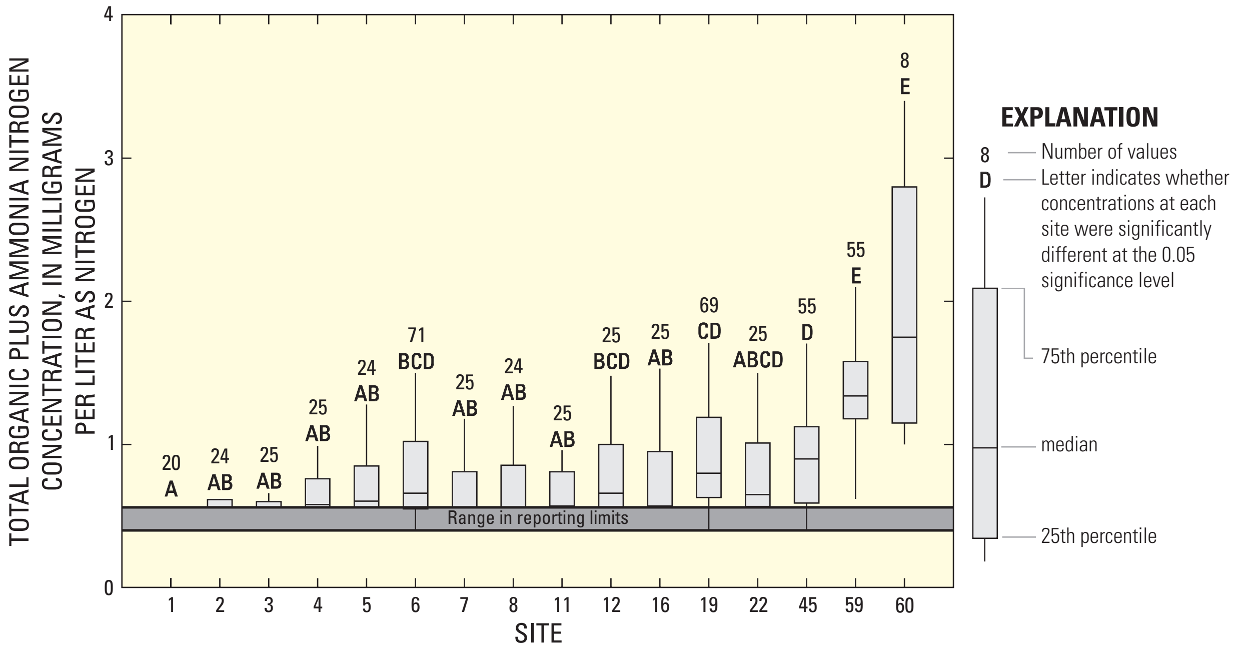

Figure 13. Total organic plus ammonia nitrogen concentrations in Mosquito Lagoon by site, 1999-2003. Sites are arranged in order from north to south. Median values with the same letter were not statistically different.

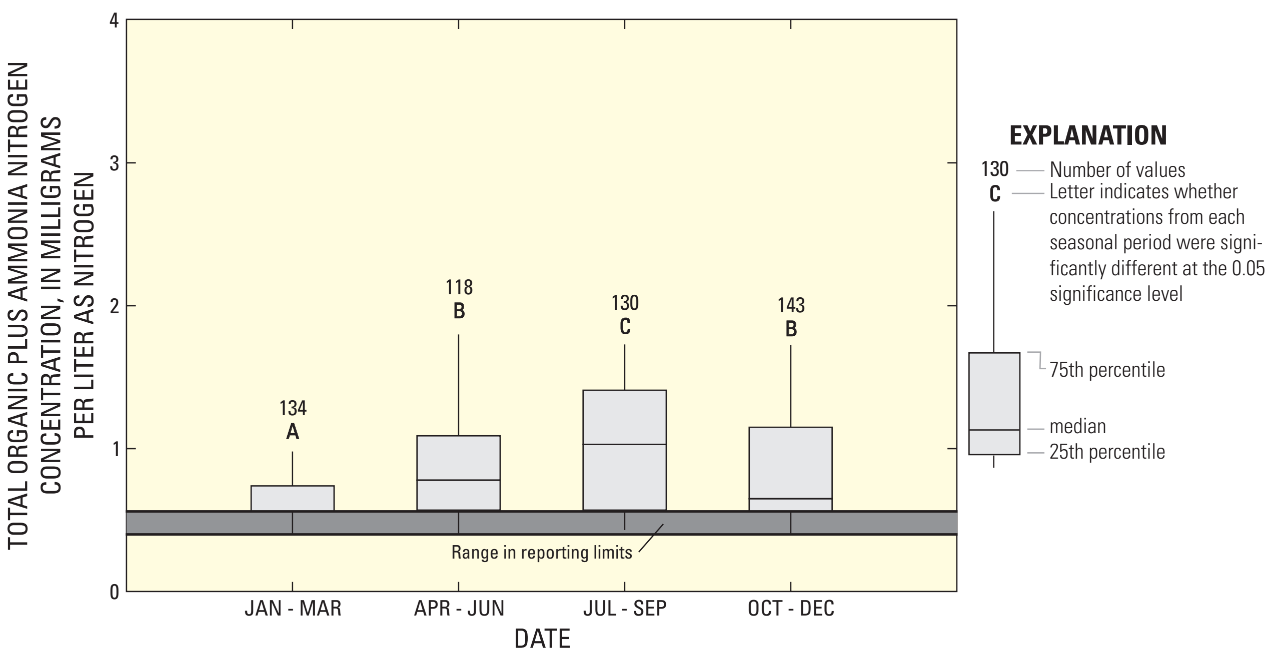

Figure 14. Generalized seasonal distribution of total organic plus ammonia nitrogen concentrations in Mosquito Lagoon, 1999-2003. Median values with the same letter were not statistically different.

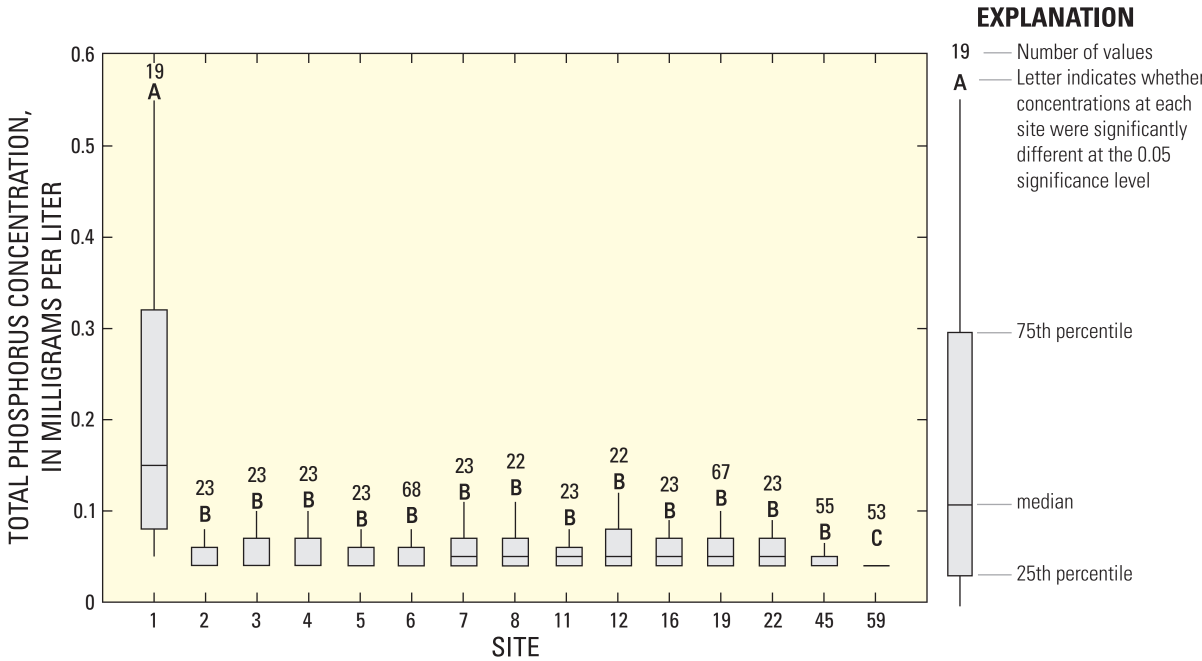

Figure 15. Total phosphorus concentration in Mosquito Lagoon by site, 1999-2003. Sites are arranged in order from north to south. Median values with the same letter were not statistically different.

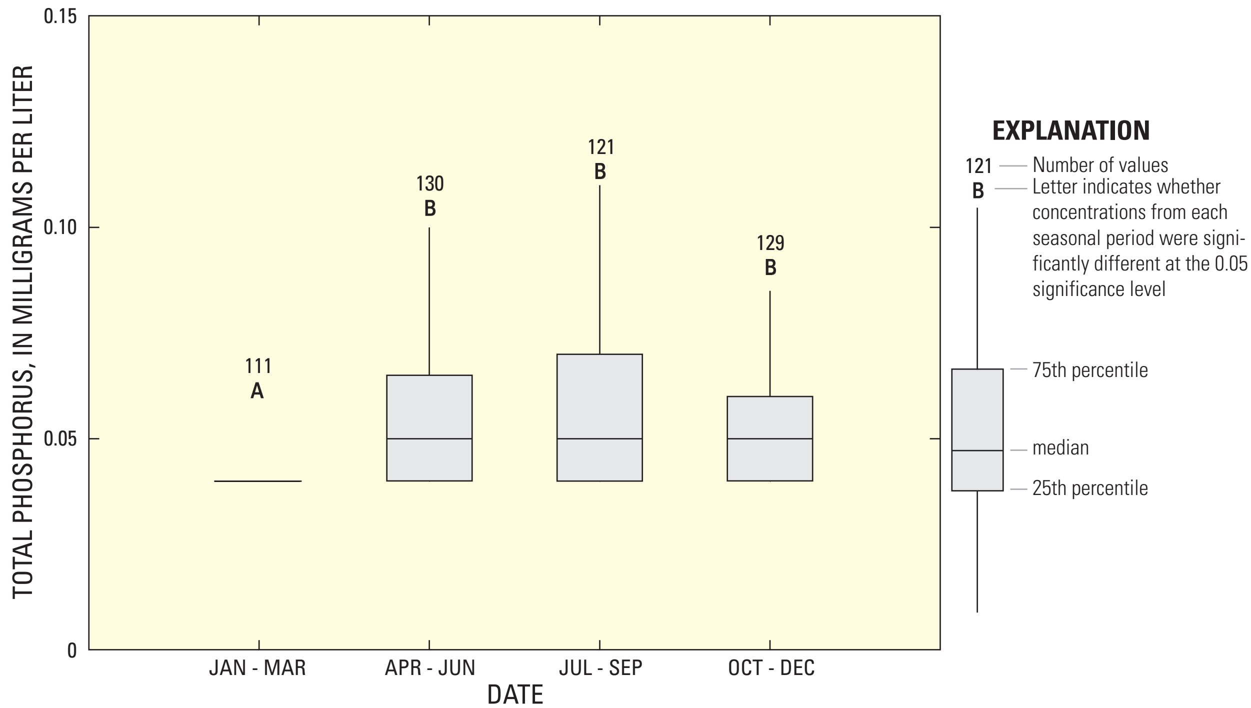

Figure 16. Generalized seasonal distribution of total phosphorus concentrations in Mosquito Lagoon, 1999-2003. Median values with the same letter were not statistically different.

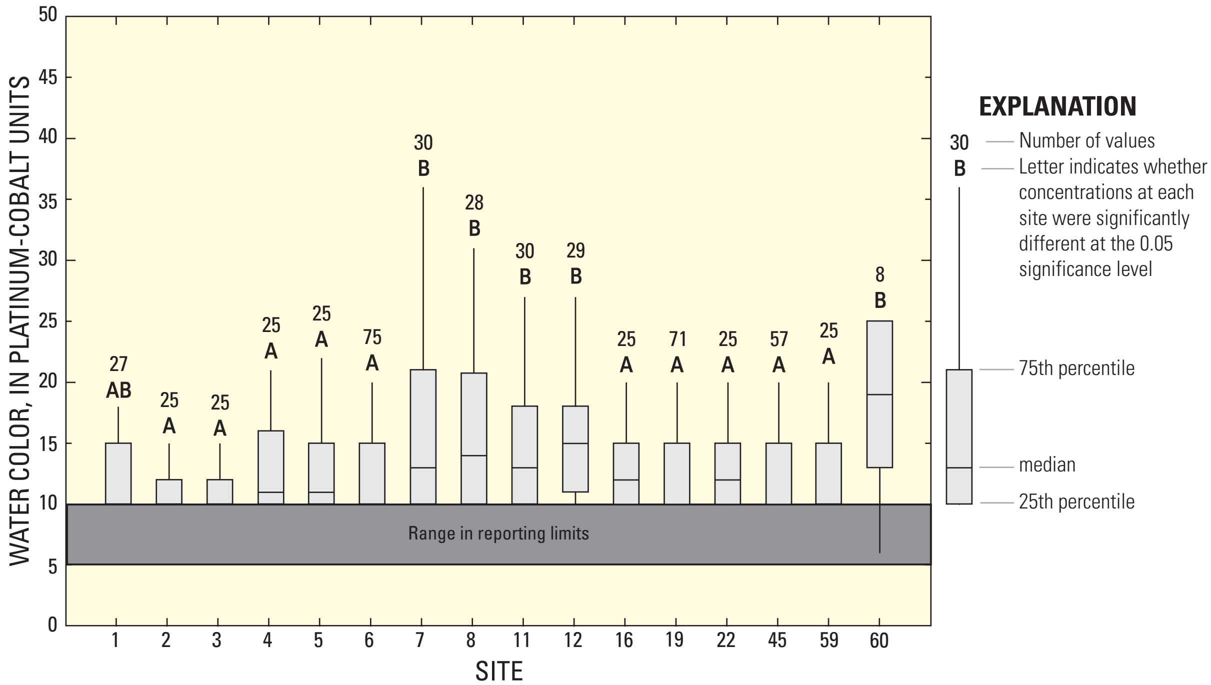

Figure 17. Water color values in Mosquito Lagoon by site, 1999-2003. Sites are arranged in order from north to south. Median values with the same letter were not statistically different.

Computed Redfield ratios indicated phytoplankton growth in Mosquito Lagoon generally was limited by the availability of phosphorus. The Redfield ratio is the molar ratio of total nitrogen to total phosphorus concentration in the water. Redfield ratios greater than 7 generally indicate that phosphorus is the limiting nutrient for phytoplankton growth. Ratios were computed at all sites with sufficient data. Ratios in Mosquito Lagoon ranged from 1.1 to 55.1 during 1999-2003. About 96 percent of the computed ratios were 7 or greater, which indicated that phytoplankton growth in Mosquito Lagoon generally was limited by the availability of phosphorus.

Water Color, Suspended Solids, and Chlorophyll-*a*

The survival and growth of seagrasses in an estuary are primarily dependent upon available nutrients and light for photosynthesis. Reduced light transmission through the water column is one of the major factors implicated in the loss of seagrass coverage in Mosquito Lagoon and the rest of the Indian River Lagoon (Steward and others, 2003). Dissolved and particulate components in the water, including organic matter, suspended sediment, and algae, all reduce light penetration into the water column (Dennison and others, 1993; Rey and Rutledge, 2006).

Monitoring to determine the concentrations of some of the substances which affect light attenuation was done in Mosquito Lagoon from 1999 to 2003. Water color values and concentrations of suspended sediment and chlorophyll-*a* generally were reported at the same 16 sites which had nutrient data (figs. 5a-b, sites 1-8, 11, 12, 16, 19, 22, 45, 59, and 60); however, chlorophyll-*a* concentrations were not reported at site 60. Monitoring of chlorophyll-*a* concentrations was discontinued at many sites in 2002, with those data only reported at sites 6, 19, 45, and 59 in 2003.

Humic substances leached from soils or wetlands likely resulted in the water from Mosquito Lagoon containing some color. Water color values ranged from less than 10 to 175 Pt-Co units during 1999-2003; however, 90 percent of the values were less than 21 Pt-Co units. Water color values were significantly greater at four sites (figs. 5a and 17, sites 7, 8, 11, and 12) near Edgewater compared to most of the other sites. The seasonal distribution of values indicated humic substances, possibly originating from soil or wetland leachate, were the likely source of colored materials in the estuary. Humic substances are high molecular weight, yellow-color organic acids that are refractory end products in the degradation of plant and microbial organic matter (McKnight and others, 1985), and account for 30 to 80 percent of the dissolved organic carbon in water (Thurman and Malcolm, 1983). Leachate from soils and wetlands may contain high concentrations of humic substances (Beck and others, 1974), which may be transported to surface water bodies by runoff. Urban and others (1989) reported high dissolved organic matter concentrations and water color values from drainage of a wetland in north-central Minnesota. The seasonal distribution of water color values in Mosquito Lagoon was consistent with a runoff source. Water color values in the estuary were significantly greater during October to December (end of wet season) compared to other times of the year (fig. 18).

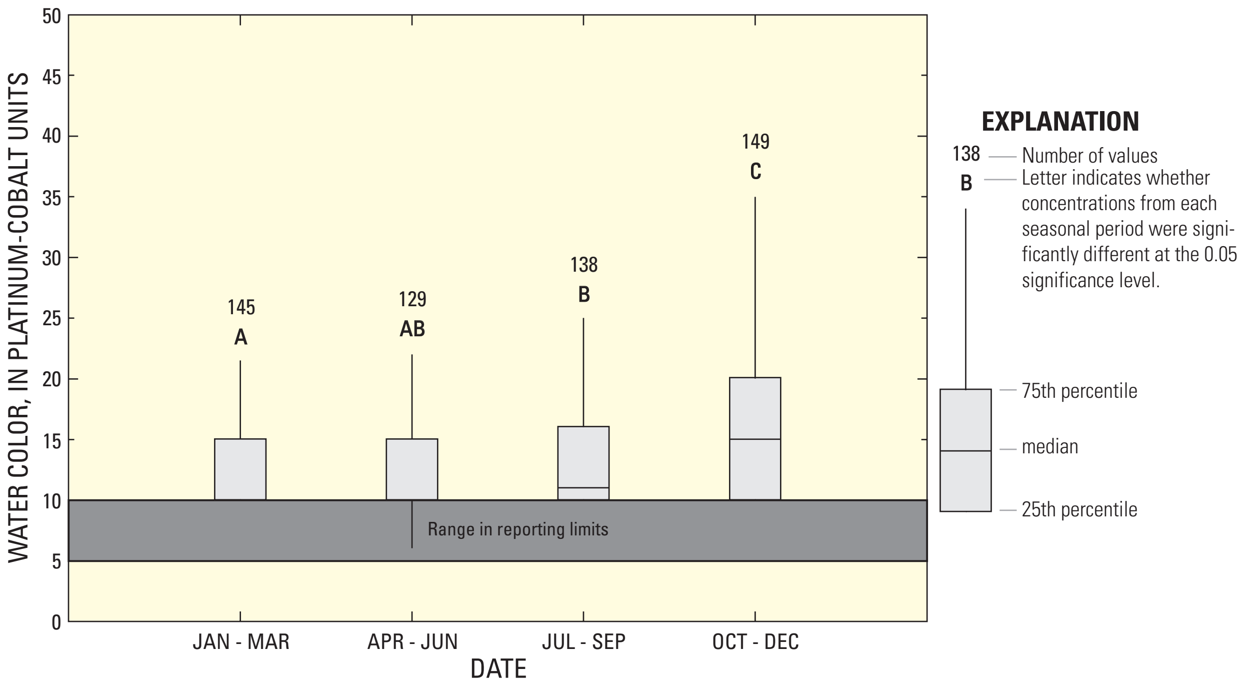

Figure 18. Generalized seasonal variations in water color values in Mosquito Lagoon, 1999-2003.

Total suspended solids concentrations in Mosquito Lagoon were significantly greater at sites 6, 19, 45, and 59 during 1999-2003, in comparison to the other sites (fig. 19). Concentrations during this period ranged from less than 5 to 113 mg/L (outlying value not shown). Concentrations near the maximum value did not occur often, and 90 percent of the concentrations were less than 61 mg/L. Total suspended solids concentrations generally varied seasonally. Reported concentrations were significantly greater during April to December compared to other times of the year (fig. 20). Increased total suspended solids concentrations in the southern part of the lagoon may be due to wind resuspension of the bottom sediments. The potential for wind resuspension of sediments was not assessed, but was studied in the Indian River Lagoon by Sun and Sheng (2001). The time scale associated with sediment suspension was determined to be on the order of minutes to hours.

Chlorophyll-*a* concentrations did not vary significantly among the sites analyzed in Mosquito Lagoon (p-value = 0.86) but did show significant seasonal variations. Reported concentrations ranged from less than 1 to 902 µg/L; however, 90 percent of the values were less than 10 µg/L. Concentrations were significantly greater from July to September than at other times of the year (fig. 21). The July to September period corresponds to when total phosphorus concentrations generally were high and water temperatures were very warm, which may have provided optimal concentrations for phytoplankton growth. Data on algal taxa were not compiled as part of this report but have been assessed in previous studies. Diatoms were identified as the most dominant algae taxa in Mosquito Lagoon, in terms of biovolume, from 1997 to 1999 (Badylak and Phlips, 2004). The structure of the phytoplankton community in Mosquito Lagoon and the rest of the Indian River Lagoon, however, varies from year to year, which likely is due to a combination of factors including rainfall variation (Badylak and Phlips, 2004).

The effect of tripton, water color, and chlorophyll-*a* concentrations on light attenuation in the Indian River Lagoon was examined by Christian and Sheng (2003). Tripton (defined as non-algal particulate matter) and total inorganic solids had the largest effect, accounting for 59 to 78 percent of the light attenuation. There also was a positive correlation between tripton concentrations and the daily average wind speed.

Pesticides and Polychlorinated Biphenyls (PCBs)

Data were reported for about 20 pesticides or pesticide degradates (table 3) from six sites (fig. 11, sites P2-P6 and P8) in Mosquito Lagoon. The data primarily described organochlorine insecticide concentrations in water during 1991-92. No data were located on pesticide concentrations in the bottom sediments or fish. The analyzed pesticides or degradates typically were not detected in Mosquito Lagoon at reporting levels which generally ranged from 0.002 to 0.1 µg/L. The only reported detection was for alpha hexachlorobenzene (1.24 µg/L) at site P8 in February 1991 and February 1992.

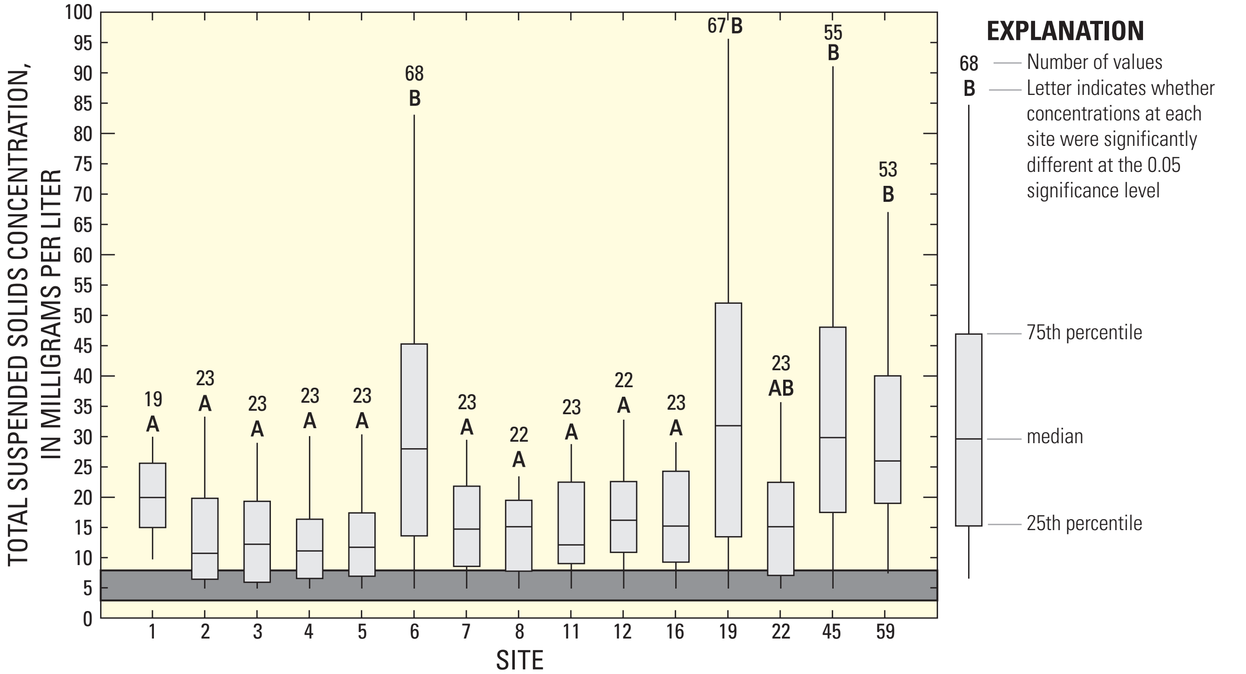

Figure 19. Total suspended solids concentrations in Mosquito Lagoon by site, 1999-2003. Sites are arranged in order from north to south. Median values with the same letter were not statistically different.

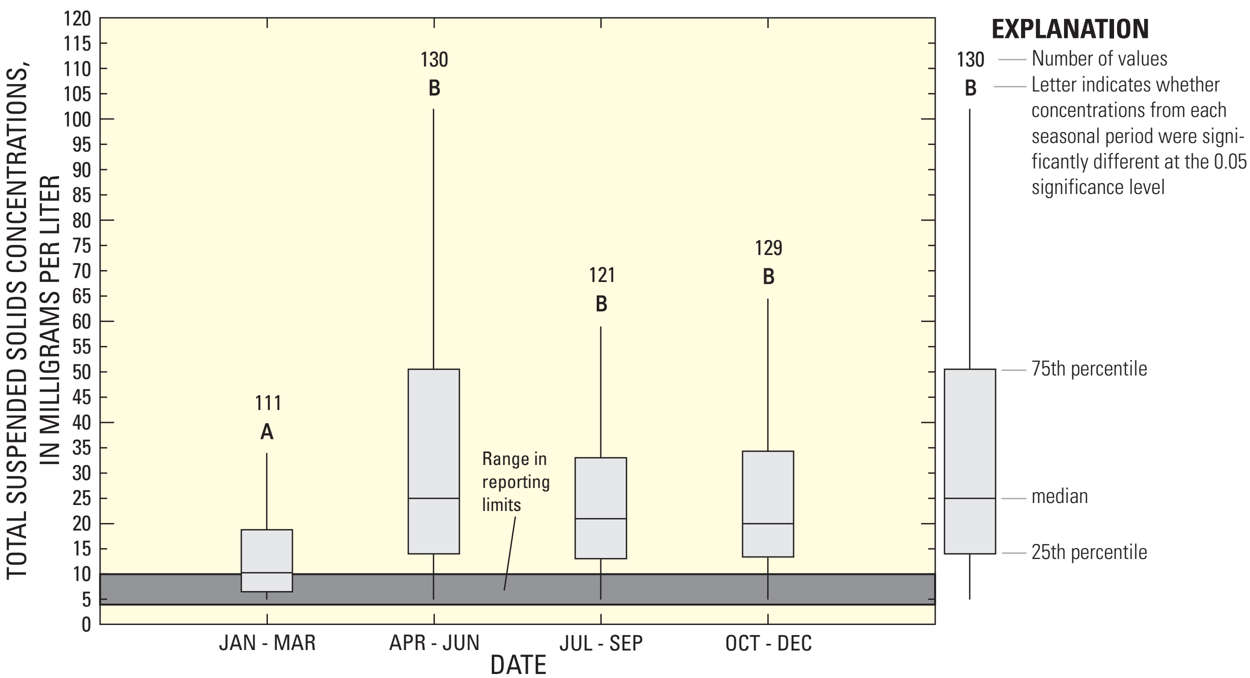

Figure 20. Generalized seasonal variations in total suspended solids concentrations in Mosquito Lagoon, 1999-2003. Median values with the same letter were not statistically different.

Data on PCB concentrations in fish were compiled from sites P2-P6 and P-8 in Mosquito Lagoon (fig. 11). These data were collected by the NPS during 1991-92. All reported concentrations were less than the reporting limit of 0.1 mg/kg wet weight. It was not specified as to which fish species, or part of the fish, was analyzed (for example, the whole fish or only the edible tissue), or whether one single fish was analyzed or if several fish were composited for analysis.

Trace Elements

Water column trace element data were compiled for eight sites (P1-P8) in Mosquito Lagoon from 1978 to 2002 (fig. 11). Most of these data were collected in the early 1990s, except for site P8, which was sampled at least annually from 1991 to 2002. Arsenic, cadmium, chromium, copper, nickel, and zinc were detected periodically (1978-2002) in water from Mosquito Lagoon (table 7). Mercury was not detected at reporting levels from 0.1 to 1 µg/L. Median chromium (11.0 µg/L) and cadmium (0.29 µg/L) concentrations were greatest at site P3.

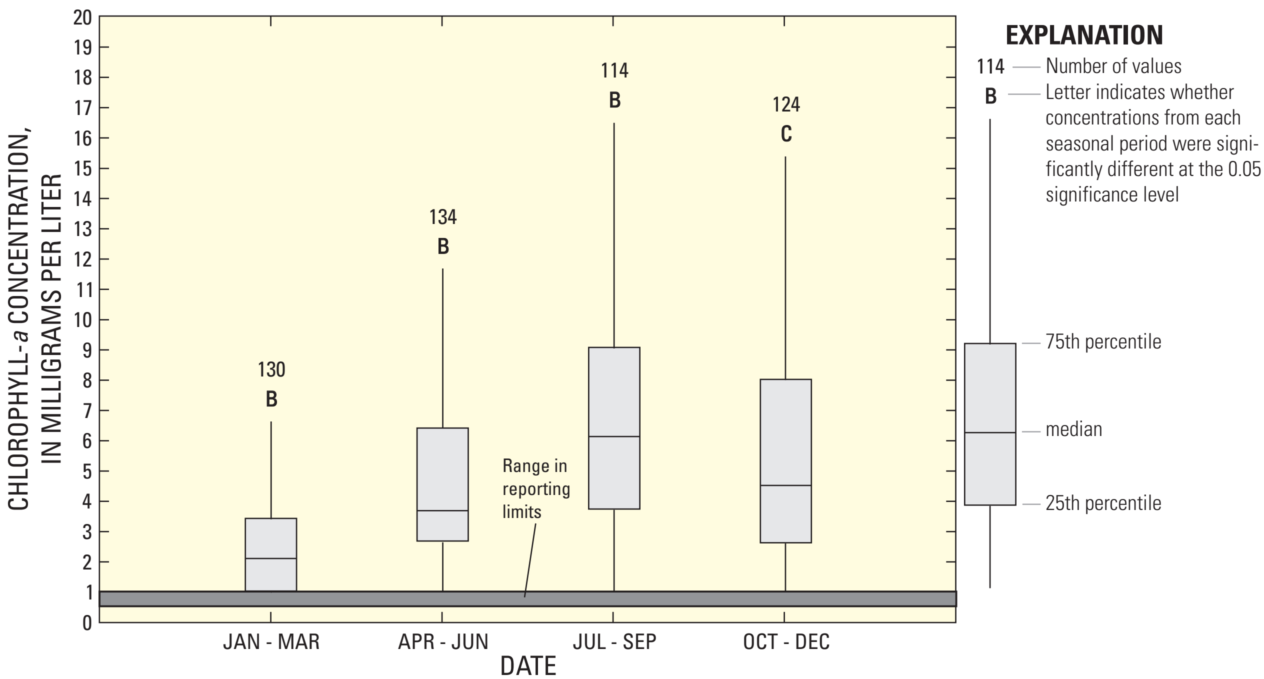

Figure 21. Generalized seasonal variations in chlorophyll-*a* concentrations in Mosquito Lagoon, 1999-2003. Median values with the same letter were not statistically different.

Table 7. Range in selected trace element concentrations in water from Mosquito Lagoon, 1978-2002.

[BRLs, below reporting limits]

Trace element	Range in concentrations, micrograms per liter	Range in reporting limits, micrograms per liter
Arsenic	BRLs to 241	3.6 - 500
Cadmium	BRLs to 7.1	0.1 - 100
Chromium	BRLs to 258	1 - 100
Copper	BRLs to 1,200	2 - 100
Nickel	BRLs to 580	1 - 60
Zinc	BRLs to 310	5 - 1,000

Ground-Water Quality

Ground-water quality conditions in the Mosquito Lagoon Basin were analyzed using data collected from the surficial aquifer system and Upper Floridan aquifer. Information on the aquifer that the ground-water samples represent and the well depth is necessary to interpret ground-water-quality data. Concentrations of anthropogenic contaminants in ground water typically vary among the aquifers underlying a region, and concentrations generally are higher in water from shallow aquifers because these are less protected by relatively impermeable materials (Lapham and others, 2005). Natural features of an aquifer, such as hydrogeology, mineral composition, and oxidation-reduction conditions, affect water-quality constituent concentrations in an aquifer (Lapham and others, 2005). For example, concentrations of total dissolved solids, which represent the amount of inorganic constituents dissolved in the water, were significantly greater in the Upper Floridan aquifer in central Florida compared to the surficial aquifer system (Adamski and Knowles, 2001). The high dissolved solids concentrations likely were due to the dissolution of the carbonate minerals, which form the Upper Floridan aquifer (Sprinkle, 1989). The surficial aquifer system primarily is composed of quartz sand, which is not very soluble in natural waters (Stumm and Morgan, 1981).

Information on the aquifer that the wells tapped was not included in the data compiled for this study. Published maps showing the depth to the top of the Floridan aquifer system (Rutledge, 1985), depth to the top of the middle semiconfining unit (O'Reilly and others, 2002), and the thickness of the middle semiconfining unit (O'Reilly and others, 2002) were used to identify the aquifer that each of the wells tapped (table 8). It was assumed that all 25 wells at 100 ft deep or less represented water from the surficial aquifer system because in the northern part of the basin, the top of the Floridan aquifer system is about 100 ft below NGVD 29. Twenty-three wells ranged from 110 to 360 ft deep and likely tapped the Upper Floridan aquifer. Depth information was not available for wells 17, 37, 39, and 40; however, field notes indicated these were flowing wells which likely discharged from the Upper Floridan Aquifer. Water from well number 1 at a depth of 600 ft likely represented the middle semiconfining unit, and water from wells 10 and 12 represented a mixture of water from the Upper Floridan aquifer, middle semiconfining unit, and possibly the Lower Floridan aquifer because these two wells have long (about 850 ft) open intervals.

About 100 constituents were analyzed in well water samples from 1954 to 2004. The major constituent groups included physical properties, nutrients, major ions, trace elements, pesticides, pesticide degradates, PCBs, organic carbon, and volatile organic compounds. A complete listing of the constituents analyzed in ground water in the Mosquito Lagoon Basin is given in table 9.

Geochemical Composition

Ground water commonly is classified by the general type, such as calcium bicarbonate water or sodium chloride water. The water type is determined by the cation and anion that constitutes more than one-half of the cations and anions in the water. For example, in calcium bicarbonate water, calcium and bicarbonate constitute more than 50 percent of the cations and anions present. Waters in which no one cation or anion dominates the ion balance are referred to as a mixed type. The water type likely varies at different points in aquifers in coastal areas due to the predominant source of the recharge water (precipitation or Atlantic Ocean water), the minerals present in the aquifer, the duration that the water is in contact with the aquifer matrix, and the flow patterns within the aquifers. A trilinear diagram (fig. 22) is a common graphical method used to depict the inorganic composition of natural waters. The two triangles in the diagram display the anions and cations present, and the diamond-shaped diagram between the triangles shows the composition of the water with respect to both anions and cations. Each apex of the triangles in the diagram represents a 100-percent composition of one of the three constituents.

The water type varied between and at different points in the surficial aquifer system and Upper Floridan aquifer within the Mosquito Lagoon Basin. Sufficient data were available from three wells that tap the surficial aquifer system (wells 51-53) and four wells that tap the Upper Floridan aquifer (wells 11, 21, 25, and 45) to determine the water types (figs. 5a-b and table 8). The surficial aquifer system wells used in this analysis ranged from 20 to 60 ft deep, and the Upper Floridan aquifer wells ranged from 150 to 210 ft deep. There were sufficient data from some wells to determine the water type on more than one sampling date. Only the most recent data were used from these wells to avoid weighting the results to a particular well. Surficial aquifer system wells (numbers 52 and 53) contained calcium bicarbonate type water, which indicates the water in these wells was fresh. Water in the three shallowest Upper Floridan aquifer wells (150 to 180 ft deep) was a mixed type and probably were not deep enough to encounter the saltwater interface. McGurk and others (1998) estimated that water containing more than 5,000 mg/L chloride was located between 200 and 600 ft below NGVD 29 in the northern part of the Mosquito Lagoon Basin. One well tapping the Upper Floridan aquifer (well 11, 210 ft deep) contained sodium chloride type water.

Salinity and Nutrient Content

The quality of ground-water discharge affects the salinity and nutrient content of coastal ecosystems. These conditions subsequently affect the plant species composition and productivity of these systems. For example, plants tolerant of more saline conditions colonized the most brackish areas of a salt marsh in Massachusetts (Barlow, 2003), and plant species more commonly associated with freshwater conditions were located in areas which received continuous fresh

Table 8. Wells monitored to determine water-quality conditions in the Mosquito Lagoon Basin.

[Locations shown in figures 5a and 5b. LFA, Lower Floridan aquifer; MSCU, middle semiconfining unit; SAS, surficial aquifer system; and UFA, Upper Floridan aquifer]

Well number	Well identifier	Latitude	Longitude	Depth to bottom of casing (feet)	Depth to bottom of well (feet)	Hydrogeologic unit
1	V-0294	29° 03′ 25″	80° 56′ 34″		600	MSCU
2	290310080542101	29° 03′ 10″	80° 54′ 21″	12	15	SAS
3	290155080560301	29° 01′ 55″	80° 56′ 03″	13	16	SAS
4	290152080553401	29° 01′ 52″	80° 55′ 34″	110	115	UFA
5	290147080534701	29° 01′ 47″	80° 53′ 47″	20	26	SAS
6	290141080540501	29° 01′ 41″	80° 54′ 05″	90	130	UFA
7	290134080554201	29° 01′ 34″	80° 55′ 42″	15	18	SAS
8	290129080551101	29° 01′ 29″	80° 55′ 11″		100	SAS
9	290126080551101	29° 01′ 26″	80° 55′ 11″		100	SAS
10	290106080552501	29° 01′ 06″	80° 55′ 25″	134	992	UFA-MSCU/LFA
11	V-0508	29° 01′ 04″	80° 55′ 19″	170	210	UFA
12	V-0180	29° 01′ 03″	80° 55′ 19″	130	998	UFA-MSCU/LFA
13	290025080544801	29° 00′ 25″	80° 54′ 48″	93	123	UFA
14	290010080543901	29° 00′ 10″	80° 54′ 39″	100	143	UFA
15	290006080544101	29° 00′ 06″	80° 54′ 41″	36	39	SAS
16	285938080542101	28° 59′ 38″	80° 54′ 21″		360	UFA
17	285921080541001	28° 59′ 21″	80° 54′ 10″			UFA
18	285916080520301	28° 59′ 16″	80° 52′ 03″	17	20	SAS
19	285915080563801	28° 59′ 15″	80° 56′ 38″	90	110	UFA
20	285904080554601	28° 59′ 04″	80° 55′ 46″		158	UFA
21	V-0399	28° 59′ 04″	80° 55′ 46″		158	UFA
22	285902080551101	28° 59′ 02″	80° 55′ 11″	13	18	SAS
23	285858080555701	28° 58′ 58″	80° 55′ 57″		180	UFA
24	285852080561401	28° 58′ 52″	80° 56′ 14″		180	UFA
25	V-0438	28° 58′ 52″	80° 56′ 14″		180	UFA
26	V-0436	28° 58′ 46″	80° 56′ 32″	90	200	UFA
27	V-0435	28° 58′ 32″	80° 57′ 18″	100	174	UFA
28	285825080535601	28° 58′ 25″	80° 53′ 56″	25	29	SAS
29	285742080533201	28° 57′ 42″	80° 53′ 32″	22	25	SAS
30	285715080504001	28° 57′ 15″	80° 50′ 40″	10	14	SAS
31	285704080502801	28° 57′ 04″	80° 50′ 28″	26	29	SAS
32	285647080522801	28° 56′ 47″	80° 52′ 28″		145	UFA
33	285645080523501	28° 56′ 45″	80° 52′ 35″		133	UFA
34	285625080521801	28° 56′ 25″	80° 52′ 18″		115	UFA
35	285625080525202	28° 56′ 25″	80° 52′ 52″		69	SAS
36	285625080525201	28° 56′ 25″	80° 52′ 52″	32	32	SAS
37	285612080520701	28° 56′ 12″	80° 52′ 07″			UFA
38	285545080493201	28° 55′ 45″	80° 49′ 32″			SAS
39	285503080514103	28° 55′ 03″	80° 51′ 41″			UFA
40	285502080514102	28° 55′ 02″	80° 51′ 41″			UFA
41	285502080514101	28° 55′ 02″	80° 51′ 41″		126	UFA
42	285447080520201	28° 54′ 47″	80° 52′ 02″	33	36	SAS
43	285403080490001	28° 54′ 03″	80° 48′ 60″			SAS
44	285403080514390	28° 54′ 03″	80° 51′ 43″		150	UFA
45	V-0419	28° 54′ 03″	80° 51′ 43″		150	UFA
46	V-0561	28° 53′ 46″	80° 51′ 19″		140	UFA
47	V-0560	28° 53′ 43″	80° 51′ 20″		130	UFA
48	285330080513701	28° 53′ 30″	80° 51′ 37″		24	SAS
49	285248080503501	28° 52′ 48″	80° 50′ 35″		116	UFA
50	V-1036	28° 51′ 33″	80° 51′ 04″	50	60	SAS
51	V-1035	28° 51′ 33″	80° 51′ 04″	20	30	SAS
52	285129080510501	28° 51′ 29″	80° 51′ 05″	60	60	SAS
53	285129080510502	28° 51′ 29″	80° 51′ 05″	30	30	SAS
54	285037080504801	28° 50′ 37″	80° 50′ 48″	29	32	SAS
55	284522080461401	28° 45′ 22″	80° 46′ 14″		20	SAS

Table 9. Constituents analyzed in ground water in the Mosquito Lagoon Basin.

Physical properties	Nutrients
Acid neutralizing capacity	Nitrogen
Alkalinity	Ammonia nitrogen
Bicarbonate	Organic plus ammonia nitrogen
Carbonate	Nitrate nitrogen
Dissolved oxygen	Nitrite plus nitrate nitrogen,
Hardness	Nitrite nitrogen
Noncarbonate hardness	Organic nitrogen
pH	Phosphorus
Specific conductance	Orthophosphate phosphorus
Temperature, water	**Pesticides, pesticide degradates, and other trace organic compounds**
Total dissolved solids	
True color	2,4,5-T
Turbidity	2,4,5-TP
Major inorganic constituents	2,4-D
	Aldrin
Calcium	Chlordane (technical)
Chloride	Dichlorprop
Fluoride	Dieldrin
Magnesium	Endosulfan I
Potassium	Endrin
Silica	Endrin aldehyde
Silicon	Gamma benzene hexachloride (lindane)
Sodium	Heptachlor
Sulfate	Heptachlor epoxide
Volatile organic compounds	Mirex
	p,p′ DDD
1,1,1-trichloroethane	p,p′ DDE
1,1,2,2-tetrachloroethane	P,p′ DDT
1,1,2-trichloroethane	p,p′-ethyl-DDD
1,1-dichloroethane	p,p′-methoxychlor
1,1-dichloroethene	PCBS
1,2-dichloroethane	Polychlorinated naphthalenes
1,2-dichloropropane	Toxaphene
1,3-dichloropropene	**Trace elements**
2-chloroethyl vinyl ether	Aluminum
Benzene	Arsenic
Bromodichloromethane	Barium
Bromomethane	Cadmium
Chlorobenzene	Chromium
Chloroethane	Copper
Dibromochloromethane	Iron
Dichlorodifluoromethane	Lead
Dichloromethane	Manganese
Ethylbenzene	Mercury
Tetrachloroethene	Nickel
Tetrachloromethane	Selenium
trans-1,2-dichloroethene	Silver
Tribromomethane	Strontium
Trichloroethene	Vinyl chloride
Trichlorofluoromethane	**Other constituents**
Trichloromethane	Carbon dioxide
Toluene	Organic carbon

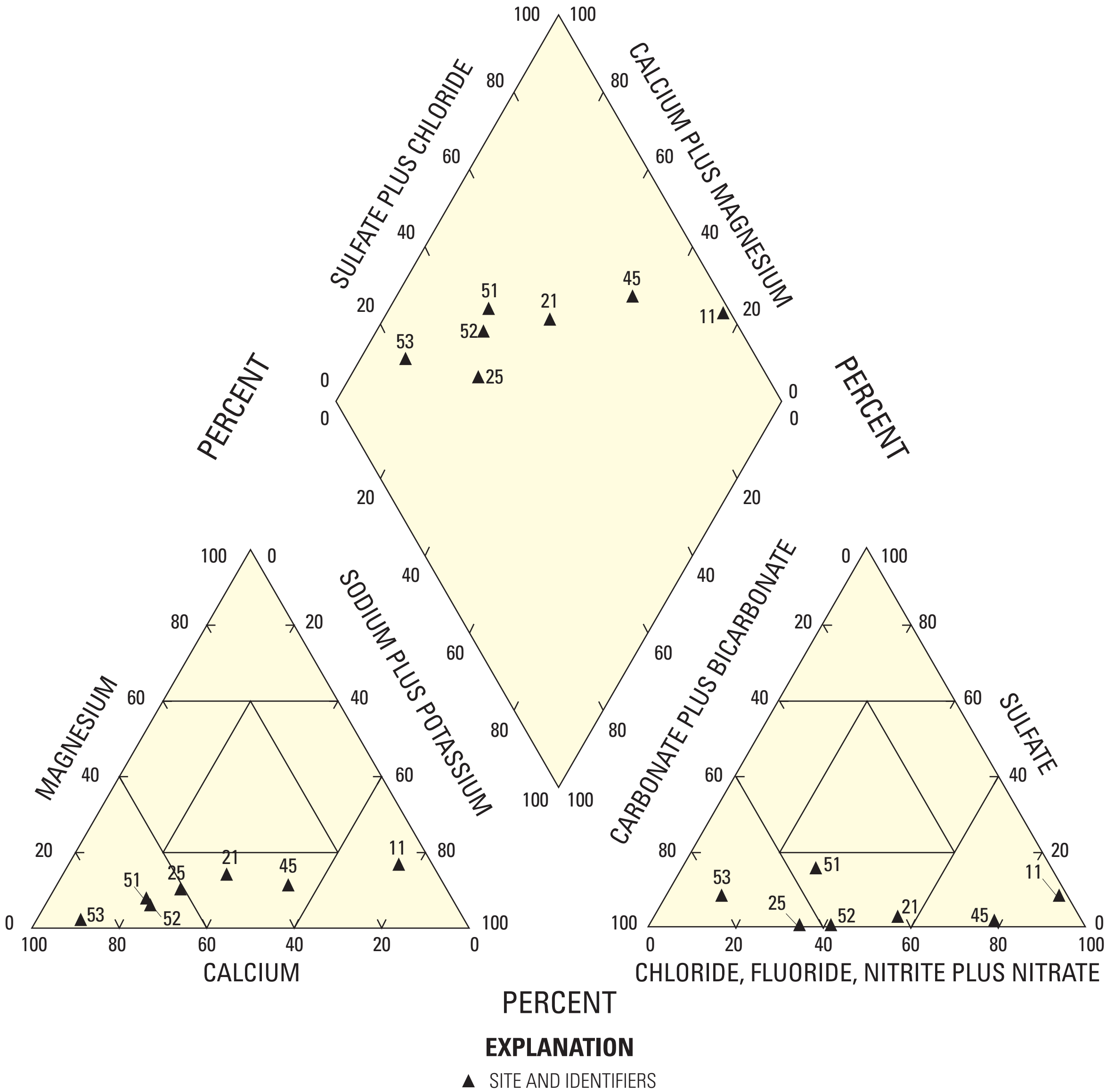

Figure 22. Trilinear diagrams showing water samples collected from wells in the Mosquito Lagoon Basin, 1987-2003. Site identifiers correspond to table 8.

ground-water seepage. Fresh ground water also may transport excess nutrients associated with human activities to estuaries as has been observed near the Nauset Marsh estuary in Massachusetts, where ground water is directly discharged from several seeps along the shoreline (Barlow, 2003). Houses and businesses in the vicinity of the Nauset Marsh are serviced by OSDS. Some of the seeps discharged water with high nitrate concentrations, and the highest concentrations occurred in areas where the housing density was greatest.

Chloride concentrations often are used as an indicator of the salinity of an aquifer. Concentrations were reported from 22 wells that tap the surficial aquifer system, 28 wells that tap the Upper Floridan aquifer, and 2 wells that may extend into the Lower Floridan aquifer. Chloride concentrations in water from wells in the Mosquito Lagoon Basin were significantly greater in the Upper Floridan aquifer than in the surficial aquifer system (p-value = 0.012) and varied considerably within each aquifer based on data compiled from 1954 to 2004. The median concentration was 465 mg/L in the Upper Floridan aquifer compared to 83 mg/L in the surficial aquifer system. Higher concentrations in the Upper Floridan aquifer likely resulted from relict seawater that entered the aquifer during a higher stand of sea level in the geologic past or upwelling of saline water from deeper strata. Chloride concentrations in the surficial aquifer system and Upper Floridan aquifer varied considerably within the aquifers. Concentrations ranged from 11 to 21,000 mg/L in the surficial aquifer system. The highest concentrations (11,000-21,000 mg/L) were reported in wells 30 and 31, which are less than 30 ft deep and located on the eastern shore of Mosquito Lagoon (figs. 5a and 23 and table 8).

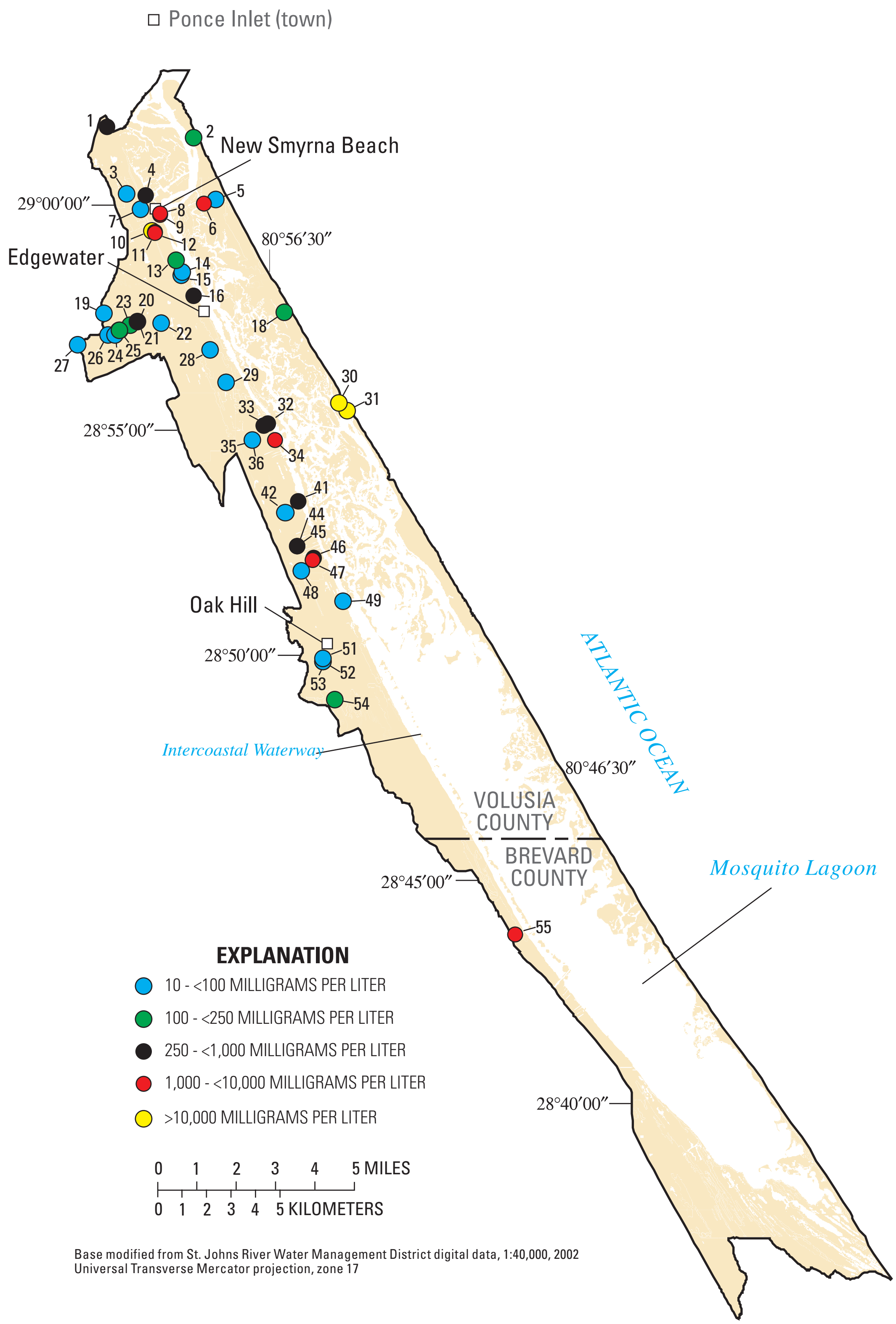

Figure 23. Chloride concentrations in wells from the Mosquito Lagoon Basin, 1954-2004.

Chloride concentrations in water from wells in the Floridan aquifer system ranged from 35 to 19,000 mg/L. The highest concentrations in water ranged from 9,000 to 19,000 mg/L at wells 10 and 12 (about 1,000 ft deep) that may penetrate the Lower Floridan aquifer (figs. 5a and 23 and table 8). Chloride concentrations were lower in the Upper Floridan aquifer than in the Lower Floridan aquifer, ranging from 35 to 5,400 mg/L. The Floridan aquifer system is chemically stratified and chloride concentrations often are higher with increased depths in the aquifer (Sprinkle, 1989; O'Reilly and others, 2002). Chloride concentrations were greater than 250 mg/L (the secondary drinking water regulation set by the U.S. Environmental Protection Agency) in more than 50 percent of the Upper Floridan aquifer wells and about 20 percent of the surficial aquifer system wells.

Nitrate, ammonia, organic plus ammonia nitrogen, and orthophosphate concentration data were reported from 13 wells in the Mosquito Lagoon Basin. Wells 2, 3, 35, 36, 38, 43, and 51- 53 represented water from the surficial aquifer system, and wells 11, 20, 27, and 44 represented water from the Upper Floridan aquifer (fig. 5a and table 8). All wells were located in the northern part of the basin. Reported well depths (when available) for the surficial aquifer system wells ranged from 15 to 69 ft deep, and reported well depths for the Upper Floridan aquifer wells ranged from 150 to 210 ft deep. Ammonia, nitrite plus nitrate nitrogen, organic plus ammonia nitrogen, and orthophosphate concentrations were analyzed in the surficial aquifer system wells. In the Upper Floridan aquifer, four wells were sampled to determine nitrate concentrations and one well was sampled to determine orthophosphate concentrations. Ranges in nutrient concentrations are listed in table 10. The limited data suggested nitrate concentrations in the basin may be higher in the surficial aquifer system than in the Upper Floridan aquifer.

Table 10. Range in selected nutrient concentrations in ground water from the Mosquito Lagoon Basin, 1976-2004.

[SAS, surficial aquifer system; UFA, Upper Floridan aquifer; <, less than]

Constituent	Number of wells with data	Aquifer	Range in concentrations, in milligrams per liter
Nitrite plus nitrate nitrogen	9	SAS	<0.02 to 0.87
Nitrite plus nitrate nitrogen	4	UFA	.01 to .43
Organic plus ammonia nitrogen	9	SAS	<.2 to 1.6
Ammonia nitrogen	9	SAS	.04 to .94
Orthophosphate phosphorus	9	SAS	<.017 to 1.3
Orthophosphate phosphorus	1	UFA	.03

Organic Compounds and Trace Elements

The presence of volatile organic compounds (VOCs), pesticides, pesticide degradates, PCBs and related compounds, and trace elements (table 9) in water from wells also indicate anthropogenic contamination of the ground water. Limited monitoring was done to determine the presence of these constituents in ground water in the Mosquito Lagoon Basin based on the compiled data. Concentrations of VOCs were reported from one well that taps the Upper Floridan aquifer in the basin (fig. 5a and table 8, well 20). This Upper Floridan aquifer well was 158 ft deep and was sampled in 1983. VOCs generally were not reported in water analyzed with a reporting limit of 3 μg/L. One compound, dichloromethane, was detected at a concentration of 4 μg/L. Wells 20 and 44 at depths of 158 and 150 ft, respectively (fig. 5a and table 8), were periodically sampled to determine concentrations of pesticides and other trace organic compounds from 1976 to 1983. These data primarily described organochlorine insecticide concentrations in water but also included information on PCBs and polychlorinated naphthalenes (a precursor to PCBs). These compounds were not detected at reporting limits ranging from 0.01 to 1 μg/L.

Monitoring of trace elements in the ground water also was limited. Concentrations of aluminum, arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc were periodically reported in water from a cluster of surficial aquifer system wells 51-53 and Upper Floridan aquifer wells 20 and 44 (fig. 5a and table 8). Trace-element concentration data from the Upper Floridan aquifer wells were collected from 1976 to 1983, and data from the surficial aquifer system wells were collected from 1991 to 1994. Summary statistics are presented in table 11. All reported arsenic, cadmium, chromium, mercury, and selenium concentrations were less than the maximum contaminant level set by the U.S. Environmental Protection Agency (2003) for drinking water of 10, 5, 100, 2, and 50 μg/L, respectively. Lead concentrations were less than the action level of 1,300 μg/L set by the U.S. Environmental Protection Agency (2003) for drinking water.

Atmospheric Deposition Conditions

Atmospheric deposition may be a substantial source of some contaminants to the Mosquito Lagoon Basin. Atmospheric deposition contributes a substantial amount of nitrogen to some estuaries in the Nation. For example, about one-third of the nitrogen load to Chesapeake Bay originated from atmospheric deposition to the land surface (U.S. Environmental Protection Agency, 2007), and atmospheric deposition may be a substantial source of trace elements to this estuary (Scudlark and others, 1994). Sources of nitrogen and trace element emissions include fossil fuel combustion, fertilizer applications, animal excreta, soils, and waste incineration.

Nitrate and ammonia nitrogen were present in most wet deposition samples in the Mosquito Lagoon Basin. Nitrate nitrogen was present in 96 percent of the wet deposition samples at site A4 (fig. 1, table 4) and in 100 percent of the wet deposition samples at site A2 from 2003 to 2007. Ammonia nitrogen was present in 77 percent of the wet deposition samples at site A4 and in 95 percent of the samples at site A2. Nitrate and ammonia nitrogen concentrations varied substantially in the weekly wet deposition samples collected at these sites. Nitrate nitrogen concentrations in the weekly wet deposition samples at site A4 ranged from below the method reporting limit (0.001 mg/L) to 3.10 mg/L during 1983-2004, and concentrations at site A2 ranged from 0.03 to 1.04 mg/L during 2003-07. Ammonia nitrogen concentrations at site A4 ranged from below the method reporting limit (0.02 mg/L) to 2.68 mg/L during 1983-2004, and concentrations at site A2 ranged from below the method detection limit (0.01 mg/L) to 1.56 mg/L during 2003-07.

Nitrate nitrogen concentrations in wet deposition at sites A2 and A4 were substantially lower from October to December compared to other times of the year. Data from site A4 indicated ammonia nitrogen concentrations were substantially greater from January to June than from July to December.

Table 11. Summary statistics of trace element concentrations in water from wells in the Mosquito Lagoon Basin, 1976-94.

[Concentrations in micrograms per liter; SAS, surficial aquifer system; UFA, Upper Floridan aquifer; MRL, method reporting limit]

Trace element	Aquifer	Number of samples	Minimum	Median	Maximum
Aluminum	SAS	6	21	75	1,800
Arsenic	SAS	3	1	1	3
Arsenic	UFA	4	<1	1	1
Barium	SAS	9	7.5	13.0	54
Barium	UFA	3	<MRL[1]	<MRL[1]	<MRL[1]
Cadmium	SAS	5	0.2	1	1
Cadmium	UFA	1	<MRL[2]	<MRL[2]	<MRL[2]
Chromium	SAS	5	5	5	5
Chromium	UFA	4	<MRL[3]	10.5	30
Copper	SAS	5	5	10	10
Copper	UFA	1	90	90	90
Lead	SAS	7	1	1	4
Lead	UFA	2	<MRL[4]	<MRL[4]	<MRL[4]
Mercury	SAS	5	.1	0.1	0.2
Mercury	UFA	4	<MRL[5]	<.5	.5
Nickel	SAS	5	10	10	20
Selenium	SAS	5	1	1	2
Selenium	UFA	4	<1	<1	<1
Silver	SAS	5	<MRL[6]	1	1
Silver	UFA	1	<MRL[2]	<MRL[2]	<MRL[2]
Zinc	SAS	8	4	7	12
Zinc	UFA	1	30	30	30

[1]Method reporting limit less than 100 micrograms per liter during 1976-83.

[2]Method reporting limit less than 1 microgram per liter in 1983.

[3]Method reporting limit ranged from 1 to 20 micrograms per liter.

[4]Method reporting limit ranged from 1 to 2 micrograms per liter during 1976-83.

[5]Method reporting limit ranged from 0.1 to 0.5 microgram per liter during 1976-83.

[6]Method reporting limit at 0.4 microgram per liter in 1983.

Nitrate nitrogen also was present in all dry deposition samples at site A2 in 2003-07. Nitrate nitrogen concentrations in dry deposition at this site ranged from 0.39 to 2.50 mg/L. Ammonia nitrogen was present in about 60 percent of the dry deposition samples in 2003-05, and concentrations ranged from below the method detection limit (0.01 mg/L) to 0.16 mg/L. Ammonia nitrogen concentrations in the dry deposition were not reported at this site in 2006 and 2007.

Most of the nitrogen present in the wet deposition was deposited in the Mosquito Lagoon Basin in the form of nitrate. The amount of total nitrogen deposited at site A4 ranged from 1.3 lbs/acre in 1986 to 3.9 lbs/acre in 2004, and was, on average, 2.3 lbs/acre (based on data from 1984-2005). This corresponded to an average annual basin-wide loading of 90 tons, assuming the atmospheric loading across the basin was similar to that at site A4. Nitrate was the predominant form of nitrogen deposited in the basin, and accounted for more than 85 percent of the total wet deposition of nitrogen, on average.

Mercury was detected in all wet deposition samples collected at site A3 (fig. 1, table 4). Concentrations in the wet deposition varied substantially. The average concentration was 11.8 ng/L, and concentrations ranged from 2.2 to 47.1 ng/L in 2003-07. About 2.76 oz of mercury, on average, was deposited in the Mosquito Lagoon Basin each year (2003-07), assuming the concentration of mercury in wet deposition at site A3 is similar to that deposited in the Mosquito Lagoon Basin. Part of the deposited mercury likely is sequestered in the soils within the basin, especially organic and clay soils (Gabriel and Williamson, 2004). Mercury associated with the soils, however, may be transported to Mosquito Lagoon in runoff (Gabriel and Williamson, 2004).

Assessment of Surface- and Ground-Water Resources

Urban development is the predominant factor that may affect the quality of water resources in the Mosquito Lagoon Basin, and the collection of additional data would help to improve the understanding of the impact of increased urban land use on the surface- and ground-water resources. The populations of some towns in the basin have increased about 50 percent from 1990-2004, and population growth in these areas is expected to continue increasing (Walters and others, 2001). Increased nutrient, pesticide, trace element, and VOC concentrations in surface and ground waters may result from urban development in the basin. National assessments of water-quality conditions have measured increased nutrient and pesticide concentrations in surface and ground waters from urban areas compared to undeveloped areas (U.S. Geological Survey, 1999; Gilliom and others, 2006). The occurrence of VOCs in ground water also has been related to urban land use and the presence of OSDS (Zogorski and others, 2006), and increased concentrations of copper, lead, mercury, and zinc in stream-bottom sediments have been associated with urban land use (Callender and Rice, 2000; Rice, 1999).

The pesticide monitoring conducted in the Mosquito Lagoon Basin based on compiled data likely is not representative of currently used compounds. Most pesticides analyzed in the surface and ground waters of the basin were organochlorine insecticides. These pesticides were used heavily during the 1950s and 1960s (Gilliom and others, 2006), and generally not used during 1990-2006. Agricultural use of most of these insecticides was banned in the 1970s, and the remaining urban uses were cancelled during the 1980s. Of the 28 pesticides or pesticide degradates measured in the surface and ground waters in the Mosquito Lagoon Basin, only five compounds (2,4-D, dichlorprop, endosulfan, lindane, and methoxychlor) were in use from 1990 to 2004.

Organochlorine insecticides, however, still persist in the environment and may be present in Mosquito Lagoon Basin despite their decreased usage because many of these compounds are resistant to degradation (Wong and others, 2000; Gilliom and others, 2006). These compounds are hydrophobic and would not be expected to be present in the water column, which was sampled in Mosquito Lagoon and in ground water from the basin. Concentrations of these insecticides also generally are higher in aquatic biota and bottom sediments compared to the water column because these organic compounds preferentially accumulate in these matrices (Wong and others, 2000). Only data on PCBs in fish tissue were compiled as part of the data analysis; data on pesticides in bottom sediments or in fish tissue were not compiled. Monitoring the bottom sediments or aquatic biota of the Mosquito Lagoon Basin for organochlorine insecticides and PCBs instead of the water column would better define the presence and distribution of these trace organic compounds in the basin.

VOCs may be present in shallow ground water in the Mosquito Lagoon Basin, especially in areas with urban land use or septic systems. Nationally, VOC occurrence in ground water has been related to several factors including urban land use, septic systems, and dissolved oxygen concentrations in the water (Zogorski and others, 2006). Data from one well sampled in 1983 suggested most VOCs were not present in water at reporting limits of 3 µg/L. VOCs present in ground water likely would not have been detected by analytical methods using reporting limits of 3 µg/L. National assessments of VOCs in ground water conducted using low-level methods have shown that 90 percent of the total VOC concentrations in samples were less than 1 µg/L (Zogorski and others, 2006).

The data on trace element concentrations in ground and surface waters of the Mosquito Lagoon Basin likely do not represent an adequate baseline for subsequent assessments. Data were available from three Upper Floridan aquifer wells and a cluster of three surficial aquifer system wells located near Oak Hill. Data from these few wells likely do not represent conditions throughout the surficial aquifer system and Upper Floridan aquifer in the basin. The reported trace element data also may be affected by contamination because they were collected during 1976-94, a period generally preceding documentation of trace element sample contamination from improperly decontaminated sampling equipment, preservation reagants, or the filtration process (Windom and others, 1991; Taylor and Shiller, 1995; Ivahnenko and others, 2001). No information was available regarding the sampling and analytical methods used to collect these data to confirm adequate sampling techniques were used.

Additional data collection is needed to determine the quality of water from a drainage canal, which discharges untreated water into Mosquito Lagoon near Oak Hill (fig. 5b), and to improve understanding of spatial variations in water quality in the southern part of the lagoon. The potential effect of the canal on Mosquito Lagoon water quality previously was identified as an issue of concern by the NPS (Walters and others, 2001). The quality of the canal water is unknown because no data were available for analysis. Water-quality data compiled for this study showed statistically significant differences in several constituent concentrations in the southern part of the lagoon, which is managed by the NPS. Thirteen of the 61 sites sampled in Mosquito Lagoon from 1999 to 2003 were located in the southern part of the lagoon, and most of these 13 sites primarily were sampled to determine bacteria counts. To better define the spatial distribution of water-quality constituents in Mosquito Lagoon, additional nutrient, suspended sediment, and organic carbon data at surface-water sites south of Oak Hill are needed.

Additional monitoring is needed to determine the effects that OSDS and other land-use practices have on the quality of the ground-water resources in the Mosquito Lagoon Basin and CANA. Few ground-water quality data were available in the part of the basin which encompasses CANA. Only three surficial aquifer system wells near Oak Hill (fig. 5b and table 8, wells 51-53) were sampled to determine nutrient concentrations in the vicinity of property managed by the NPS during 2000-04.

Some surface-water-quality monitoring networks, such as the USGS National Water-Quality Assessment Program (Gilliom and others, 1995), include monitoring of major ions. The complete suite of major ions generally was not monitored in Mosquito Lagoon from 1999 to 2003; however, additional monitoring of major ion concentrations probably is not warranted because the distribution of estuarine vegetation and organisms is more affected by the salinity values, which regulate the osmotic pressure within aquatic organisms, rather than the concentrations of individual ions.

Development of a Water-Quality Monitoring Network

A proposed surface- and ground-water-quality monitoring network was developed for CANA to supplement existing data coverage in the Mosquito Lagoon Basin. The goals were to: (1) assess the effects of increasing urban land use on the quality of Mosquito Lagoon, (2) assess unmonitored areas which may adversely affect the quality of Mosquito Lagoon, and (3) increase the spatial coverage of monitoring in the lagoon, particularly in the southern part where spatial variations in water quality occurred.

The proposed surface-water-quality network consists of two components—a synoptic site monitoring network and a fixed-station network. The synoptic site monitoring network will provide comprehensive data on the quality of Mosquito Lagoon from a larger number of sites compared to the fixed-station network. Information from the synoptic site monitoring network will form the basis for future adjustments to the proposed fixed-station monitoring network. The fixed-station monitoring network is intended to document any substantial spatial or temporal variations in Mosquito Lagoon water quality, including long-term temporal trends in water quality.

The synoptic site monitoring network consists of 28 sites in Mosquito Lagoon (fig. 24, table 12). These sites were selected randomly using an iterating grid approach as described by Scott (1990). This approach was used to ensure the network included sites in the northern part of Mosquito Lagoon, which has the greatest density of urban land use. Preliminary attempts at synoptic site selection using simpler random selection approaches resulted in few sampling sites in the northern part of the estuary. The nonselection of sites in this area using the simpler random selection approaches likely was an artifact of the uneven distribution of open-water areas due to the large amount of islands. This resulted in potential sampling sites in the northern part of Mosquito Lagoon having little or no probability of being selected. Field reconnaissance should be done of all potential water-quality sites prior to sampling.

The fixed-station monitoring network includes eight sites (fig. 24, table 13). Most of these sites, except for site F4, were previously sampled. Site F4 is located near the outlet of the canal in Oak Hill and would characterize the quality of water discharging into Mosquito Lagoon. Sites F1 to F3 and F5 to F8 would be sampled to further characterize the distribution of selected constituents in Mosquito Lagoon. Sites F1 to F3 correspond to sites formerly sampled by Volusia County near Intracoastal Waterway channel markers 13A and 22. Site F7 would be sampled to characterize conditions near Haulover Canal, and is co-located with site 55 (fig. 5a and table 5), which is currently (2006) being sampled by the FDACS to determine bacteria counts. The highest priority is to sample sites F1 to F3 to characterize conditions in the canal draining Oak Hill and to expand the water-quality characterization of Mosquito Lagoon within the rapidly urbanizing Oak Hill area.

Sampling the fixed-station monitoring sites for a wide suite of inorganic and organic constituents on a monthly basis will help document season variations in concentrations. The suite of constituents suggested for analysis of water-quality samples (tables 14-16) was selected to: (1) characterize the basic water chemistry; (2) determine compliance with the State of Florida class II water-quality criteria; and (3) monitor constituents indicative of urban land use, such as pesticides used in urban areas and other organic compounds indicative of human activities. An analysis of bottom sediments often is used to determine the occurrence and distribution of trace elements in surface-water systems rather than water samples because trace elements accumulate onto fine-grained par-

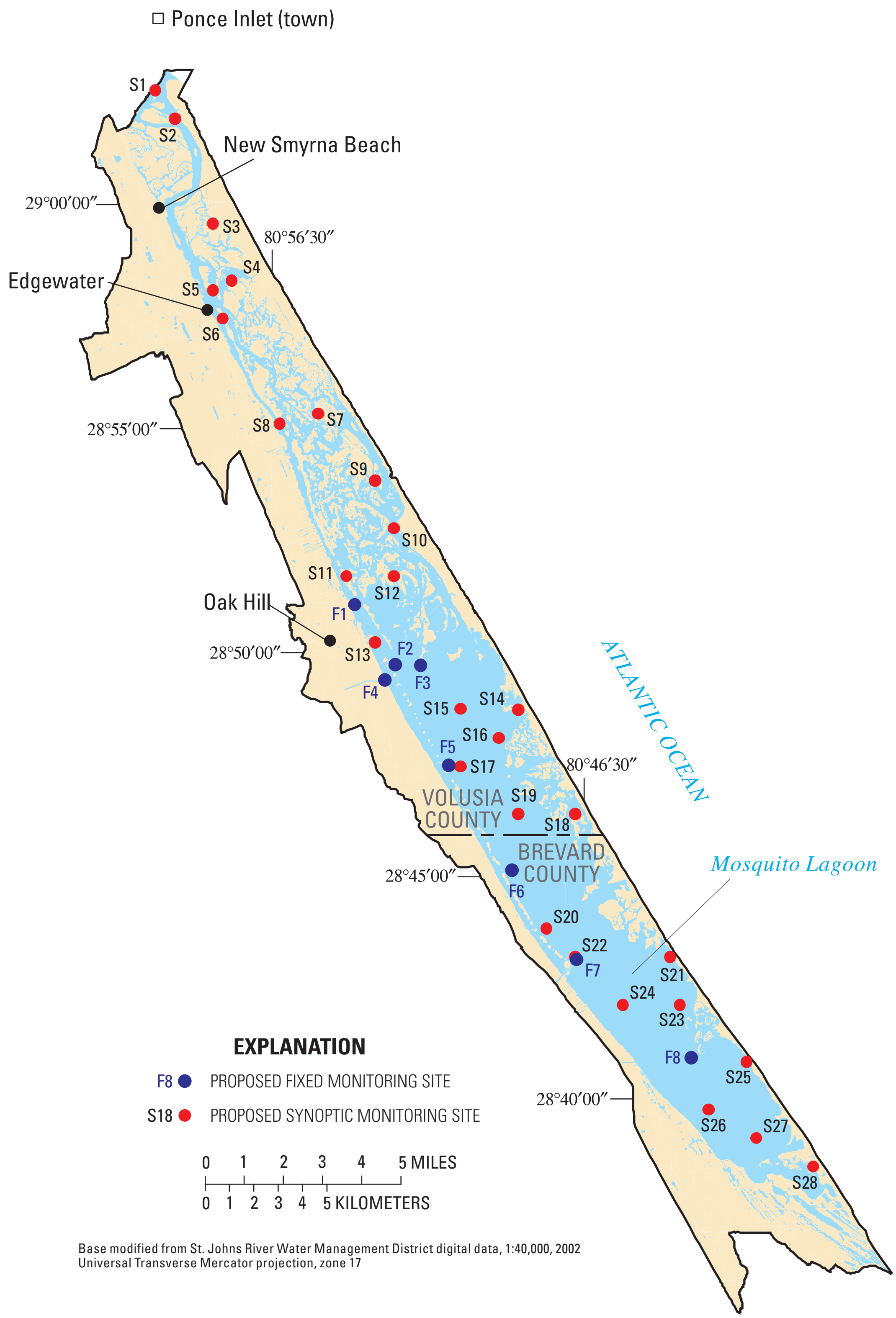

Figure 24. Proposed surface-water sites for the Canaveral National Seashore Network.

Table 12. Synoptic monitoring sites for the proposed water-quality monitoring network for Canaveral National Seashore.

Site identifier	Latitude	Longitude
S1	29° 04′ 15″	80° 55′ 26″
S2	29° 03′ 36″	80° 54′ 57″
S3	29° 01′ 15″	80° 53′ 59″
S4	28° 59′ 58″	80° 53′ 29″
S5	28° 59′ 45″	80° 53′ 59″
S6	28° 59′ 07″	80° 53′ 44″
S7	28° 56′ 58″	80° 51′ 18″
S8	28° 56′ 45″	80° 52′ 17″
S9	28° 55′ 28″	80° 49′ 51″
S10	28° 54′ 24″	80° 49′ 22″
S11	28° 53′ 20″	80° 50′ 35″
S12	28° 53′ 20″	80° 49′ 22″
S13	28° 51′ 50″	80° 49′ 51″
S14	28° 50′ 20″	80° 46′ 13″
S15	28° 50′ 20″	80° 47′ 40″
S16	28° 49′ 41″	80° 46′ 42″
S17	28° 49′ 03″	80° 47′ 40″
S18	28° 47′ 58″	80° 44′ 46″
S19	28° 47′ 59″	80° 46′ 13″
S20	28° 45′ 24″	80° 45′ 30″
S21	28° 44′ 46″	80° 42′ 20″
S22	28° 44′ 46″	80° 44′ 46″
S23	28° 43′ 41″	80° 42′ 06″
S24	28° 43′ 41″	80° 43′ 33″
S25	28° 42′ 24″	80° 40′ 24″
S26	28° 41′ 20″	80° 41′ 23″
S27	28° 40′ 41″	80° 40′ 10″
S28	28° 40′ 03″	80° 38′ 43″

Table 13. Fixed station monitoring sites for the proposed water-quality monitoring network for Canaveral National Seashore.

[ICWW, intracoastal waterway; CM, channel marker]

Site identifier	Description	Latitude	Longitude
F1	Mosquito Lagoon near ICWW, CM 7	28° 52′ 62″	80° 50′ 22″
F2	Mosquito Lagoon at ICWW, CM 13A	28° 51′ 20″	80° 49′ 20″
F3	Mosquito Lagoon east of CM 13A	28° 51′ 19″	80° 48′ 42″
F4	Outlet of Oak Hill drainage canal	28° 51′ 01″	80° 49′ 35″
F5	Mosquito Lagoon at ICWW, CM 22	28° 50′ 06″	80° 47′ 60″
F6	Mosquito Lagoon east of CM 31	28° 44′ 42″	80° 44′ 44″
F7	Mosquito Lagoon	28° 46′ 45″	80° 46′ 26″
F8	Mosquito Lagoon	28° 42′ 32″	80° 41′ 49″

ticles and organic matter in surface-water bodies (Shelton and Capel, 1994). Analysis of trace elements in water samples was included in the proposed network for CANA because these constituents are listed in the State of Florida water-quality criteria for class II surface water bodies. Sampling fixed-station sites on a monthly basis will help characterize any seasonal variations in concentrations which likely occur. Sampling synoptic monitoring sites once during the winter (Jan. - Mar.) and summer (July - Sept.) will help characterize water quality over a wide range of hydrologic conditions. Analysis of pesticides and other trace organic compound concentrations should consider using low-level methods such as those described by Zaugg and others (1995), Lindley and others (1996), Sandstrom and others (2001), Zaugg and others (2002), and Madsen and others (2003). Reporting limits for these methods range from about 0.01 to 0.08 µg/L. Analytical methods, using low reporting limits, will allow for early detection of any potential contaminants. Suggested analytes in the surface-water-quality monitoring network include pesticides which are currently used in urban areas, such as fipronil and the pyrethroid pesticides, cis-permethrin, cyfluthrin, and cypermethrin (Kreidich and others, 2005). Any pesticides or other trace organics analyzed in water samples as part of this network will need continued reassessment due to ongoing changes in the use of individual compounds.

The proposed ground-water-quality network will document water-quality conditions in the surficial aquifer system and Upper Floridan aquifer in the Mosquito Lagoon Basin, including the effect that urban land use has had on water quality, and will determine compliance with State of Florida ground-water-quality criteria. Monitoring should emphasize the southern two-thirds of the basin where few data were available. About 20 wells are needed initially for sampling as part of this new monitoring effort—with one-half of these wells located in the surficial aquifer system and the remaining wells in the Upper Floridan aquifer. Wells may be either existing or newly constructed. Sufficient information should be available from existing wells to determine: (1) the hydrogeologic unit represented by the measured water, (2) whether the well was installed to monitor a known contaminant source, and (3) the well construction. About one-half of the wells sampled to determine water-quality conditions in the surficial aquifer system and Upper Floridan aquifer should be located in undeveloped parts of the basin to determine background conditions, and the remainder should be located in developed parts, especially urban-residential areas with OSDS, to quantify the effect urban development has on ground-water quality. Consideration should be given to selecting or constructing wells in the upper parts of the surficial aquifer system and Upper

Table 14. Trace elements, physical properties, nutrients, and other constituents suggested for analysis in water samples for the proposed water-quality monitoring network for Canaveral National Seashore.

Trace elements	Physical properties
Aluminum	Salinity
Antimony	Specific conductance
Arsenic	Water temperature
Barium	Water pH
Cadmium	Dissolved oxygen concentration
Chromium	Turbidity
Cobalt	**Nutrients**
Copper	Unfiltered phosphorus
Lead	Filtered orthophosphate
Manganese	Unfiltered organic plus ammonia nitrogen
Mercury	Filtered ammonia nitrogen
Molybdenum	Filtered nitrite plus nitrate nitrogen
Nickel	**Other**
Selenium	Suspended sediment
Silver	Organic carbon
Uranium, natural	Water color
Zinc	Fecal coliform bacteria
	Enterococcus group bacteria

Floridan aquifer, to provide an early warning of any possible ground-water contamination. Sampling wells annually will help determine trends in water quality conditions. It is suggested to analyze the same constituents as in the surface-water samples (tables 14-16) and volatile organic compounds (table 17). Similar to the fixed-station and synoptic sites, analysis of pesticides or other trace organics in well water samples will need continued reassessment as a result of the initial findings when the network is implemented and due to ongoing changes in the use of individual compounds.

Collecting quality-control samples, including field blank samples, field replicate samples, and field matrix spikes (for pesticide and other trace organic constituents), will help document the quality of data collected as part of the surface- and ground-water-quality monitoring networks. Knowledge of the quality of the data collected is necessary for proper data interpretations. Results from field blank samples can be used to identify potential contaminant sources and the magnitude of contamination, and results from field replicate samples can be used to quantify the variability in concentrations associated with sampling processing, handling, and analysis. Field matrix spike results can be used to assess the loss or gain of analytes due to the water-matrix characteristics, field processing or handling, or laboratory analytical procedures. Consideration should be given to collecting a field blank and field replicate sample during each sampling event for the synoptic, fixed-station, and ground-water-quality monitoring networks. Consideration also should be given to collecting field matrix spike samples quarterly for the proposed surface-water-quality monitoring network, and annually for the proposed surficial aquifer system and Upper Floridan aquifer ground-water-quality monitoring network. Standard procedures for collecting and processing quality-control samples are described in the USGS National Water-Quality Field Manual (U.S. Geological Survey, 1997-2006).

Mosquito Lagoon and the canal that drains part of Oak Hill needs to be assessed to determine the occurrence and distribution of organochlorine pesticides and PCBs. These compounds likely reside in the aquatic biota or bottom sediments. Sampling the bottom sediments of the lagoon and canal, as well as selected aquatic biota inhabiting these waters, will help to determine whether these constituents are present. Bottom sediment and aquatic biota samples are needed at sites F1-F8 (fig. 24, table 13), with samples collected according to USGS protocol (Crawford and Luoma, 1993; Shelton and Capel, 1994). Appropriate taxa for aquatic biota samples are organisms which are: (1) abundant within studied waters; (2) sufficiently sedentary to reflect concentrations in the study area but not so sensitive to be killed by low levels of contaminants; and (3) sufficiently long lived to integrate the effects of environmental exposure for several months. Bivalves and bottom feeding fish were used to assess the occurrence and distribution of trace hydrophobic organic contaminants in the USGS National Water-Quality Assessment Program (Wong and others, 2000).

Table 15. Pesticides suggested for analysis in water samples for the proposed water-quality monitoring network for Canaveral National Seashore.

[Def, defoliant; Fum, fumigant; F, fungicide; H, herbicide; I, insecticide; M, pesticide metabolite; N, nematocide

Pesticide	Type	Pesticide	Type
1-Naphthol	M	Fipronil sulfide	M
2-chloro-2,6-diethylacetanilde	M	Fipronil sulfone	M
2-ethyl-6-methylanline	M	Desulfinylfipronil	M
3,4-dichloroaniline	M	Fipronil	I
4-chloro-2-methylphenol	M	Fonofos	I
Acetochlor	H	Hexazinone	H
Alachlor	H	Iprodione	M
2,6-diethylaniline	M	Isofenphos	I
Atrazine	H	Malaoxon	M
Azinphos-methyl	H	Malathion	I
Azinphos-methyl, oxygen analog	M	Metalaxyl	F
Benfluralin	H	Methidathion	I
Carbaryl	I	Parathion-methyl	I
Chlorpyrifos	I	Metolachlor	H
Chlorpyrifos, oxygen analog	M	Metribuzin	H
Cis-permethrin	I	Myclobutanil	F
Cyfluthrin	I	Paraoxon-methyl	M
Cypermethrin	I	Pendimethalin	H
Dacthal	H	Phorate	I
2-chloro-4-isopropylamino-6-amino-s-triazine	M	Phorate oxygen analog	M
Diazinon	I	Phosmet	I
Diazinon, oxygen analog	M	Phosmet oxon	M
Dichlorvos	Fum	Prometon	H
Dicrotophos	I	Prometryn	H
Dieldrin	I	Propyzamide	H
Dimethoate	I	Simazine	H
Ethion	I	Tebuthiuron	H
Ethion monoxon	M	Terbufos	I
Fenamiphos	N	Terbufos oxygen analog sulfone	M
Fenamiphos sulfone	M	Terbuthylazine	H
Fenamiphos sulfoxide	M	Tribufos	Def
Desulfinylfipronil amide	M	Trifluralin	H

Table 16. Organic compounds, indicative of domestic and industrial waste, suggested for analysis in water samples for the proposed water-quality monitoring network for Canaveral National Seashore.

Constituent	Constituent
Acetophenone	Isophorone
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	Isopropylbenzene (cumene)
Anthracene	Isoquinoline
Anthraquinone	d-Limonene
Benzo[a]pyrene	Menthol
Benzophenone	Metalaxyl
5-Methyl-1H-benzotriazole	Metalachlor
Bisphenol A	Naphthalene
Bromacil	2,6-Dimethylnaphthalene
Bromoform	1-Methylnaphthalene
3-*tert*-Butyl-4-hydroxy anisole (BHA)	2-Methylnaphthalene
Caffeine	p-Nonylphenol (total)
Camphor	4-Nonylphenol diethoxylates
Carbaryl	4-n-Octylphenol
Carbazole	4-*tert*-Octylphenol
Chlorpyrifos	4-Octylphenol diethoxylate (OPEO2)
Cholesterol	4-Octylphenol monoethoxylate (OPEO1)
Triethyl citrate (ethyl citrate)	Phenanthrene
Tetrachloroethylene	Phenol
2-beta Coprostanol	Pentachlorophenol
Cotinine	Tributyl phosphate
p-Cresol	Triphenyl phosphate
p-Cumylphenol	Tris(2-butoxyethyl) phosphate
Decafluorobiphenyl	Tris(2-chloroethyl)phosphate
Diazinon	Tris(dichlorisopropyl)phosphate
1,4-dichlorobenzene	Prometon
N,N-diethyl-meta-toluamide (DEET)	Pyrene
Fluoranthene	Methyl salicylate
Hexadydrohexamethylcyclopentabenzopyran (HHCB)	*beta*-Sitosterol
Indole	*beta*-stigmastanol
3-Methyl-1(H)-indole (Skatole)	Triclosan
Isoborneol	

Summary

The Mosquito Lagoon Basin encompasses 124 mi^2 in east-central Florida. Mosquito Lagoon, the northernmost lagoon in the Indian River Lagoon system, comprises a large percentage of the basin. Canaveral National Seashore (CANA), a national park, comprises the southern two-thirds of the basin. Increasing urban land use is a major issue in the basin. From 1994 to 2004, the human population increased about 36 percent.

Knowledge of water-quality conditions in the basin is necessary for CANA staff to manage the waters of the park, effectively participate in state and local water management planning, and seek the highest level of protection for the water resources of the park. Surface- and ground-water quality data from the Mosquito Lagoon Basin were compiled and analyzed to describe historical and current monitoring in the basin, and summarize surface- and ground-water quality conditions with an emphasis on identifying those areas that require additional monitoring. A surface- and ground-water-quality network designed to meet CANA's goals was developed.

Water-quality data compiled for this report were obtained from the U.S. Environmental Protection Agency's STORET data system, U.S. Geological Survey (USGS) National Water Information System, or from the agency collecting the data. Data were analyzed to describe recent conditions in the Mosquito Lagoon Basin, when sufficient data were available. Most surface-water quality data analyzed were from 1999 to 2003. The entire period of record was analyzed for pesticide, polychlorinated biphenyl, and trace element data in surface water and all ground-water-quality data (1954-2004) because these data were not collected as frequently.

Table 17. Volatile organic compounds suggested for analysis in ground-water-quality samples for the proposed water-quality monitoring network for Canaveral National Seashore.

Constituent	Constituent	Constituent
Acetone	1,4-Dichlorobenzene	Methyl methacrylate
Acrylonitrile	*trans*-1,4-Dichloro-2-butene	4-Methyl-2-pentanone
Benzene	1,1-Dichloroethane	Naphthalene
Bromobenzene	1,2-Dichloroethane	*tert*-Pentyl methyl ether
Bromochloromethane	1,1-Dichloroethylene	n-Propylbenzene
Bromodichloromethane	*cis*-1,2-Dichloroethylene	Styrene
Bromoethene	*trans*-1,2-Dichloroethylene	1,1,1,2-Tetrachloroethane
1,4-Bromofluorobenzene	Dichlorodifluoromethane	1,1,2,2-Tetrachloroethane
Bromoform	Dichloromethane	Tetrahydrofuran
Bromomethane	1,2-Dichloropropane	Tetrachloroethylene
2-Butanone	1,3-Dichloropropane	Tetrachloromethane
Butylbenzene	2,2-Dichloropropane	1,2,3,4-Tetramethylbenzene
sec-Butylbenzene	1,1-Dichloropropene	1,2,3,5-Tetramethylbenzene
tert-Butylbenzene	*cis*-1,3-Dichloropropene	Toluene
tert-Butyl methyl ether	*trans*-1,3-Dichloropropene	1,2,3-Trichlorobenzene
Carbon disulfide	Diethyl ether	1,2,4-Trichlorobenzene
Chlorobenzene	Diisopropyl ether	1,1,1-Trichloroethane
Chloroform	Ethylbenzene	1,1,2-Trichloroethane
Chloroethane	Ethyl methacrylate	Trichloroethylene
Chloromethane	Ethyl tert-butyl ether	Trichlorofluoromethane
3-Chloropropene	*o*-Ethyl toluene	1,1,2-Trichlorotrifluoroethane
2-Chlorotoluene	Hexachlorobutadiene	1,2,3-Trimethylbenzene
4-Chlorotoluene	Hexachloroethane	1,2,4-Trimethylbenzene
1,2-Dibromo-3-chloropropane	2-Hexanone	1,3,5-Trimethylbenzene
1,2-Dibromoethane	Isopropylbenzene	Vinyl chloride
Dibromomethane	4-Isopropyl-1-methylbenzene	*o*-Xylene
Dibromochloromethane	Methyl acrylate	*m*- and *p*-Xylene
1,2-Dichlorobenzene	Methyl acrylonitrile	
1,3-Dichlorobenzene	Methyl iodide	

Most water-quality monitoring in the Mosquito Lagoon Basin has focused on assessing conditions in the lagoon. About two-thirds of the sites with data compiled for this report were sampled to determine conditions in Mosquito Lagoon. No data were located for the small tributaries or canals which discharge to the lagoon. The agencies who have sampled Mosquito Lagoon include: (1) Brevard County, (2) Florida Department of Agriculture and Consumer Services, (3) Florida Department of Environmental Protection (FDEP), Marine Resources Council of East Florida, (4) NASA, (5) St. Johns River Water Management District (SJRWMD), (6) USGS, and (7) Volusia County. Ground-water-quality conditions in the basin have been assessed by the FDEP, SJRWMD, and USGS. The quality of atmospheric deposition in the vicinity of the basin has been measured by the National Atmospheric Deposition Program/National Trends Network, National Atmospheric Deposition Program/Mercury Deposition Network, and SJRWMD.

There were significant spatial and seasonal variations in water-quality constituent values in Mosquito Lagoon. Dissolved oxygen concentrations were significantly lower at sites in the southern part of the lagoon compared to the other areas. Fecal coliform bacteria counts varied among the shellfish harvesting areas. There were no significant spatial variations in enterococcus group bacteria counts; however, these were only analyzed in the northern part of the lagoon. Total nitrogen and total suspended solids concentrations were significantly greater in the southern part of the estuary compared to other areas. Total phosphorus concentrations were significantly greater near the Ponce de Leon inlet (northern part of the study area) compared to the other sites. There were significant seasonal variations in many of the constituent values as well.

Trace organic, trace element, and ground-water-quality data were limited in the Mosquito Lagoon Basin. Available pesticide data were limited to organochlorine insecticide and degradate concentrations in water from Mosquito Lagoon and selected wells. Most of these compounds were not used from 1990-2002. Additionally, these compounds are hydrophobic and would be expected to preferentially accumulate in aquatic biota and bottom sediments compared to the water column. Ground-water-quality data were compiled from 55 wells in the basin. Most of these wells had not been recently sampled. Three of the 55 wells had chloride or nutrient data from 1999 to 2004.

A surface- and ground-water-quality monitoring network was designed for CANA. Surface-water monitoring included a synoptic and fixed-station network. The fixed-station monitoring network would include monitoring at eight sites, including a canal draining Oak Hill and sampling sites in the southern part of Mosquito Lagoon where spatial variations in water-quality constituents were quantified. Ground-water quality monitoring was proposed at about 20 wells in the surficial aquifer system and Upper Floridan aquifer. Wells in each of these aquifers would be further distributed between developed and undeveloped parts of the basin. A wide range of constituents should be considered for sampling, including physical properties, nutrients, suspended sediment, and constituents associated with increased urban development such as pesticides, other trace organic compounds associated with domestic and industrial waste, and trace elements.

References Cited

Adamski, J.C., and Knowles, Leel, Jr., 2001, Ground-water quality of the surficial aquifer system and the Upper Floridan aquifer, Ocala National Forest and Lake County, Florida, 1990-99: U.S. Geological Survey Water-Resources Investigations Report 01-4008, 51 p.

Alber, Merryl, and Flory, Janice, 2002, The effects of changing freshwater inflow to estuaries—A Georgia perspective: Georgia Coastal Research Council, 45 p.

Badylak, S., and Phlips, E.J., 2004, Spatial and temporal patterns of phytoplankton composition in a subtropical coastal lagoon, the Indian River Lagoon, Florida, USA: Journal of Plankton Research, v. 26, p. 1229-1247.

Barlow, P.M., 2003, Ground water in freshwater-saltwater environments of the Atlantic Coast: U.S. Geological Survey Circular 1262, 113 p.

Beck, K.C., Reuter, J.H., and Perdue, E.M., 1974, Organic and inorganic geochemistry of some coastal plain rivers of the southeastern United States: Geochimica et Cosmochimica Acta, v. 38, p. 341-364.

Belanger, T., Heck, H., and Andrews, M., 1997, Groundwater flow characteristics of the Mosquito Lagoon, Florida: Melbourne, Fla., NPS Project Report Number CANA-N-027.000, Florida Institute of Technology.

Belanger, T., and Walker, R.B., 1990, Groundwater seepage in the Indian River Lagoon, Florida, in tropical hydrology and Caribbean water resources: Proceedings of the International Symposium American Water Resources Association, p. 367-375.

Browning, W.J., 2000, Comprehensive shellfish harvesting area survey of the South Volusia, Volusia County, Florida: Tallahassee, Florida Department of Agriculture and Consumer Services, Shellfish Environmental Assessment Section, variously paged.

Cable, J.E., Martin, J.B., Swarzenski, P.W., Lindenberg, M.K., and Steward, Joel, 2004, Advection within shallow pore waters of a coastal lagoon, Florida: Ground Water, v. 42, p. 1011-1020.

Callender, Edward, and Rice, K.C., 2000, The urban environmental gradient—Anthropogenic influences on the spatial and temporal distributions of lead and zinc in sediments: Environmental Science and Technology, v. 34, p. 232-238.

Christian, David, and Sheng, Y.P., 2003, Relative influence of various water quality parameters on light attenuation in Indian River Lagoon: Estuarine Coastal and Shelf Science, v. 57, p. 961-971.

City of Edgewater, 2006, Wastewater treatment plant processes: Accessed Nov. 20, 2006, at *http://www.cityofedgewater.org/environment/awtp.php*

Crawford, J.K., and Luoma, S.N., 1993, Guidelines for studies of contaminants in biological tissues for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 92-494, 69 p.

Dennison, W.C., Orth, R.J., Moore, K.A., Stevenson, J.C., Carter, Virginia, Kollar, Stan, Bergstrom, P.W., and Batiuk, R.A., 1993, Assessing water quality with submerged aquatic vegetation: BioScience, v. 43, p. 86-94.

Fitzgerald, S.A., 1997, Results of quality-control sampling of water, bed sediment, and tissue in the western Lake Michigan drainages study unit of the National Water-Quality Assessment Program: U.S. Geological Survey Water-Resources Investigations Report 97-4148, 24 p.

Florida Department of Environmental Protection, 2004, Criteria for surface water quality characteristics: Florida Administrative Code, Rule 62-302.30.

Gabriel, M.C., and Williamson, D.G., 2004, Principal biogeochemical factors affecting the speciation and transport of mercury through the terrestrial environment: Environmental Geochemistry and Health, v. 26, p. 421-434.

Gately, M., 1991, Comprehensive quality assurance and quality control for Volusia County Environmental Health Laboratory: Daytona Beach, Fla.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program—Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Gilliom, R.J., Barbash, J.E., Crawford, C.G., Hamilton, P.A., Martin, J.D., Nakagaki, Naomi, Nowell, L.H., Scott, J.C., Stackelberg, P.E., Thelin, G.P., and Wolock, D.M., 2006, The quality of our Nation's waters—Pesticides in the Nation's streams and ground water, 1992-2001: U.S. Geological Survey Circular 1291, 169 p.

Gilmour, C.C., Henry, E.A., and Mitchell, R., 1992, Sulfate stimulation of mercury methylation in freshwater sediments: Environmental Science and Technology, v. 26, p. 2281-2287.

Helsel, D.R., 1990, Less than obvious—Statistical treatment of data below the detection limit: Environmental Science and Technology, v. 24, p. 1766-1774.

Helsel, D.R., 2005a, Nondetects and data analysis—Statistics for censored environmental data: Hoboken, New Jersey, Wiley-Interscience, 250 p.

Helsel, D.R., 2005b, More than obvious: Better methods for interpreting nondetect data: Environmental Science and Technology, v. 39, p. 419A-423A.

Helsel, D.R., and Cohn, T.A., 1988, Estimation of descriptive statistics for multiply censored water-quality data: Water Resources Research, v. 24, p. 1997-2004.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources: U.S. Geological Survey Techniques of Water Resources Investigations, book 4, chap. A3, 512 p.

Howell, J.M., Coyne, M.S., and Cornelius, P.L., 1996, Effect of sediment particle size and temperature on fecal bacteria mortality rates and the fecal coliform/fecal streptococci ratio: Journal of Environmental Quality, v. 25, p. 1216-1220.

Ivahnenko, Tamara, Szabo, Zoltan, and Gibs, Jacob, 2001, Changes in sample collection and effects on retrospective comparability of low-level concentrations of trace elements in ground water: Water Research, v. 35, no. 15, p. 3611-3624.

Kjerfve, Björn, and Magill, K.E., 1989, Geographic and hydrodynamic characteristics of shallow coastal lagoons: Marine Geology, v. 88, p. 187-199.

Kreidich, N.I., Flint, M.L., Wilen, C.A., and Zhang, Minghua, 2005, Tracking non-residential pesticide use in urban areas of California: Davis, University of California, 111 p.

Lapham, W.W., Hamilton, P.A., and Myers, D.N., 2005, National Water-Quality Assessment Program—Cycle II regional assessment of aquifers: U.S. Geological Survey Fact Sheet 2005-3013, 4 p.

Lee, D.R., 1977, A device for measuring seepage flux in lakes and estuaries: Limnology and Oceanography, v. 22, p. 140-147.

Lindley, C.E., Stewart, J.T., and Sandstrom, M.W., 1996, Determination of low concentrations of acetochlor in water by automated solid-phase extraction and gas chromatography with mass selective detection: Journal of AOAC International, v. 79, p. 962-966.

Madsen, J.E., Sandstrom, M.W., and Zaugg, S.D., 2003, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—A method supplement for the determination of fipronil and degradates in water by gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 02-462, 11 p.

Marine Resources Council of East Florida, 2003, Indian River Lagoon watch fact sheet—Water quality testing program: Accessed May 5, 2006, at *http://www.mrcirl.org/water/pdf/FactSheet.pdf*

Marine Resources Council of East Florida, 2004, Instruction manual for water-quality testing: Rockledge, Fla., Marine Resources Council, 28 p.

Marine Resources Council of East Florida, 2007, Indian River Lagoonwatch: Accessed May 1, 2007, at *http://www.mrcirl.org/water/watch.html*

Martin, J.B., Cable, J.E., and Swarzenski, P.W., 2002, Quantification of ground water discharge and nutrient loading to the Indian River Lagoon: Palatka, Fla., St. Johns River Water Management District Special Publication SJ2002-SP5, 246 p.

Martin, J.B., Cable, J.E., Swarzenski, P.W., and Lindenberg, M.K., 2004, Enhanced submarine ground water discharge from mixing of pore water and estuarine water: Ground Water, v. 42, p. 1000-1010.

Martin, J.D., Gilliom, R.J., and Schertz, T.L., 1999, Summary and evaluation of pesticides in field blanks collected for the National Water-Quality Assessment Program, 1992-95: U.S. Geological Survey Open-File Report, 102 p.

McGurk, B., Burger, P., and Toth, D., 1998, Chloride content of groundwater within the Floridan aquifer system in east-central Florida [abs.]: American Water Resources Association Annual Water Resources Conference, Point Clear, Alabama, November 16-19, 1998, p. 85.

McKnight, D.M., Thurman, E.M., Wershaw R.L., and Hemond, Harold, 1985, Biogeochemistry of aquatic humic substances in Thoreau’s Bog, Concord, Massachusetts: Ecology, v. 66, p. 1339-1353.

Menheer, M.A., and Brigham, M.E., 1997, Ground-water sampling methods and quality-control data for the Red River of the North Basin, Minnesota, North Dakota, and South Dakota, 1993-95: U.S. Geological Survey Water-Resources Investigation Report 96-4317, 34 p.

Mueller, D.K., 1998, Quality of nutrient data from streams and ground water sampled during 1993-95—National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 98-276, 25 p.

National Atmospheric Deposition Program, 1999, National trends network—-Site operation manual, NADP Manual 1999-01: Champaign, IL, Water Survey, accessed Nov. 20, 2006, at *http://nadp.sws.uiuc.edu/lib/manuals/opman.pdf*

Obiri-Danso, K., and Jones, K., 2000, Intertidal sediments as reservoirs for hippurate negative campylobacters, salmonellae and faecal indicators in three EU recognised bathing waters in northwest England: Water Research, v. 34, p. 519-527.

O’Reilly, A.M., Spechler, R.M., and McGurk, B.E., 2002, Hydrogeology and water-quality characteristics of the Lower Floridan Aquifer in east-central Florida: U.S. Geological Survey Water-Resources Investigations Report 02-4193, 60 p.

Pandit, A., and El-Khazen, C.C., 1990, Groundwater seepage into the Indian River Lagoon at Port St. Lucie: Florida Scientist, v. 53, p. 169-179.

Pierson, W.L., Bishop, K., Van Sendern, D., Horton, P.R., and Adamantidis, C.A., 2002, Environmental water requirements to maintain estuarine processes: Environment Australia, National River Health Program, 147 p.

Rantz, S.E., 1982, Measurement and computation of streamflow: U.S. Geological Survey Water Supply Paper 2175, 631 p.

Rey, J.R., and Rutledge, C.R., 2006, Seagrass beds on the Indian River Lagoon: Gainesville, University of Florida IFAS Extension Publication ENY-647, 5 p.

Rice, K.C., 1999, Trace-element concentrations in streambed sediment across the conterminous United States: Environmental Science and Technology, v. 33, p. 2499-2504.

Rutledge, A.T., 1985, Ground-water hydrology of Volusia County, Florida, with emphasis on occurrence and movement of brackish water: U.S. Geological Survey Water-Resources Investigations Report 84-4206, 84 p.

Sandstrom, M.W., Stroppel, M.E., Foreman, W.T., and Schroeder, M.P., 2001, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of moderate-use pesticides and selected degradates in water by C-18 solid-phase extraction and gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01-4098, 70 p.

Scott, J.C., 1990, Computerized stratified random site-selection approaches for design of a ground-water-quality sampling network: U.S. Geological Survey Water-Resources Investigations Report 90-4101, 109 p.

Scudlark, J.R., Conko, K.M., and Church, T.M., 1994, Atmospheric wet deposition of trace elements to Chesapeake Bay—CBAD study year 1 results: Atmospheric Environment, v. 28, p. 1987-1498.

Shelton, L.R., and Capel, P.D., 1994, Guidelines for collecting and processing samples of streambed sediment for analysis of trace elements and organic contaminants for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94-458, 20 p.

Sigua, G.C., Steward, J.S., and Tweedale, W.A., 1996, Indian River Lagoon water quality monitoring network—Proposed modifications: Palatka, Fla., St. Johns River Water Management District Technical Memorandum Number 12, 70 p.

Sigua, G.C., Steward, J.S., and Tweedale, W.A., 2000, Water-quality monitoring and biological integrity assessment in the Indian River Lagoon, Florida—Status, trends, and loadings (1988-94): Environmental Management, v. 25, p. 199-209.

Sigua, G.C., and Tweedale, W.A., 2004, Assessing redesigned effectiveness of the water quality monitoring program in the Indian River Lagoon, Florida: Aquatic Conservation—Marine and Freshwater Ecosystems, v. 14, p. 49-64.

Sprinkle, C.L., 1989, Geochemistry of the Floridan aquifer system in Florida and parts of Georgia, South Carolina, and Alabama: U.S. Geological Survey Professional Paper 1403-I, 105 p.

St. Johns River Water Management District, 2002, Land use/land cover, 2000: Accessed Oct. 1, 2003, at *http://sjr.state.fl.us/gisdevelopment/index.html*

Steward, J.S., Brockmeyer, R., Virnstein, R., Gostel, P., Sime, P., and Van Arman, J., 2003, Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan, 2002 Update: Palatka, Fla., St. Johns River Water Management District, and West Palm Beach, South Florida Water Management District, 272, p.

Steward, J.S., and Higman, J.C., 1991, Master water-quality monitoring network quality assurance/quality control manual for the Indian River Lagoon surface-water quality monitoring network project, 1988-1990: Palatka, Fla., St. Johns River Water Management District, 331 p.

Steward, J.S., Virnstein, R., Haunert, D., and Lund, F., 1994, Surface Water Improvement and Management (SWIM) Plan for the Indian River Lagoon: Palatka, Fla., St. Johns River Water Management District, and West Palm Beach, South Florida Water Management District, 120 p. plus appendices.

Stumm, Werner, and Morgan, James, 1981, Aquatic chemistry—An introduction emphasizing chemical equilibria in natural waters, (2d ed): New York, John Wiley and Sons, 780 p.

Sun, D., and Sheng, Y.P., 2001, Modeling suspended sediment transport under combined wave current actions in Indian River Lagoon: Gainesville, University of Florida, Civil and Coastal Engineering Department.

Taylor, H.E., and Shiller, A.M., 1995, Mississippi River methods comparison study—Implications for water quality monitoring of dissolved trace elements: Environmental Science and Technology, v. 29, p. 1313-1317.

Thurman, E.M., and Malcolm, R.L., 1983, Structural study of humic substances—New approaches and methods, *in* Christman R.F. and Gjessing, E.T. (eds.), Aquatic and Terrestrial Humic Materials: Michigan, Ann Arbor Press.

Tibbals, C.H., 1990, Hydrology of the Floridan aquifer system in east-central Florida: U.S. Geological Survey Professional Paper 1403-E, 98 p.

Toth, D.J., 1988, Salt water intrusion in coastal areas of Volusia, Brevard, and Indian River Counties: Palatka, Fla., St. Johns River Water Management Technical Publication 88-1, 160 p.

U.S. Census Bureau, 2005, U.S. Census Bureau Population Finder [cited September 2005]: Accessed Nov. 20, 2006, at *http://www.census.gov*

U.S. Congress, 1975, An Act—To establish the Canaveral Seashore in the State of Florida, and for other purposes: Public Law 93-626, Title 16, Chapter 1, Section 459j, January 3, 1975.

U.S. Department of Agriculture, 1991, State Soil Geographic (STATSGO) data base: Fort Worth, Texas, Miscellaneous Publication 1492, National Cartography and GIS Center.

U.S. Department of Agriculture, 1994, State Soil Geographic (STATSGO) data base, data use information: Fort Worth, Texas.

U.S. Environmental Protection Agency, 1986, Ambient water quality criteria for bacteria–1986: Washington D.C., Report Number 440/5-84-002, 18 p.

U.S. Environmental Protection Agency, 2003, National primary drinking water standards: Washington D.C., Report 816-F-03-016.

U.S. Environmental Protection Agency, 2006, National estuary program: Accessed Nov. 20, 2006, at *http://www.epa.gov/owow/estuaries/programs/irl.htm*

U.S. Environmental Protection Agency, 2007, EPA relying on existing clean air act regulations to reduce atmospheric deposition to the Chesapeake Bay and its watershed: Report Number 2007-P-00009, 13 p. plus appendices.

U.S. Geological Survey, 1997-2006, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9.

U.S. Geological Survey, 1999, The quality of our Nation's waters—Nutrients and pesticides: U.S. Geological Survey Circular 1225, 82 p.

Urban, N.R., Bayley, S.E., and Eisenreich, S.J., 1989, Export of dissolved organic carbon and acidity from peatlands: Water Resources Research, v. 25, p. 1619-1628.

Utilities Commission of New Smyrna Beach, 2006, Wastewater: Accessed Nov. 20, 2006, at *http://www.ucndb.net/water/waste.shtml*

Virnstein, R.W., Mikkelsen, P.S., Cairns, K.D., and Capone, M.A., 1983, Seagrass beds versus sand bottoms—The trophic importance of their associated benthic invertebrates: Florida Scientist, v. 46, p. 363-381.

Volusia County Health Department, 1999, Recommendations on the status of sewage disposal and collection in Volusia County, Florida, 1999: Daytona Beach, Fla., Volusia County Health Department.

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A., 2006, Guidelines and standard procedures for continuous water-quality monitors—Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. and 8 attachments.

Walters, Linda, Roman, Arte, Stiner, John, and Weeks, Don, 2001, Water resources management plan—Canaveral National Seashore, Florida: Titusville, Fla., National Park Service, 224 p. and appendices.

Windom, H.L., Byrd, J.T., Smith, R.G., and Huan, Feng, 1991, Inadequacy of NASQAN data for assessing metal trends in the Nation's rivers: Environmental Science and Technology, v. 25, p. 1137-1142.

Wong, C.S., Capel, P.D., and Nowell, L.H., 2000, Organochlorine pesticides and PCBs in stream sediment and aquatic biota—Initial results from the National Water-Quality Assessment Program, 1992-1995: U.S. Geological Survey Water-Resources Investigations Report 00-4053, 87 p.

Zaugg, S.D., Sandstrom, M.W., Smith, S.G., and Fehlberg, K.M., 1995, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of pesticides in water by C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry with selected-ion monitoring: U.S. Geological Survey Open-File Report 95-181, 60 p.

Zaugg, S.D., Smith, S.G., Schroeder, M.P., Barber, L.B., and Burkhardt, M.R., 2002, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—Determination of wastewater compounds by polystyrene-divinylbenzene solid-phase extraction and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01-4186, 37 p.

Zieman, J.C., 1982, Food webs in tropical seagrass systems; coral reefs, seagrass beds, and mangroves—Their interaction in the coastal zones of the Caribbean, Proceedings of a workshop: St. Croix, U.S. Virgin Islands, West Indies Laboratory, May 1982, UNESCO Reports in Marine Science, Paris, no. 23, p 80-86.

Zogorski, J.S., Carter, Janet, Ivahnenko, Tamara, Lapham, W.W., Moran, M.J., Rowe, B.L., Squillace, P.J., and Toccalino, P.L., 2006, The quality of our Nation's waters—Volatile organic compounds in the Nation's ground water and drinking-water supply wells: U.S. Geological Survey Circular 1292, 101 p.