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A Summary of Estuarine and Marine Water Quality Information, EVER, BISC, and Adjacent Estuaries, 1879 to 1977

NATIONAL PARK SERVICE
DEPARTMENT OF THE INTERIOR

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A summary of estuarine and marine water quality information collected in Everglades National Park, Biscayne National Monument, and adjacent estuaries from 1879 to 1977.

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Table of Contents

List of Figures

List of Tables

Executive Summary

The south Florida regional drainage system comprises about 36,000 km^2 (Fig. 1). The upland watershed covers some 13,600 km^2 and extends 150 km from Lake Okeechobee to the Gulf of Mexico and Florida Bay. Within this system, the National Park Service manages about 4,400 km^2 of upland watershed and 3,800 km^2 of estuary and coastal coral reefs in Everglades National Park, Big Cypress National Preserve, and Biscayne National Monument. For the purposes of this report, the watershed was divided into four drainage systems based on climate, physiography, freshwater runoff-salinity dilution dynamics, and the influence of man: (1) Big Cypress; (2) Everglades; (3) Taylor Slough; (4) Southeastern Atlantic Coastal Ridge. The estuaries and coastal waters were divided into six zones based on physiography and watershed: (1) Big Cypress estuary; (2) Everglades estuary; (3) Florida Bay; (4) Barnes Sound and Card Sound; (5) southern Biscayne Bay; and (6) northern coral reef tract. The central Everglades drainage comprises over three-fourths of the region upstream from Whitewater Bay and the southeastern Gulf of Mexico estuaries. To the west and east, the Big Cypress and Taylor Slough watersheds flow into the Big Cypress estuaries and Florida Bay respectively. These three estuaries are each approximately 1,000 km^2 in size. The remaining watershed southeast of the Atlantic Coastal Ridge influences the much smaller systems of Card-Barnes Sounds, southern Biscayne Bay, and to a lesser extent, the northern coral reef track east of the upper Florida Keys. To protect and perpetuate the biotic communities in these aquatic ecosystems in a natural state, it is necessary to be able to evaluate the effects of watershed management on the estuaries and to detect contamination from adjacent systems. A comprehensive water quality monitoring system is needed to provide the information to make such evaluations.

This report summarizes many published and unpublished reports of water quality information in Everglades National Park, Biscayne National Monument, and adjacent estuaries as the first step in the design, development, and implementation of a comprehensive monitoring system. Most of these data were collected in conjunction with short-term multi-disciplinary investigations. A total of 55 hydrographic studies dating from 1879 to the present are summarized in Figures 2, 4, 6, 9, 11, and 12. Over half of the studies were conducted for a period of one year or less; less than 40% between one and five years; and only 6% were over five years in duration.

Twenty-three studies were conducted in Florida Bay, 17 in the Everglades estuary, 16 in southern Biscayne Bay, 14 in Card-Barnes Sound, 7 in the Big Cypress estuary, and five in the area of the northern coral reef tract.

A total of 981 coastal water quality stations were identified from 47 studies reporting specific station locations. The number and distribution of these stations are presented in Figures 3, 5, 7, 8, 10, and 13. A list of studies with station codes are shown in Table 1.

In decreasing order, the most frequently measured water quality parameters from the 55 studies were salinity (87%), water temperature (74%), dissolved oxygen (38%), pH (26%), turbidity (11%), and chemical constituents (8%).

A summary of variations and minimum and maximum values of these parameters follows. For a more complete report, refer to Tables 2-7 and the original studies cited in the references.

The greatest variations in salinity occur in Florida Bay. During the intensive drought periods of 1965-66 and 1974-75, salinities varied along the northern Florida Bay shoreline from 0 to 67 o/oo and 1 to 67 o/oo respectively. The highest coastal salinity known in the region, 70 o/oo was recorded in Snake Bight (Florida Bay) during the 1954 drought period.

Water temperatures ranged between 11 and 42°C. Temperatures ranged from 11°C near the Buttonwood Canal to 40°C over the shallow eastern Florida Bay mud flats while temperatures in southern Biscayne Bay varied from 11°C to about 42°C in waters near the influence of the Turkey Point Power Plant.

Dissolved oxygen concentrations ranged from 0 to 15 ppm. The lowest values were recorded during peak periods of freshwater runoff in river headwaters and northeast Florida Bay, and in northcentral Florida Bay during the late summer die-off of seagrasses. The highest value (15 ppm) of record was observed over a shallow water, shoalgrass-algal community in western Florida Bay. The most extensive coastal dissolved oxygen analyses (diel observations) were recorded in the Everglades estuary.

The Florida Bay waters also showed the greatest variations in recorded pH values. Coastal pH values ranged from 5.8 over the shallow western Florida Bay seagrass flats to 9.6 over the mid-bay, shallow water algal beds. These pH and dissolved oxygen values reflected the peak periods of respiratory and photosynthetic activity, respectively.

Turbidities fluctuated from 0 to 73 FTU. In Florida Bay, turbidity ranged from 0.3 FTU, offshore in the western portions of the Bay and along the eastern boundary near Key Largo, to 53-73 FTU near the northern Florida Bay coastline. Consistently low values of 0-3 FTU were reported in the Everglades estuary and in southern Biscayne Bay.

Several investigations reported chemical data for selected drainage basins. These publications give the range of variation, minima-maxima over occasionally very irregular sampling periods. Constituents of particular importance are those that have exceeded recommended levels which constitute a hazard in the marine environment as determined by the U.S. Environmental Protection Agency (Water

Quality Criteria, 1972; and Quality Criteria for Water, 1976) and include the following: ammonia, aluminum, arsenic, iron, copper, manganese, mercury, fluoride, magnesium, and calcium (Table 8).

INTRODUCTION

The marine and estuarine waters of Everglades National Park and Biscayne National Monument play a vital role in the economic, political, and social development of South Florida. Park estuaries and coastal areas generate fishery products of great significance in addition to their aesthetic, scientific, and recreational values. It is important to understand the ecological nature and quality of the water masses which determine in large part the structure and composition of the biotic communities in these aquatic ecosystems, if they are to be protected and perpetuated in a natural state.

Everglades National Park, which contains most of south Florida's coastal zone, is one of the most complex coastal systems in the United States and is largely dependent on freshwater flow from north of its boundaries. Runoff is one of the most important factors affecting south Florida ecosystems since it results in brackish-water conditions which create the estuarine habitat so necessary to development of coastal organisms.

For nearly a century, the principal natural drainage patterns of South Florida have been increasingly altered by man. Originally, the effective Everglades watershed extended north to Ocala in Central Florida covering about 23,000 km^2. Earliest reports of disrupted water flow occurred during the construction of Lake Okeechobee drainage canals to the Gulf of Mexico in the 1880's. These activities then quickly expanded southward from Lake Okeechobee into the Everglades peat and muck lands and continued extensively through the 1920's for land reclamation, agricultural, and flood control purposes. The drainage of freshwater retentive peat beds lead to compaction, oxidation and frequently to burning of the peat deposits. This in turn, led to reversal of direction of sheet flow, to reductions of the water table and changes in estuarine salinity. Following the hurricane of 1928, additional canals, levees and water control structures were built, draining thousands of cubic meters of water into the Gulf of Mexico and the Atlantic Ocean particularly before each hurricane season. Spurred on by $60 million of damage caused by two hurricanes and an exceptionally wet rainy season in 1947, the U. S. Army Corps of Engineers developed a comprehensive plan for water management in south Florida for approval by the State of Florida. The Central and Southern Florida Flood Control Project was authorized in 1948, and the South Florida Flood Control District (changed to South Florida Water Management District in 1977) was created by the State in 1949. Efforts to conserve water needed to recharge the depleted aquifer system were undertaken, and large, shallow water conservation areas were built, but their levees prevented the natural flow of freshwater into the lower Everglades.

By 1960 the original 23,000 km^2 Everglades watershed was reduced to about 7,800 km^2, resulting in increased coastal salinities, intensified drought periods, and a considerable reduction of the hydroperiod in the rivers and estuaries of South Florida (Tabb et al., 1962). The effects of channelization have further resulted in concentrations of domestic, industrial, and agricultural pollutants (Marshall, 1971). Although Park coastal waters are relatively free from domestic and industrial contamination (Kolipinski and Higer, 1969), much of the southeast Atlantic Coastal Ridge drainage has long suffered from inadequately treated effluents, which have caused local health problems and frequent fish kills (National Academy of Sciences, 1970).

While Park estuaries and rivers have escaped the adversities of industrial and domestic contamination, thus far, they are not immune to the effects of persistent insecticides, trace metals, and macronutrients. These chemical parameters continue to be a threat to the coastal environments of south Florida. Upland agricultural practices, particularly by winter vegetable, citrus, and sugarcane growers, require the use of various pesticides, trace elements, and nutrients for the healthy growth of their crops. Undesirable concentrations of these chemical pollutants are routinely transported southward by canalization, frequently resulting in unnaturally high concentrations in surface sediments, marine biota, and in the overlying waters of the bays and rivers.

A comprehensive water quality monitoring system is needed in South Florida coastal zones to help evaluate the effects of watershed management on the estuaries and to detect contamination from adjacent areas. Before developing such a system, it was necessary to review the history of previous water quality investigations in the region. The purpose of this report is to summarize published and unpublished water quality information collected in Everglades National Park and Biscayne National Monument from 1879 to 1977. Biotic and soil concentrations of potentially toxic chemicals, presumably from agriculture runoff to the north, have been previously reported and summarized by various authors (Klein et al., 1970; Harris et al., 1973; Little, et al., 1970; Ogden et al., 1974) and are not included in this report.

AREA DESCRIPTION

Regional Climate

Florida has two major climatic zones, the wet subtropical and the tropical rainy. Based on seasonal air temperature and rainfall variations, these groups are located to the north and south of Lake Okeechobee, respectively.

Within the tropical rainy zone mean annual air temperatures range from 17°C immediately south of the "Lake" to 29°C along the Florida Keys. The coastal zone is influenced principally by the heat capacities of the Gulf of Mexico and the

Atlantic Ocean. The Gulf stream has the most prominent effect during the winter months causing isotherms between Homestead and Fort Pierce to align parallel to the Atlantic Coastal Ridge. South Florida estuarine and coastal marine water bodies are essentially tropical in nature while freshwaters are characterized as subtropical.

The mean annual rainfall varies regionally from 102 cm in the upper Florida Keys to 165 cm over the northern Atlantic Coastal Ridge. Cyclic rainfall patterns can best be expressed as bimodal annual rainfall with peaks in June and September/October, and a five year recurrence period of above normal rainfall years, chiefly over the Atlantic Coastal Ridge. Maximum rainfall, along with most tropical storms and depressions, occurs from May through October.

December through March are months of minimum rainfall, averaging less than 10 cm per month. Relatively moderate southeast tradewinds occur during the spring-summer months with a notable wind speed increase from northlies during the fall-winter passage of cold fronts. It should be noted that while these figures are mean values extending over many years, there are substantial monthly departures from these observations.

Rainfall eventually percolates through the porous soil and bedrock forming a dynamic groundwater system which interacts with precipitation, evaporation, freshwater runoff, tides, winds, water quality parameters, sediments, flora, and fauna to influence chemical, physical, and biological processes occurring throughout the South Florida environment.

Big Cypress Estuary (Chokoloskee Bay to Broad River)

The 6,400 km^2 Big Cypress drainage system is located in southwest Florida in portions of Collier, Lee, Monroe, Dade, Broward, and Hendry Counties. It is bounded by the lower land elevations of the Everglades drainageway on the east and on the southwest by the coastal mangrove forest of the Ten Thousand Islands. It is an area of relatively flat land with an average elevation of about 5 meters above sea level. Numerous rock outcrops and small circular depressions mark the surface of the Tamiami limestone bedrock. The land slopes in a southerly direction, dropping from 8 to 16 cm/km. For a more detailed description of the Big Cypress watershed, the reader is referred to Carter et al., (1973).

Large upland areas are characterized by small to medium Cypress trees, swamps containing large Cypress and deciduous broad leaf trees; pine islands; and wet prairies. To the south, the marsh vegetative associations are dominated by sawgrass, cattails and spike rush. An extensive coastal mangrove belt abounds seaward from the marsh associates. Seagrasses, particularly shoalgrass and turtlegrass dominate the intertidal and subtidal estuarine and marine basin waters of the Big Cypress drainage system.

The soil of the Big Cypress Swamp is composed of sand, marl, or mixtures of both which form layers usually less than 60 cm deep on the limestone. Peat and muck accumulate in depressions to depths of a meter or more.

Based on bedrock configurations and man-made waterways, drainage patterns in the Big Cypress can be divided into three sub-areas. Sub-area A northeast of a low ridge containing about 1,170 km^2, drains southeastward into Conservation area 3A; some of this water eventually reaches the Park. Sub-area B includes approximately 1,430 km^2 in the western portion of the swamp and drains southward between Naples and the Fahka Union Canal into the Gulf of Mexico. Sub-area C (3,760 km^2) located in the central portion of the Big Cypress between the Fahka Union Canal and the L-28 Tieback Levee drains to the southwest toward the western portion of Everglades National Park (Figure 1). It is this area that supplies over 56 percent of the surface water flow into Everglades National Park (Klein et al., 1970) and serves as the major watershed for the 1,013 km^2 Big Cypress estuarine basin located between Chokoloskee Bay and Broad River.

Although water quality in the Big Cypress is relatively good it has been degraded to some extent by man's activities (McPherson, 1974).

Rainfall in the Big Cypress Swamp, particularly in sub-area C (herein designated as the watershed of the Big Cypress Estuary) averages between 140-150 cm a year. To the south, near Everglades City and Naples the average annual percipitation ranges between 125-140 cm.

The nearshore environment of the drainage basin is characterized by shallow, (1-2 m) muddy bays and rivers with numerous oyster shell banks. Depths of the rivers occasionally exceed the average depth of the bays by 1 to 2 meters. Mixed semidiurinal tides of the area vary considerably along the Gulf Coast shoreline. According to National Ocean Survey's Tide Tables, the normal range at Lostman's River is 128 cm, 79 cm at Everglades City and 27 cm at Onion Bay.

The nearshore basin sediments are composed primarily of soft mud and shell sand,whereas soft to firm shell-sands characterize the offshore environments.

The large, water tolerant animal species of the upland wilderness areas include deer, bear, and panther. The larger dominant species which spend part of their life history in the aquatic habitat include alligators and wading birds (white ibis and great egret).

Other dominant species which are completely water-dependent in the fresh-water and marine environment are chiefly fishes, benthic crustaceans, and the manatee. Small fish species, killifish and sunfish predominate in the temporary fresh-water zones while the Florida gar and bowfin are the larger, major predatory fish species found in man-made canal habitats. The crayfish Procambarus alleni, is the principal macrocrustacean found in the swampy freshwater environment. Commercially important stone crabs, pink shrimp and blue crabs are common in the marine environment. Small forage fishes, anchovies, sardines, porgies, and mullet dominate the coastal habitats adjacent to the western boundary of the Park and presumably represent the principal fish species found between Chokoloskee Bay and Broad River. Larger fish, snook and red drum, are seasonally common in the sportfish harvest while striped mullet dominate the commercial finfishery.

Everglades Estuary (Harney River to Whitewater Bay)

The 7,770 km^2 Everglades watershed extends north to Lake Okeechobee, and is all that remains of the original 22,500 km^2 drainage system which covered much of central and south Florida.

Topographically, the Everglades environment is underlain by Pleistocene bedrock configurations which form limestone ridges on both sides of the trough-shaped Everglades waterway. The Atlantic Coastal Ridge forms the eastern boundary while the western edge is established at the more highly elevated Tamiami limestone surfaces of the Big Cypress Swamp. The Everglades trough or channel, an area of low relief, drains to the southwest exiting to the Gulf of Mexico via the Shark River Slough (Figure 1). Gleason (1974) presents a detailed analysis of Everglades environmental characteristics. The 1,245 km^2 Everglades Estuary receives the bulk of the slow Everglades surface runoff.

Immediately south of Lake Okeechobee rainfall averages 115-130 cm per year and increases towards the central glades to 125-150 cm and then diminishes to 115-130 cm per year over the Everglades Estuary. Water depths in the estuary average from less than 1 m in Coot Bay to about 2-5 m in the Shark River. Tidal fluctuations vary considerably within the basin environments. Nearshore, shallow bays experience a normal tidal range of about only 15 cm while the greatest range (110 cm) occurs at the mouth of the Shark River.

Plant communities in the upper Everglades system are characterized by custard-apple and willow swamps, tree hammocks, water-lily sloughs, and sawgrass marsh. Red and black mangrove swamp predominates along the lower glades adjacent to the Gulf coast shoreline. The marine and estuarine flora are composed mostly of members of the algal genera Udotea, Batophora, and Chara in the nearshore bays, while shoalgrass and turtlegrass predominate offshore.

Substrate types of the Everglades system are not distinct categories but correspond generally to their overlying plant associates. Thick muck-peat often mixed with sand characterize the upland areas whereas fibrous sawgrass and mangrove peat layers constitute much of the central and southerly portions of the watershed, respectively. Major coastal substrate types include soft marls mixed with wood and shell, shell-sands, and rock outcrops.

Most of the Everglades fauna are wholly dependent upon or partially adapted to water levels. The larger, upland water associated species are bear, deer, and panther. Other larger animals which are largely dependent upon the freshwater environment for existence are alligators, wading birds (herons and white ibis), and small mammals. Mosquito fish (Gambusia affinis), dominate in the salt-freshwater transistional areas of the mangrove zone. Animal life wholly dependent upon the coastal environment are mostly found in association with particular substrate types and certain plant communities. Small species, pinfish and pigfish, are among the most abundant forage fish found in the seagrass beds while filterfeeders, anchovies and sardine-like forage fish, predominate over scantly vegetated or unvegetated mud, sand or rock-outcrop bottom types. The sportfish harvest is characterized primarily by larger estuarine-dependent species including the spotted seatrout and snook. Among the most abundant estuarine dependent shellfish species are the commercially important pink shrimp and blue crabs.

Florida Bay

Historically the coastal marine and estuarine waters of Florida Bay received some freshwater drainage from the 22,500 km^2 watershed of the south Florida Everglades. This Everglades watershed which has been reduced recently (1960) to approximately 7,800 km^2 through canalization, consists of three drainages, the Big Cypress, Shark River Slough, and Taylor Slough. The 1800 km^2 Taylor Slough region, which has probably functioned as an independent basin throughout much of its history, drains through gaps in the Atlantic Coastal Ridge, into mangrove swamps which rim the bays and sounds along the northern Florida Bay shoreline.

Only two well defined streams flow into the Florida Bay system, Taylor River and East river, which drain into Little Maderia Bay. Florida Bay is a triangular, bimodally windy, tropical lagoon-bay which lies in a shallow rock-floored trough between the emergent barrier reefs of the upper Florida Keys and two series of mangrove lined bays and sounds at the extreme southern tip of the Florida Pennisula. The Florida Bay surface area from East Cape Sable to Key Vaca is 2,250 km^2 with a diurnal tidal range of 50 cm (McNulty et al., 1972). The Florida Bay drainage basin of Everglades National Park including the coastal mangrove zone consists of approximately 1,300 km^2.

Average water depths range from about one to two meters over bank and basin regions to four meters in tidal channels near the western margin of the Bay. Rainfall in the Taylor Slough watershed averages between 125 and 150 cm a year whereas in the Cape Sable region of the basin to the west, the precipitation varies between 115 and 130 cm per year. In the Taylor Slough, dominant plant communities of sawgrass and spike rush cover primarily a freshwater calcitic marl soil. South of the sawgrass habitat is a transitional environment characterized mostly by saltgrass and blackrush. These communities are displaced seaward by the tidally influenced mangrove zone which consists of buttonwood, white, black, and predominantly small to moderate sized red mangroves over deep mangrove peat and marly soil.

The Florida Bay region is underlain by Miami oolite limestone. Calcium carbonate marl and organic muds with locally produced shell gravel and shell sand inclusions cover the oolite throughout the open bay bottom (Tabb et al., 1962). Irregularly shaped sediment banks cover a large part of Florida Bay. Thick luxuriant growths of sea grasses, chiefly turtlegrass and shoalgrass, with several species of algae, stabilize and bind the shells and calcareous plant debris to form broad banks often several kilometers wide.

Three important topographic zones characterize the Bay environment. They include an area of broad banks (western Florida Bay), a transistional area (central Florida Bay), and an area of broad rounded depressions (eastern Florida Bay) (Ginsburg, 1956 and Turney and Perkins, 1972).

Western Florida Bay is characterized by extensive, shallow water, carbonate mud banks. They are broken by numerous tide channels. Two of these, Conchie and Joe Kemp channels extend along the mainland from East Cape Sable to Joe Kemp

Key off Flamingo. They contain mixtures of clear Gulf water and highly turbid Florida Bay water inhabited by a mixture of Florida Keys and mostly west Florida shelf flora and fauna that fluctuates in abundance with seasonal salinity, turbidity and temperature (Tabb et al., 1962).

The central portion of the Bay is an area of mostly small basins and shallow water mud banks with restricted tidal flow. It is generally a stressed environment characterized by stunted marine grasses and few fish species, (mainly pinfish and mojarras).

Eastern Florida Bay consists of closely spaced, interconnecting, sub-oval, pan-shaped basins or depressions, individually upwards of 15 kilometers long and several kilometers wide (Price, 1967). The bulk of the Taylor Slough runoff flows into northeast Florida Bay. Overall, the major marine plant and animal associations display a close affinity to the biota of the upper Florida Keys - southern Biscayne Bay regions. For example, hardhead silversides and halfbeaks are among the principal fish species found in southern Biscayne Bay, Card Sound, and eastern Florida Bay.

Major forage fish species include pinfish, anchovies, mojarras, and grunts while gray snapper, spotted seatrout, red drum, and snook dominate the sportfish harvest and mullets the commercial fishery.

Among the most abundant benthic macrocrustaceans are the arrow shrimp and commercially important pink shrimp. Spiny lobsters and stone crabs characterize the major Florida Bay sport and commercial shellfisheries, respectively.

Card/Barnes Sound

The 110 km^2 Card/Barnes Sound watershed extends northwest to the Atlantic coastal ridge and is the upper part of the 130 km^2 Card-Barnes Sound basin. U.S.

Highway 1 forms the westernmost boundary of the drainage system. The system can be defined by a line drawn from the Card Sound Road south to latitude 25° 22' N along the Model Land Canal to the southern boundary of Biscayne National Monument and along the western shoreline of Key Largo to Cross Key. Geologically, an eastward projection of the Atlantic coastal Ridge (Arsnicker Keys Platform) separated the Biscayne Bay Basin to the north from Card/Barnes Sound Basin to the south. Hoffmeister (1974) provides a more complete analysis of the geologic history and topography of the area.

The Card/Barnes Sound Basin is a nearly flat, semi-enclosed lagoonal estuary approximately 20 km long, north-south, and 5 km wide, east-west. Narrow non-tidal mud banks bissect the environment into two small nearly equal-sized oval basins, Card and Barnes Sounds. Depths are nearly uniform at 2-3 meters with a maximum of almost 4 meters in Card Sound. The normal tidal range of 22 cm in Card and 15 cm in Barnes Sound (Schneider, 1969) demonstrate only small differences attributable to the restrictive effects of mud bank boundaries between sounds and weak ocean exchange in Barnes Sound. Occasionally large tidal fluctuations occur in Card Sound from wind-induced currents. The mean annual rainfall over the Card-Barnes Sound drainage system is extremely variable. The highest rainfall 150-165 cm occurs along the Coastal Ridge near Homestead and decreases rapidily to 115-130 cm over the southwestern portion of the drainage basin.

Prior to the construction of localized canals, levees and roads, bedrock contours and natural Everglades floodway channels along the coastal ridge provided the major directional flow of freshwater into the Card-Barnes Sound Basin. The drainage activities of man, in combination with the possible effects of sea level rise and/or coastal subsidence, have altered the major vegetative types represented by bayheads, sawgrass, blackrush, saltgrass, and mangroves communities. The latter have expanded inland nearly 7 km, forming wide bands of stunted, dwarf and nearly full-sized mangrove trees. The band of blackrush-saltgrass has grown from a narrow strip to more than one km wide and has moved landward 5 to 6 km. In certain areas, sawgrass zones along the shoreline have increased from up to 200 meters wide in 1928 to 6 km in width during 1976 (M. McMahon, pers. communication). Sediment accumulations are derived mostly from the overlying plant association of the original freshwater environments. Freshwater white marl soils (mainly of shallow-water periphyton origin) characterize the sedimentary environments from most of the upland regions to the deep mangrove peats of the coastal mangrove zones.

Marine grass beds are present from patchy to dense seasonal accumulations in the center of Card Sound but are not well represented along the shoreline area. In Barnes Sound, sea grasses flourish to the edge of the mangroves.

The nearshore sedimentary environments of Card Sound are represented by shallow to deep marine carbonate and quarzitic mud-sand accumulations. Shallow quarzitic and calcaerous sandy areas characterize the open portions of the Sound, whereas deeper lime mud deposits typify the nearshore sediment regime on the eastern, Keys, side. In Barnes Sound, lime mud and mostly calcaerous sand accumulations are present over nearshore and open bay bottom alike.

The freshwater dependent and associated fauna of the Card-Barnes Sound watershed has been changed by the urbanization and agricultural activities of the past 40 years. Although historical watershed faunal surveys are unavailable, the local populations of certain small mammals, alligators, and crocodiles are less frequently observed in the watershed region than in the eastern wilderness areas of nearby Everglades National Park. Although the aquatic avifauna have not been completely inventoried, diverse assemblages of 70 important estuarine species are commonly observed to the north in Biscayne National Monument and along the southeastern border of Everglades National Park. One of the most conspicious elements of the coastal populations are the large breeding colonies of pisciverous birds, primarily white ibis and cormorants.

The marine fauna are part of the Carolinean-West Indian biotic regime. A sponge-brittle star community with their associated organisms is perhaps the most conspicuous feature of the marine environment within the Basin system. The dominant invertebrate fauna are well represented by amphipods, grass shrimp, checkered pheasent shells, hermit crabs, neriids, chicken liver sponges, small sea cucumbers, brittlestars, and mud crabs. Epibenthic fish populations are dominated by the code gobies, rainwater killifishes, pipefish, and the Gulf toadfish (Roessler et al., 1975). In addition, Brook (1975) reported the most abundant pelagic and epibenthic species were hardhead silversides, silver jennys and goldspotted killifish. Pinfish is the dominant finfish of sport or commercial importance. Juvenile spiny lobsters, pink shrimp, stone crabs and blue crabs represent the major species of sport and commercial shellfish importance. At least one species of porpoise and the manatee occasionally visit the lagoonal waters.

Southern Biscayne Bay
(Biscayne National Monument)

The drainage system to southern Biscayne Bay consists of a portion of the Atlantic Coastal Ridge which extends from south of West Palm Beach to Miami and trends westward near Homestead into the Everglades where it is known as the

"Pineland Ridge". The Ridge is 3-8 meters in elevation and 3-15 km in width. It is composed mostly of silica sand to the north of Miami and cemented oolitic and bryozoan limestones from Miami southward (Wanless, 1976). Between the Atlantic Coastal Ridge and the Key Largo Ridge lies an elongated shallow basin containing Biscayne Bay, Card and Barnes Sounds. At the southern end of Biscayne Bay, the Arsenicker Keys Platform projects eastward from the ridge and separates Biscayne Bay Basin to the north from the Card-Barnes Sound Basin to the south (Wanless, 1976).

The southern Biscayne Bay Basin portion of Biscayne National Monument is an area of approximately 190 km^2. It is a shallow, tropical lagoon, 18 km long and about 15 km wide. Water depths average 2 meters with a maximum of 4 meters. Normally, tides range from about 50 cm near Homestead Bayfront Park to 60 cm at Adams Key (Schneider, 1969).

The sediments are biologically derived calcareous sands and muds which form two distinct sedimentary environments.

Towards the mainland, surface environments of the irregular bedrock configuration consist primarily of thin layered quarzite calcareous sand communities characterized by moderate to dense populations of calcareous sand producing algae, Halimeda. In the deeper eastern portions of the Bay, sparse to dense growths of seagrasses cover thick lime mud. The seagrass beds are predominantly turtlegrass and scattered shoalgrass mixed with the algae genera Penicillus, Udotea, and Acetabularia.

Along the shorelines on the western margin of Biscayne Bay a narrow (1-2 km in width) marsh-swamp forms a barrier between the fresh-water upland areas and the Bay.

The coastal swamp is a heavily forested area characterized primarily by red mangroves along the bay edges, mixed with black mangrove, white mangrove, buttonwood and recently Australian pine at higher elevations. The shoreline environment produces mostly mangrove peat sediments while sawgrass peats, peats associated with hammocks and freshwater calcitic marl, characterize the substrate landward to the Coastal Ridge. Sawgrass, cattail, willows, and spikerush commonly dominate the freshwater swamp environments. Important fresh-water conditions within the coastal ridge system are dependent upon local rainfall and the drainage activities of man.

The geographical distribution of annual rainfall varies considerably over the lower southeast coast of Florida. Rainfall is greatest over the southeastern portion of the coastal ridge near Homestead where about 70 percent of the average annual rainfall (150-165 cm per year) falls during the rainy season from June through October. East of Homestead precipitation diminishes rapidly towards the Bay to 125-140 cm per year.

The southeast portion of the main Everglades drainage system is crisscrossed by a complex network of roads and levees which intercept the natural, overland flow of freshwater to the coast. In addition, water-management structures such as canals and mosquito control ditches regulate, temporally and spatially, the flow of water out of the Everglades for flood protection and control of saltwater intrusion. In lower southeast Florida, canals connect the Everglades and Conservation Areas 3A and 3B in western Dade County with urban and agricultural areas adjacent to the coastal Ridge and southern Biscayne Bay. The hydrology of southern Biscayne Bay is influenced directly by six of these canals which discharge freshwater during periods of heavy rainfall into the basin and prevent seepage flow during the dry season. The northernmost canal, Goulds, delineates the northern boundary of the southern Biscayne Bay watershed, and the southern edge is bounded by latitude 25^{o} 22' N along the northernmost east-west extension of the Model Land canal.

The total area of the watershed is 187 km^2. Currently, the major land uses within the watershed are the Turkey Point Power Plant and agriculture.

A complete historical or recent assessment of aquatic wildlife in the southern Biscayne Bay watershed is not available. Presumably man's activities have greatly affected the numbers and distribution of freshwater dependent and associated animals which commonly inhabit the nearby wilderness areas of the Everglades drainageway. In contrast, the marine environment of Biscayne Bay region supports a rich and diverse fauna (Voss et al., 1969), as temperate species of the Carolinean Faunal Province seasonally meet with the sub-tropical and tropical species of the West Indian Faunal Province.

The fisheries resources represent an invaluable economic and aesthetic contribution to the Bay system. Nearly one-half of the total number of fish species (512) reported from Monument waters inhabit the seagrass beds and tidal flats of the Bay waters proper. The majority of these small forage species are predominantly pinfish, white grunts and silversides. Other larger species, spotted seatrout, snapper, permit, bonefish, barracuda and mackeral dominate the Bay sportfish harvest. Important commercial species include baitfish (mullet and ballyhoo), spanish mackerel, snapper and grouper. The dominant invertebrate fauna in the vicinity of the Turkey Point power plant are amphipods, caridean and paenaid shrimp, hermit and mud crabs, sea cucumbers and sponges (Roessler et al., 1975). The commercial and/or sportfishery invertebrate harvest consists primarily of baitshrimp (pink shrimp) spiny lobsters, stone crabs, conchs and sponges.

The aquatic avifauna of southern Biscayne Bay are represented chiefly by approximately 70 permanent/seasonal estuarine species. Some of the most abundant and ecologically significant coastal species are the brown pelican, double-crested cormorant, white ibis, American coot, laughing gull, herons, and egrets. Bottlenose dolphin and manatee are frequently observed in the bay. Loggerhead sea turtles are occasionally observed during the summer months.

The Northern Coral Reef Tract (Biscayne National Monument)

Biscayne National Monument contains two water masses of nearly equal size. The semi-enclosed bay waters are contained within the southern portion of the Biscayne Bay Basin. The 200 km^2 open water area of Hawk Channel and the lagoonal patch and outer reefs lie between the emergent Key Largo Limestone Ridge and the deep oceanic waters of the Florida Straits at the eastern edge of the Monument boundary.

Eastward of the Key Largo Ridge the bottom slopes gradually to an average depth of about eight meters. Several channels, the deepest with a maximum depth of about three meters have cut through the ridge forming several major islands or Keys.

The most conspicious feature within the reef tract are numerous large lagoonal patch reefs and their associated banks consisting of Bowles Bank, Bache Shoal, Margot Fish Shoal and Caesar's Creek Bank. The outer coral reefs on the eastern edge of the monument boundary from north to south are represented by Triumph, Long, Ajax and Pacific Reefs.

Offshore of the Keys a typical vertical profile through the bottom consists of calcium carbonate sediments of organic origin (mainly Halimeda segments, sea-urchin spines, alcyonarian spicules and foraminifera shells) over a relatively thin layer of post-pleistocene Key Largo limestone, and eventually older limestone rock. The recent upper limestone layer apparently contiguous with beachrock bordering the keys, increases somewhat in thickness from lagoonward to oceanward. Sections through the patch reefs are similar to those of the Keys except for supertidal unconsolidated materials and muck and peat accumulations from hardwood hammocks and mangroves.

The coral reef tract is influenced mostly by the warm Florida current. Monthly mean air temperatures range from 20^{o}C in December to 28^{o}C in August. Relatively moderate and occasionally calm prevailing winds blow mostly from the east and southeast during the summer months. Frequent "northlies" with velocities reaching 10 to 15 m/sec occur from November to April during the passage of winter cold fronts. Seasonal rainfall patterns are similar to those found in the vicinity of Biscayne Bay. Maximum rainfall, tropical storms and depressions occur from June through November with peak rainfall periods during June and October.

Water quality conditions are relatively stable and constant. Subsurface water temperatures, salinities, pH, and water clarity are not greatly different from that of the nearby oceanic waters of the Florida Straits. Average dissolved oxygen concentrations and nutrient plankton levels are generally lower than those found in the Bay proper, which are primarily influenced by seagrass productivity, but are higher than that of the surrounding open ocean (Jones, 1963).

The marine flora and fauna of the reef tract are part of the tropical West Indian biotic province; its richness and diversity are characterized chiefly by the occurrence of alcyonarian and stony corals and their associated organisms. Intertidal species of the Keys area have been described in the vicinity of eastern Biscayne Bay by Voss and Voss (1955) and in the middle Keys by Stephenson and Stephenson (1972). The distinct coral heads of the patch reefs rise 3 to 6 meters above the bottom, occasionally exposed at low tides, and the patches may range in size from small individual coral heads to coral masses, hundreds of meters across. Dominant species of the stony coral masses include brain, and star corals which are occasionally confined marginally by staghorn coral. Soft corals, primarily sea feathers, whips and fans are frequently found atop the compacted coral reef mass. Turtlegrass beds are the dominant community-type on the shallow reef flats.

The outer reefs are represented primarily by two types, Long Reef and Ajax Reef. The depressed, shallowness of Long Reef is characterized by loose accumulations of coral rock rubble consisting mostly of dead staghorn coral with a variety of marine organisms. In contrast, Ajax Reef is composed of live coral dominated by Millepora colonies (Voss et al., 1969).

Mollusks in greatest abundance are the coral shell, and a few cowries. The spiny lobster is common and comprises a large portion of the monument commercial shellfishery. Echinoderms are well represented with holothurians and echinoids locally found in high densities.

On the reefs numerous crevices, ledges and caverns form shelter for over 253 reef fish species known to inhabit the region. Numerically, the dominant families of the reef ichthyofauna are seabasses, grunts, damselfishes, wrasses, snappers, parrotfish, gobies, and tangs.

Sportfish taken primarily over the shallow patch reef environs include snapper, mackerel, grouper, jacks, and barracuda, while sailfish, dolphin, kingfish, shark and marlin are among the larger dominant species captured over the deeper outer reefs along the eastern edge of the Monument. Larger marine animals such as Bottlenose dolphins and seaturtles are occasionally observed over the shallow reef flats or the lagoonal patch reefs.

SUMMARY OF WATER QUALITY INFORMATION

Historical Review

The earliest marine water quality investigations in southern Florida (Vaughan, 1918 and Dole and Chambers, 1918) report from the late nineteenth and early twentieth centuries, but it was not until about the middle of the 1930's and 40's that data collection activities were initiated in the bays, sounds and rivers of the coastal areas. Two of these earliest estuarine studies were undertaken by Davis (1940) and Davis and Williams (1950). They measured salinity in connection with coastal mangrove studies and while determining the nature of plankton populations from the Ten Thousand Islands to eastern Florida Bay.

Beginning in the early 1950's, Ginsburg (1956) and McCallum and Stockman (1959) began to collect extensive salinity measurements in their geological investigations in Florida Bay. McCallum and Stockman published the largest number of stations (75) for any single water quality parameter (salinity) taken in the southern Florida coastal systems. These studies were followed by the two to three years long, comprehensive investigations, based on multi-parameter data collection techniques covering more than one drainage system. Finucane and Dragovitch (1959), Tabb et al., (1959), and Tabb and Dubrow (1962b) established extensive coastal water quality networks to relate biotic resources to environmental parameters. In 1962 a five year long water quality study was initiated by the U.S. Bureau of Sport Fish and Wildlife (River Basins Division) on salinity in the Big Cypress and Everglades estuaries. This study documented the presence of large scale net inland movement of saline Gulf water into the coastal estuaries during drought. In addition, the University of Miami conducted many short term (one year or less) investigations during the late 1960's and early 1970's in order to relate fishery resources to changing environmental conditions.

At nearly the same time, environmental research and monitoring efforts by the University of Miami and various governmental agencies focused on the southern Biscayne Bay and Card Sound area. A complex network of hydrobiological stations was established to measure the environmental effects of thermal effluent produced by Florida Power and Light's Turkey Point facility (Bader and Roessler, 1971; Segar et al., 1971; Roessler et al., 1975). The early results of these surveys indicated environmental degradation at the outfall points. However, with the construction of a cooling canal system, most of southern Biscayne Bay was pronounced clear of excessive contamination by the mid-1970's.

More recently, relatively continuous water quality data have been collected by the National Park Service (Schmidt, unpublished data; Davis and Hilsenbeck, 1974; Tilmant, unpublished data) to document the effects of environmental conditions not only on important fishery populations, but also on all Park and Monument biotic resources in an attempt to assure their protection and preservation.

Big Cypress Estuary (Chokoloskee Bay to Broad River)

Seven investigations (Figure 2) reporting water quality data from 80 stations (Figure 3), were identified in the Chokoloskee Bay to Broad River area (Table 2). These studies occurred intermittingly over a 36 year period from 1936 to 1972. Salinity and temperature measurements were reported for most of these studies. Only two, Finucane and Dragovitch (1959) and USGS (1964-75), reported turbidity and nutrient/chemical data.

Davis (1940) provided the earliest environmental data. He reported salinity on an irregular basis during years of 1936-38. In this area, the only long term monitoring study was conducted on salinity by the division of River Basin Studies, BSFW, under the auspices of A. Marshall (unpublished data). This investigation recorded salinity variation ranging from 0 to 40‰ over a five year period. No other parameters were measured by this investigation. Tabb (1967) made salinity observations on transects along the Lostmans, Chatham and Broad Rivers, however no permanent station locations were established. He used the data to establish a relationship between water levels in wells and Park estuarine salinities. More recently, Lindall et al., (1973) found an overall salinity range which was in fairly close agreement with previous studies.

Although no information was found on future water quality monitoring investigations in this area the Department of Environmental Regulation (State of Florida) currently monitors one primary water quality station, annually, in Chokoloskee Bay. The physiochemical characteristics on the northern margin of the 10,000 Islands have been summarized by Weinstein et al., 1977, Carter et al., 1974 and Yokel, 1975.

Everglades Estuary (Harney River to Whitewater Bay)

This area is defined geographically as the coastal waters from the Harney River south to East Cape Sable and the southern end of the Buttonwood Canal, including Whitewater Bay. A total of 17 programs (Figure 4), consisting of 198 stations (Figure 5), measured physiochemical parameters from 1938 through 1974; and macronutrients, pesticides, and heavy metals from 1964 to the present (Table 3).

A few coastal salinity observations by Davis (1940) between 1936 and 1938 are the earliest recorded environmental data in this estuary. Finucane and Dragovitch (1959) extended their red tide monitoring studies along the lower southwest coast of

Florida into the Everglades estuary. They recorded physiochemical and chemical characteristics of the coastal bays and rivers.

Tabb et al., (1962) concentrated a series of ecological studies regarding the effects of environmental alteration on coastal fisheries in Everglades estuary between 1957 and 1962. These studies produced a number of hydrographic reports (Tabb and Dubrow, 1962b, and Tabb et al., 1959).

During the early and mid-1960's the BSFW (River Basin Studies Division) and the Institute of Marine Science, University of Miami, initiated detailed hydrographic monitoring efforts from the coastal waters of the Gulf of Mexico to the headwaters of several major tributaries in the Shark Slough drainage. Most of these data were used to relate the kinds and abundance of marsh fishes to variations in specific environmental parameters. These studies were expanded by the Rosenstiel School of Marine and Atmospheric Sciences (formerly the Institute of Marine Science) to include studies in the North River on detritus formation and energy transfer in coastal marshes (Odum, 1971 and Heald, 1971); fish distribution in relation to environmental parameters in the Whitewater Bay area, (Clark, 1971 and Jannke, 1971) and Roessler (1970) in the Buttonwood Canal. Beardsley (1967), as part of a pink shrimp research program, made weekly salinity and temperature measurements in the Buttonwood Canal.

Tabb et al., (1974) concluded that "much of coastal Everglades National Park is still in a near natural state... a vast fresh water continum with a marine phase intruding briefly during drought." However, as part of a 1973 NPS hydrobiological watershed management study in the Everglades estuary, Davis and Hilsenbeck (1974) suggested that the historical low salinity system was shifting toward a coastal marine ecosystem due to extended periods of seawater intrusion in the lower Shark Slough drainage area and alterations in freshwater discharge patterns in the upper Slough.

Currently, only select physiochemical and chemical parameters are being measured irregularly in the upper Shark River area by the USGS, under contract with the NPS.

Florida Bay

The Florida Bay portion of Everglades National Park extends eastward from East Cape Sable to the Florida Keys, including a series of embayments along the south shore of the Florida peninsula. A total of 23 investigations (Figure 6) reporting water quality data from 408 stations (Figures 7 and 8) were identified in this area (Table 4).

Again, the earliest water quality records were made by Davis (1940) during his mangrove ecology study. A series of salinity stations were sampled along the mainland of Florida Bay and surrounding areas. Irregular salinity observations ranged from 26.7‰ in 1936 (a wet year) to 39.2‰ in 1938 (a dry year).

Environmental research programs conducted in the early 1950's (Ginsburg, 1956; Lloyd, 1964; McCallum and Stockman, 1959) were primarily concerned with the geology and the paleoecology of the molluscan faunal components of the Florida Bay system. Supplemental salinity and water temperature readings were the major physiochemical parameters reported.

In association with red tide studies conducted by Finucane and Dragovitch (1959) along the southwest coast of Florida, a few stations were sampled in the northwest portion of the Bay (Snake Bight) during the summer of an extremely dry year (July, 1956). They reported the highest known salinity value (70‰) from the estuarine and marine waters of southern Florida. Their data also included an extensive list of nutrients taken along transects from Chokoloskee Bay to northwest Florida Bay (Table 8).

The earliest detailed study of central and eastern Florida Bay salinity distribution was conducted by McCallum and Stockman (1959).

During the late 1950's and the 1960's a series of reports focusing on the effects of environmental alterations on coastal fisheries in Everglades National Park were produced (Tabb et al., 1962; Tabb and Dubrow 1962a; Tabb and Dubrow 1962b; Higman, 1967). Tabb et al., (1974) and Tabb (1967) sampled hydrobiological stations throughout the coastal waters of Everglades National Park. Most stations in Florida Bay (Tabb, unpublished data) were sampled during the dry year of 1965-66 which resulted in extensive hypersaline observations along the mainland from Garfield Bight in central Florida Bay, to Snipe Point in northeast Florida Bay.

Several fishery studies on pink shrimp distribution, with supplemental water quality data, converged in the Whitewater Bay-Shark Slough area (Tabb and Dubrow, 1962b and Beardsley, 1967), and Costello, Allen and Hudson (unpublished data, NMFS) carried on their pink shrimp research programs, throughout Florida Bay. They later published a checklist of the flora and fauna of the "lake" in central Florida Bay (Hudson et al., 1970).

The NPS personnel collected environmental data throughout the Bay system from 1973 to 1976 (Schmidt, unpublished data). Significant findings indicated that hypersaline conditions (41 to 66‰) were significantly related to reduced numbers of fish species, individuals, and biomass along the mainland in the central portion of the Bay (Schmidt, 1977). These data continued to illustrate the large seasonal fluctuations of salinity which occur between south Florida's pronounced wet and dry seasons.

Several NPS biological research programs are currently in progress in northeastern Florida Bay. Patty and Coleman (unpublished data) have made monthly salinity surveys in this area since late 1976. A few short term water quality monitoring studies have been conducted in eastern Florida Bay which have either been terminated (Creamer, unpublished data and Lee, unpublished data) or the data are available but not immediately accessible for analysis (Griffin, unpublished data). The Department of Environmental Regulation (State of Florida) has recently established a primary water quality station in Conchie Channel south of Flamingo.

Card and Barnes Sounds

Card and Barnes Sounds are bounded by the mainland on the west, Key Largo on the east and by Cutter Bank and Cross Key on the north and south, respectively. A total of 14 environmental monitoring studies (Figure 9) which sampled 122 stations (Figure 10) were identified in Card and Barnes Sound (Table 5). The earliest observations were only for salinity. They were recorded by Davis (1940) during his coastal mangrove study from 1936-1938.

Nearly 40 years elapsed before additional Barnes Sound water quality measurements were made in 1974 by Lee (1975). He reported hypersaline conditions of 47 $^{o}/oo$ in April, 1974 and June, 1975 as part of a study on circulation and exchange processes between Biscayne Bay and Barnes Sound.

Two years of geological data collected primarily by Griffin (unpublished data) were supplemented by water quality measurements during the period of 1972-74. Theses by Valleau (1977), Martin (1975), and a dissertation by Manker (1975) were produced from these data collections.

Eleven monitoring studies sampled 113 stations in Card Sound. These studies were concentrated primarily during the construction and early operation of Florida Power and Light Company's Turkey Point cooling canals which were connected to Card Sound. Segar et al., (1971) designed a network of 62 water quality stations to obtain baseline information on the chemical ecology of the area. This water quality program was overlapped by a study by Roessler et al., (1975) on the effects of thermal pollution in Biscayne Bay and Card Sound. Both investigations reported water temperatures greater than 38^{o} C in shallow waters near the entrance to the Model Land Canal. Other studies by Smith (1973), Hixon (1976), and Brook (1975) present water quality measurements taken in conjunction with various biological investigations, conducted before and after the operation of the disharge canal.

At this time no current or proposed water quality programs are identified in Card or Barnes Sound.

Southern Biscayne Bay (Biscayne National Monument)

Southern Biscayne Bay is bordered by the Florida mainland on the west, the northernmost of the Florida Keys (from Old Rhodes to Sands Key) on the east, and by Featherbed and Cutter Bank on the north and south, respectively. The southern Biscayne Bay water mass within Biscayne National Monument received little attention from environmental researchers prior to the late 1960's. Since then, 15 studies (Figure 11), which incorporated 173 water quality stations (Figure 13) in their investigations, have been conducted in southern Biscayne Bay (Table 6).

The earliest physiochemical measurements were recorded by Davis (1940) who reported estuarine and marine salinity values from 9 observations along the mainland and the eastern shoreline of Elliott Key. No observations were recorded again until the middle 1940's when Smith et al., (1950) recorded salinity, temperature, dissolved oxygen, and nutrient measurements from plankton studies along south Florida coastal areas. Uniform marine salinity and temperatures were recorded between 1945 and 1946.

Twenty years elapsed before the next series of water quality readings were obtained from this area (USGS, 1964-75). Water quality measurements were not made directly in Bay waters but in the eastern ends of the drainage canal systems which flow into Biscayne Bay. Temperature, dissolved oxygen, pH, and turbidity were the primary physiochemical factors reported, along with macronutrients, pesticides, herbicides, and heavy metal concentrations (USGS, 1964-1975).

In the late 1960's, during the construction of Florida Power and Light Company's Turkey Point plant, several water quality monitoring programs were established by various governmental agencies and universities. Between 1968 and 1971, the Environmental Protection Agency (Tebo et al., 1968) and the Rosenstiel School of Marine and Atmospheric Sciences University of Miami (Voss et al., 1969; Nugent, 1972; de Sylva, 1971; Segar et al., 1971) and the University of Florida (Griffin, unpublished data) conducted environmental research and surveys in the vicinity of Turkey Point, including measurements of various physiochemical parameters and selected chemical constituents.

Although the investigators concluded that ecological changes had occurred near stations affected by the heated effluent, Segar et al., (1971) and others found that "No major destructive alterations had occurred to the overall ecosystem of south Biscayne Bay."

Lee (1975) collected temperature and salinity data in southern Biscayne Bay from 1972 to 1975 as part of a larger program which sampled from Card Sound to the Port of Miami. The highest recorded salinities in southern Biscayne Bay (44‰) were observed by Lee and by Segar et al., (1971). The highest water temperatures (41.7° C) were recorded by de Sylva (1971).

Current studies in the Biscayne National Monument area include an estuarine and marine water quality monitoring project sponsored by the NPS. This study is conducted by J. Tilmant (unpublished data), and has been in progress since 1972. Plans are currently underway to expand the sampling program to include various nutrients and chemical parameters. Dr. John Wang of RSMAS is currently directing a vertically integrated, two-dimensional circulation model representing the effects of tidal and wind-driven flow in monument waters. In addition, the results of dye experiments will identify the movement and dispersion of canal pollutants within the bay system.

Northern Coral Reef Tract (Biscayne National Monument)

The remainder of Biscayne National Monument contains the open shallow waters of Hawk Channel and associated patch reefs. These waters are located between the northernmost Florida Keys (Old Rhodes to Sands Key) on the west, the outer boundary of barrier reefs along the 60' depth line on the east and from north to south between latitude 25° 31' N and John Pennekamp Coral Reef State Park.

Five environmental studies (Figure 12), reported water quality conditions from five stations (Figure 13) within the reef tract area. Two coastal investigations (Vaughan, 1918 and Dole and Chambers, 1918) conducted adjacent to, but outside the north-south monument reef tract boundaries are included as the earliest published records of marine conditions in the southern Florida area. During the 1940's Smith et al., (1950) noted the general hydrologic conditions near the outer barrier reef zone (Triumph Reef). The most detailed and comprehensive study of patch reef water quality conditions was provided by Jones, (1963). He reported relatively stable salinity, water temperature, dissolved oxygen and pH conditions in association with low nutrient levels during the 1961-1962 period of observation.

The following fifteen years were marked by a noticable absence of reef tract data monitoring programs, concomitant with an increase of research activities contiguous to the nearby construction site of Florida Power and Light's power plant facility.

Currently the USGS (Fisher Island) measures water temperature on a continuous recording basis while the NPS plans to initiate a long-term water analyses program measuring certain physiochemical (temperature, salinity, pH, DO, turbidity) and chemical (nitrates, nitrites, ammonia and phosphates) parameters associated with the preservation and protection of biotic resources within the reef tract area.

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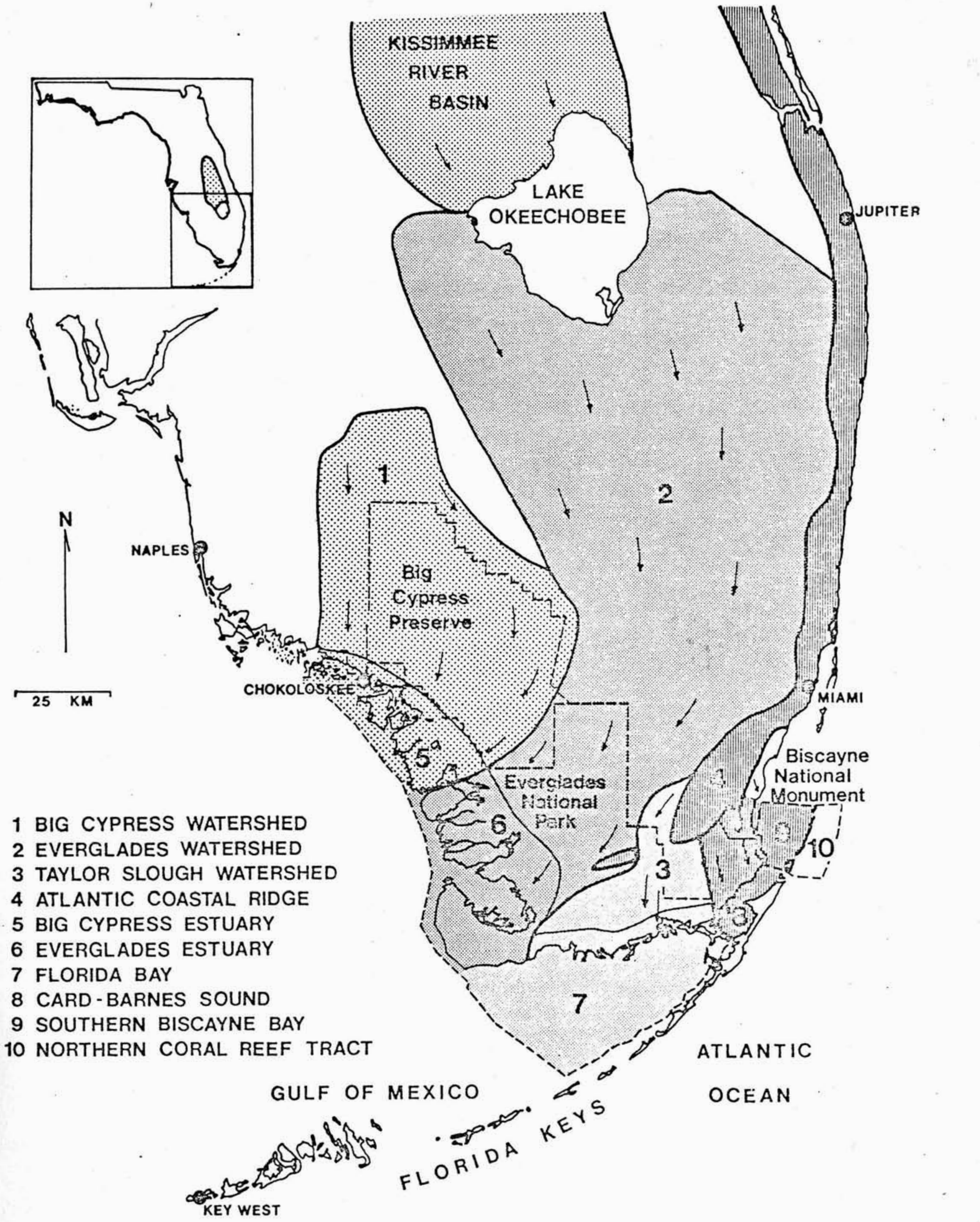


Figure 1. Map of southern Florida showing major watersheds, drainage patterns and coastal zones.

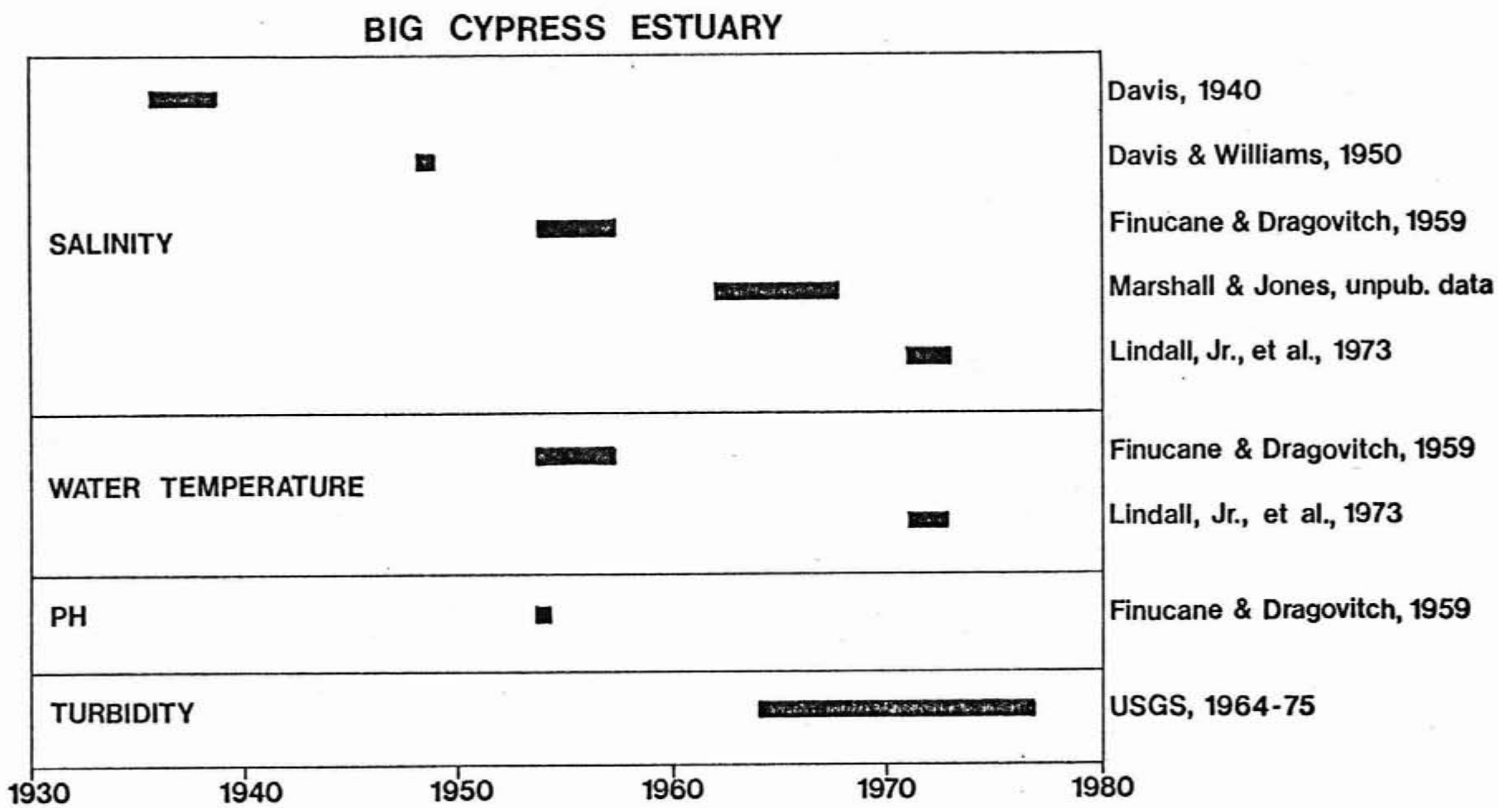


Figure 2. Summary of Big Cypress Estuary Water Quality Studies

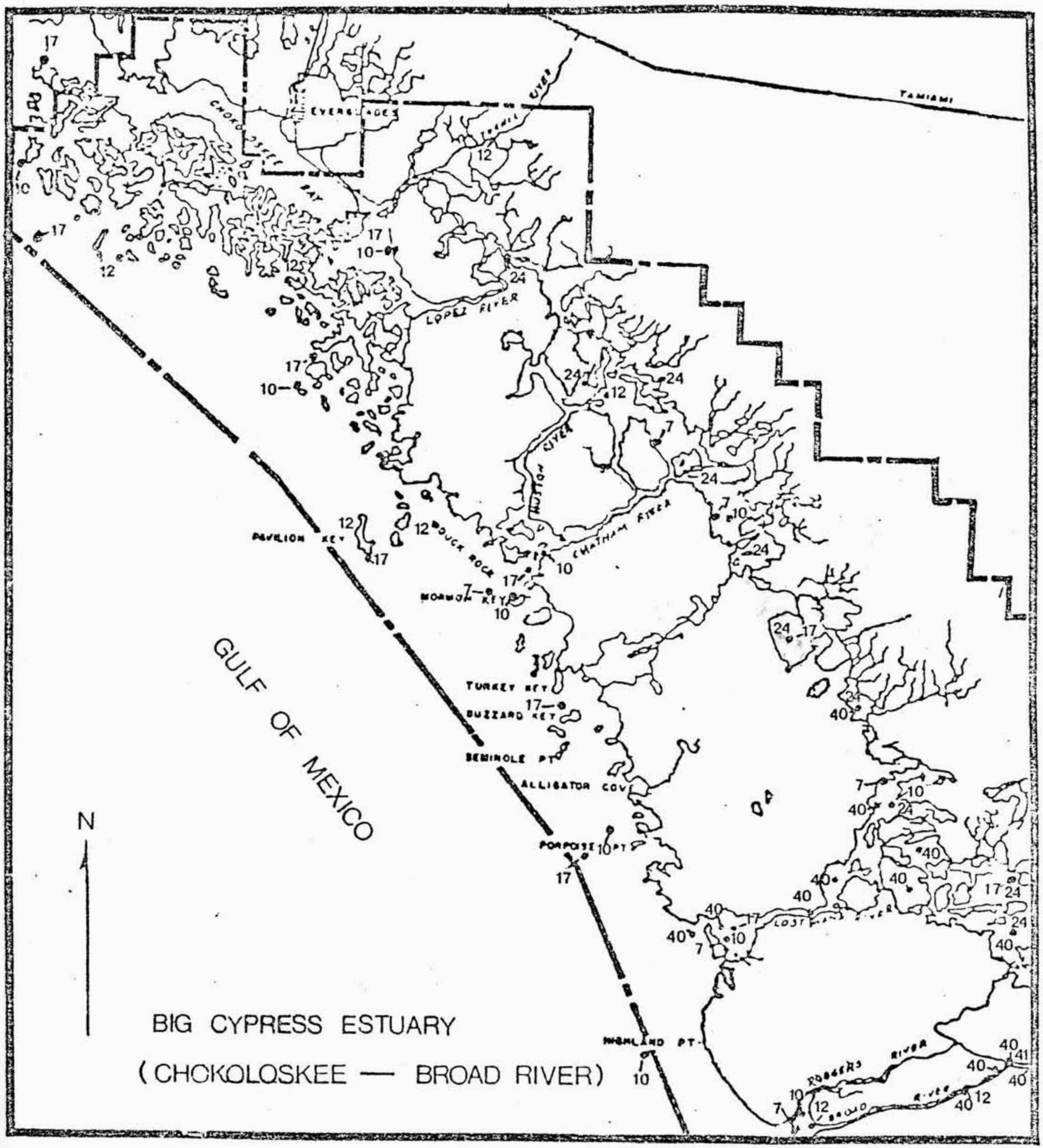


Figure 3. Map of Big Cypress estuary showing historical water quality stations.

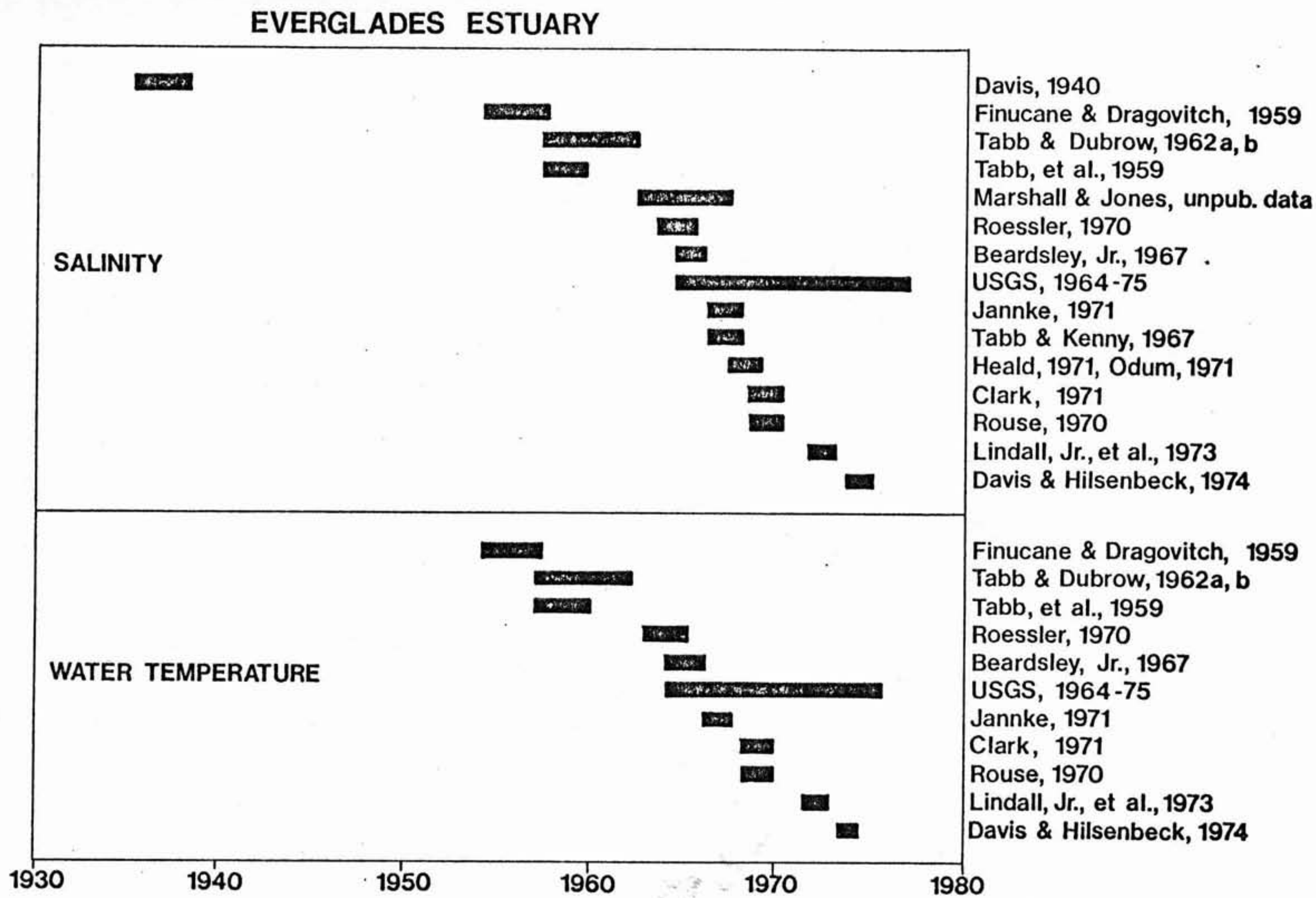


Figure 4. A Summary of Everglades Estuary Water Quality Studies

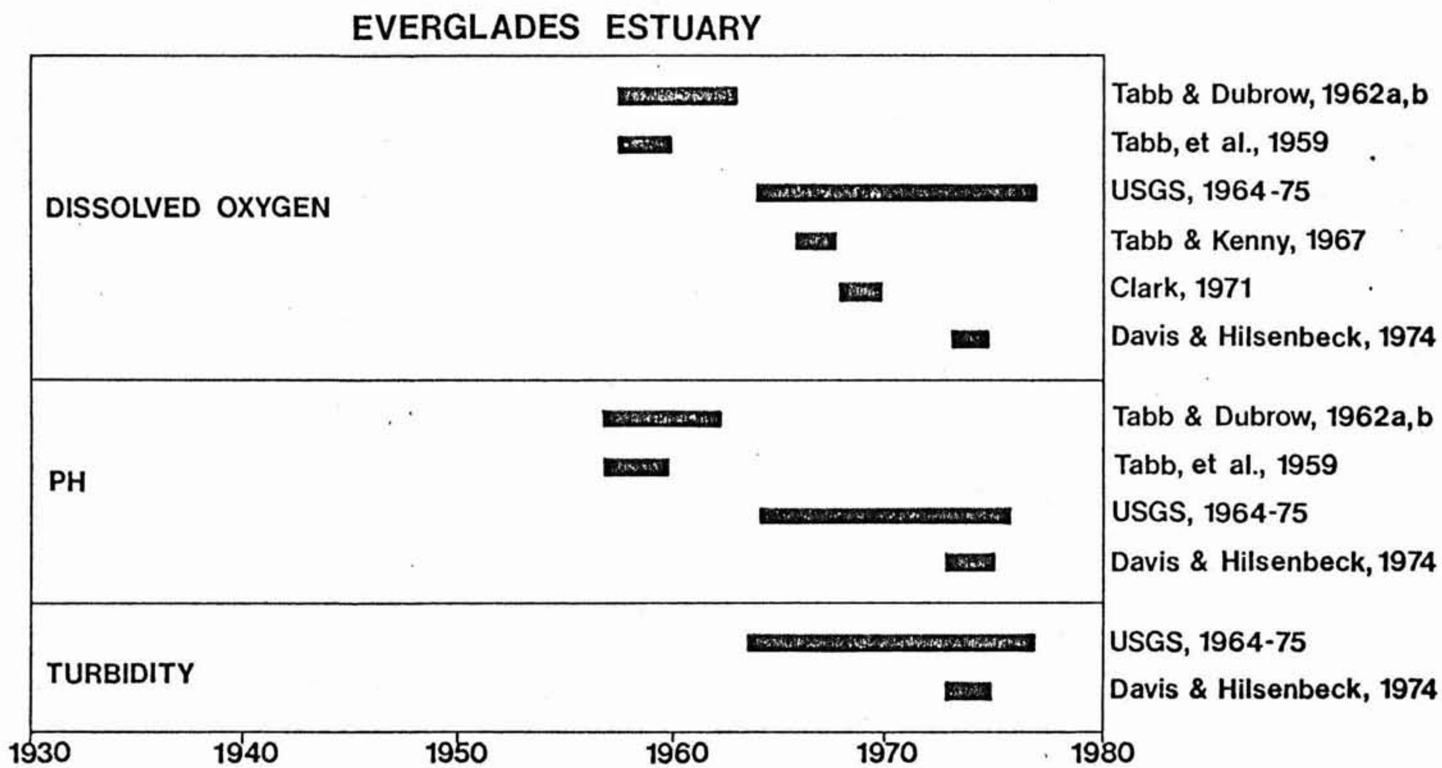


Figure 4 Continued

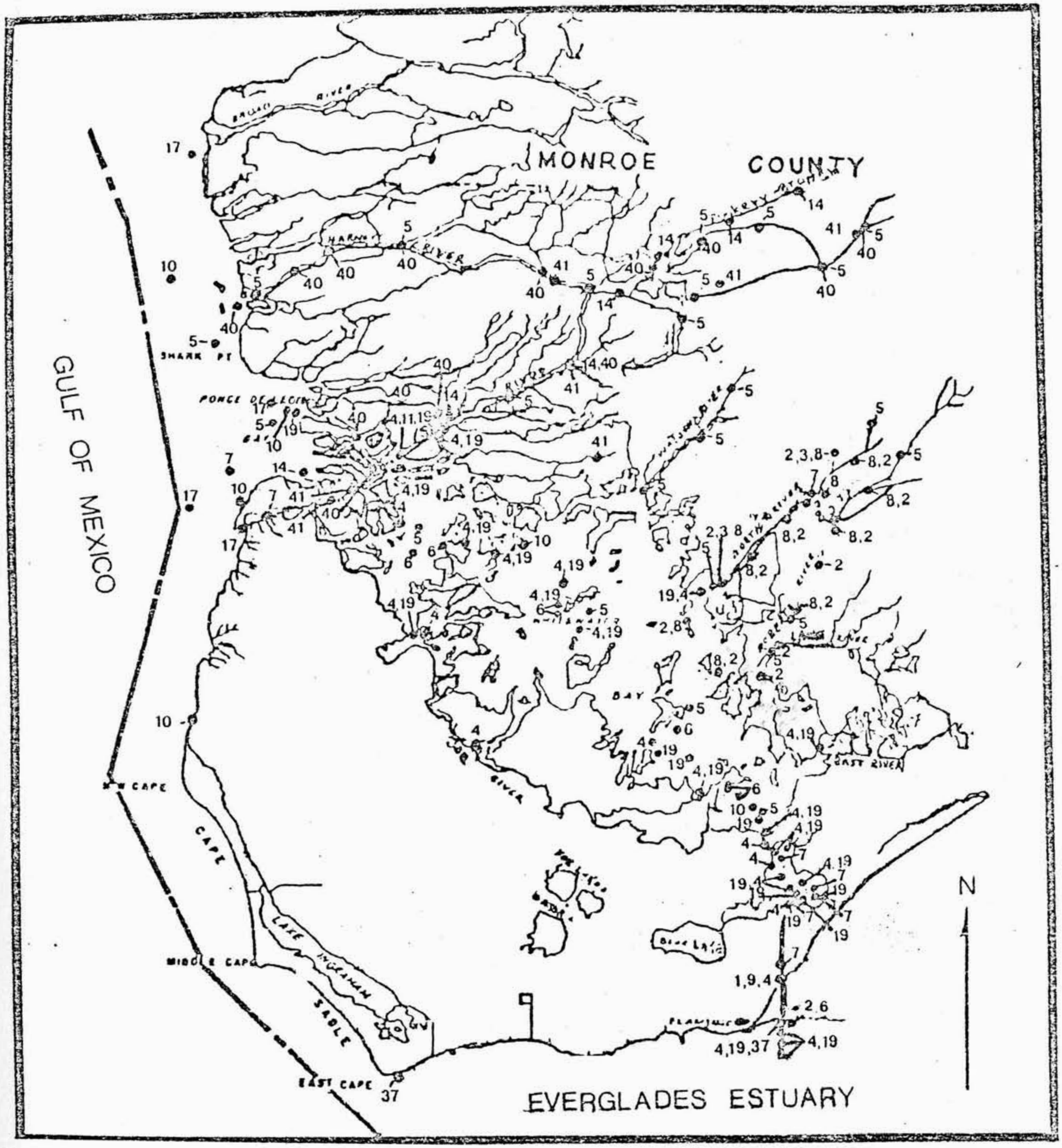


Figure 5. Map of Everglades estuary showing historical water quality stations.

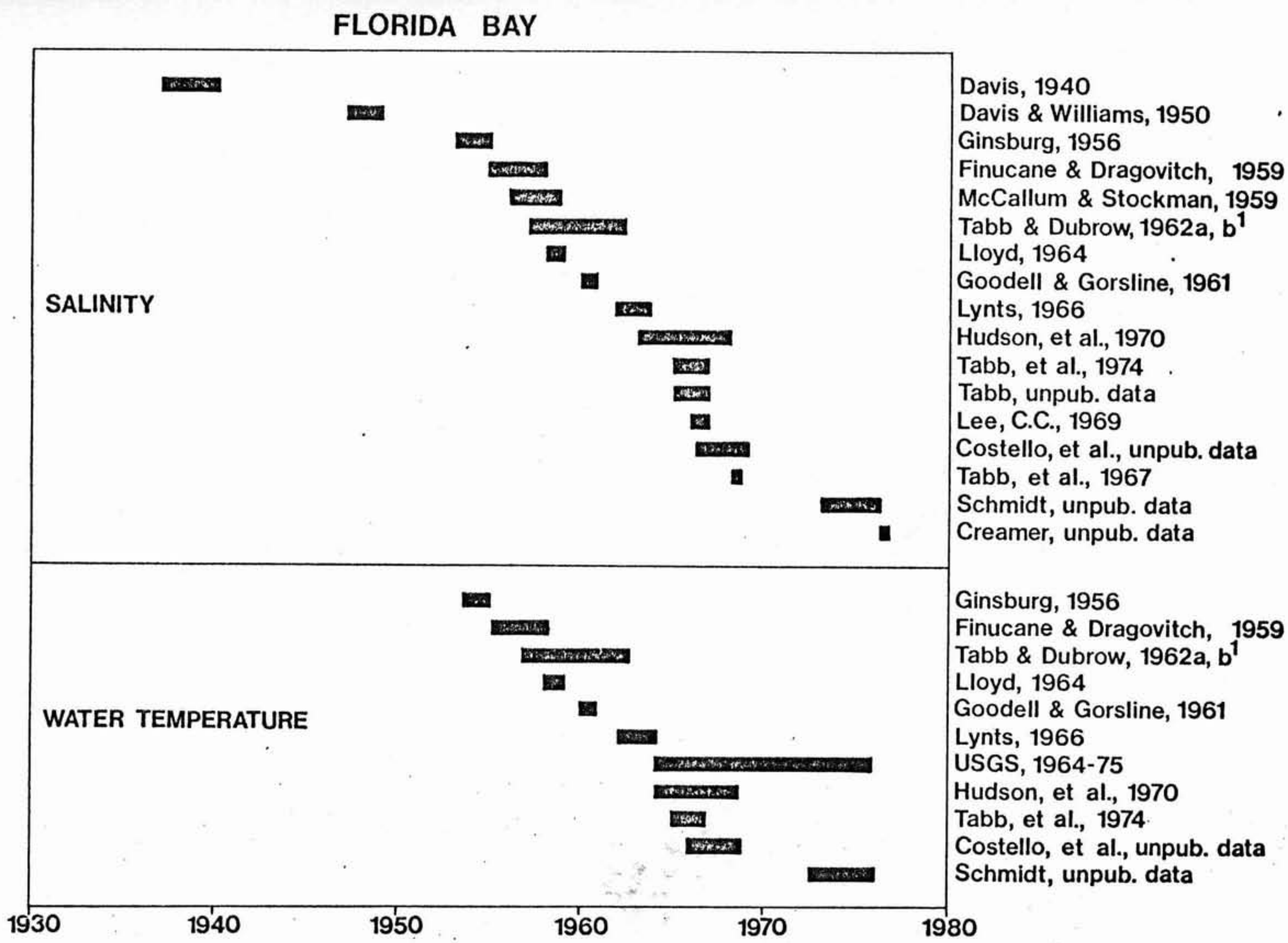
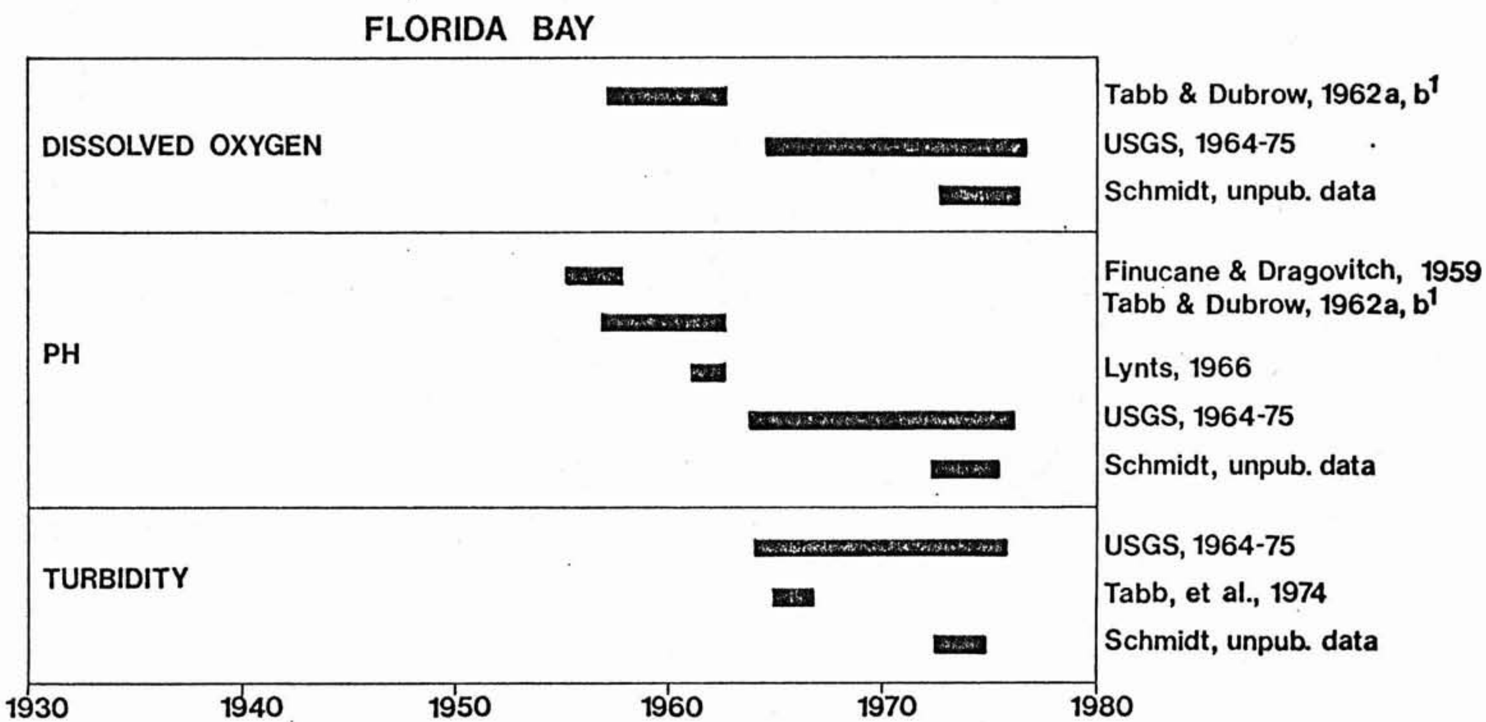


Figure 6. Summary of Florida Bay Water Quality Studies. [1]includes data from Tabb, et al., 1959



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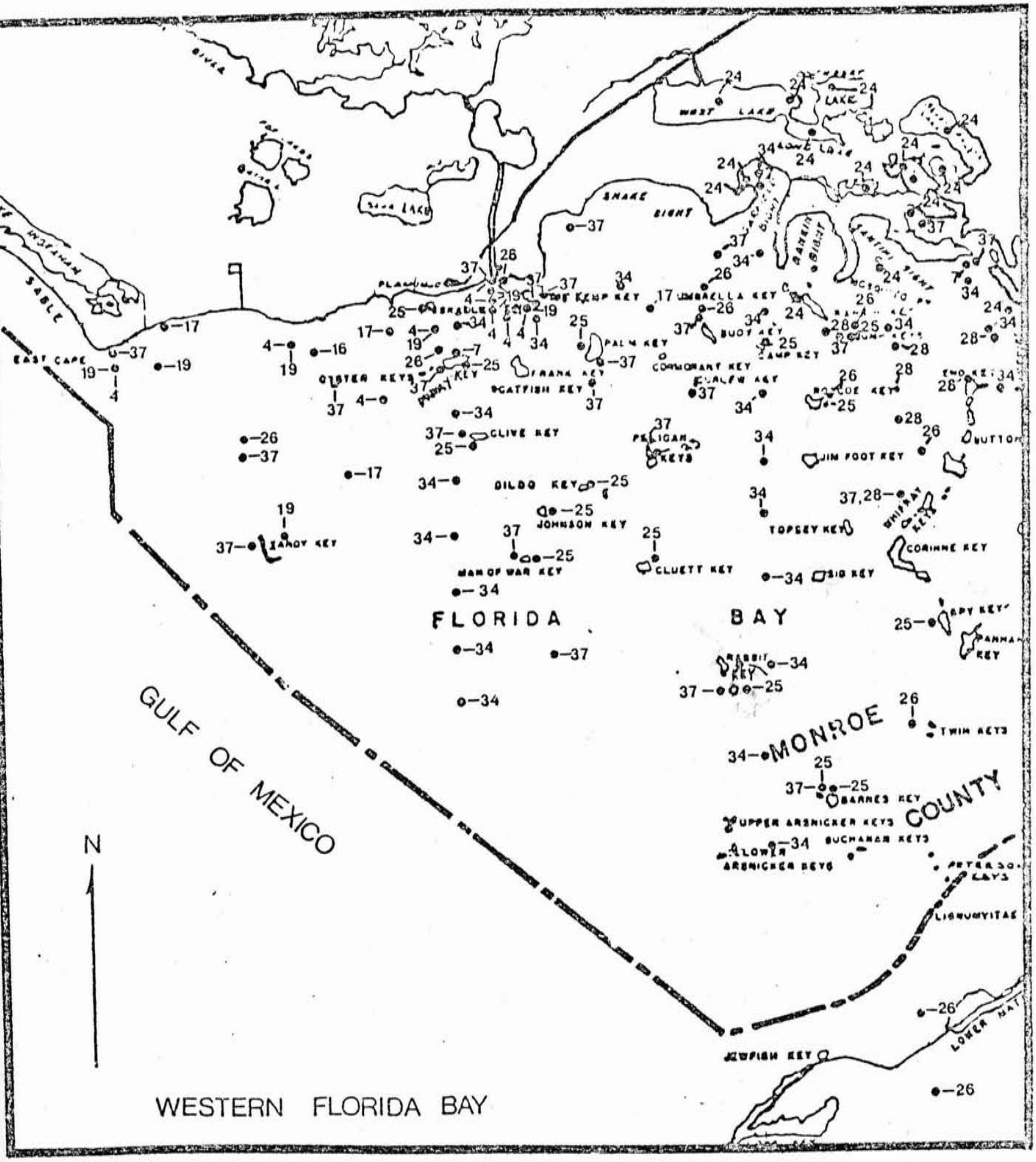

Figure 7. Map of western Florida Bay showing historical water quality stations.

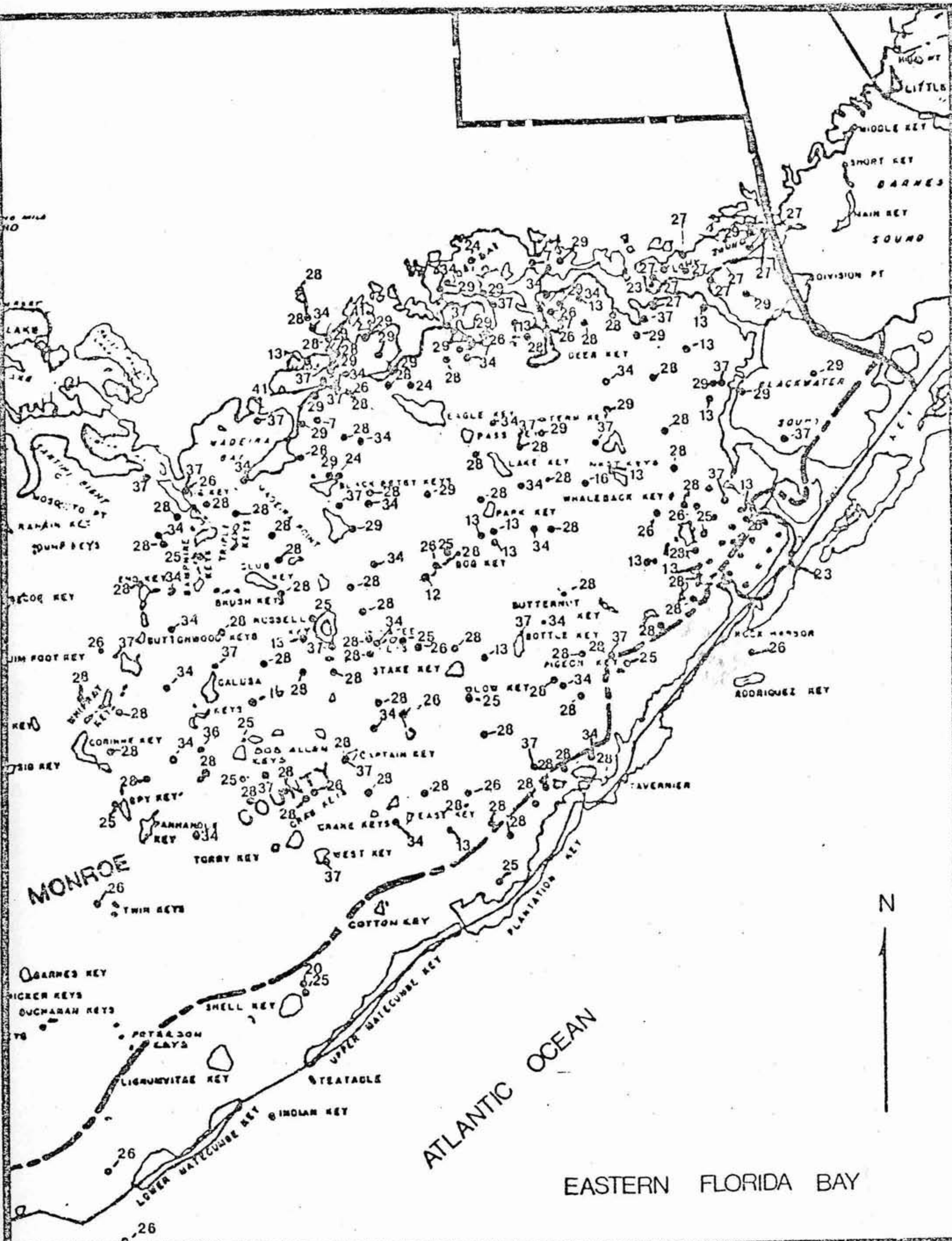

Figure 8. Map of Eastern Florida Bay showing historical water quality stations.

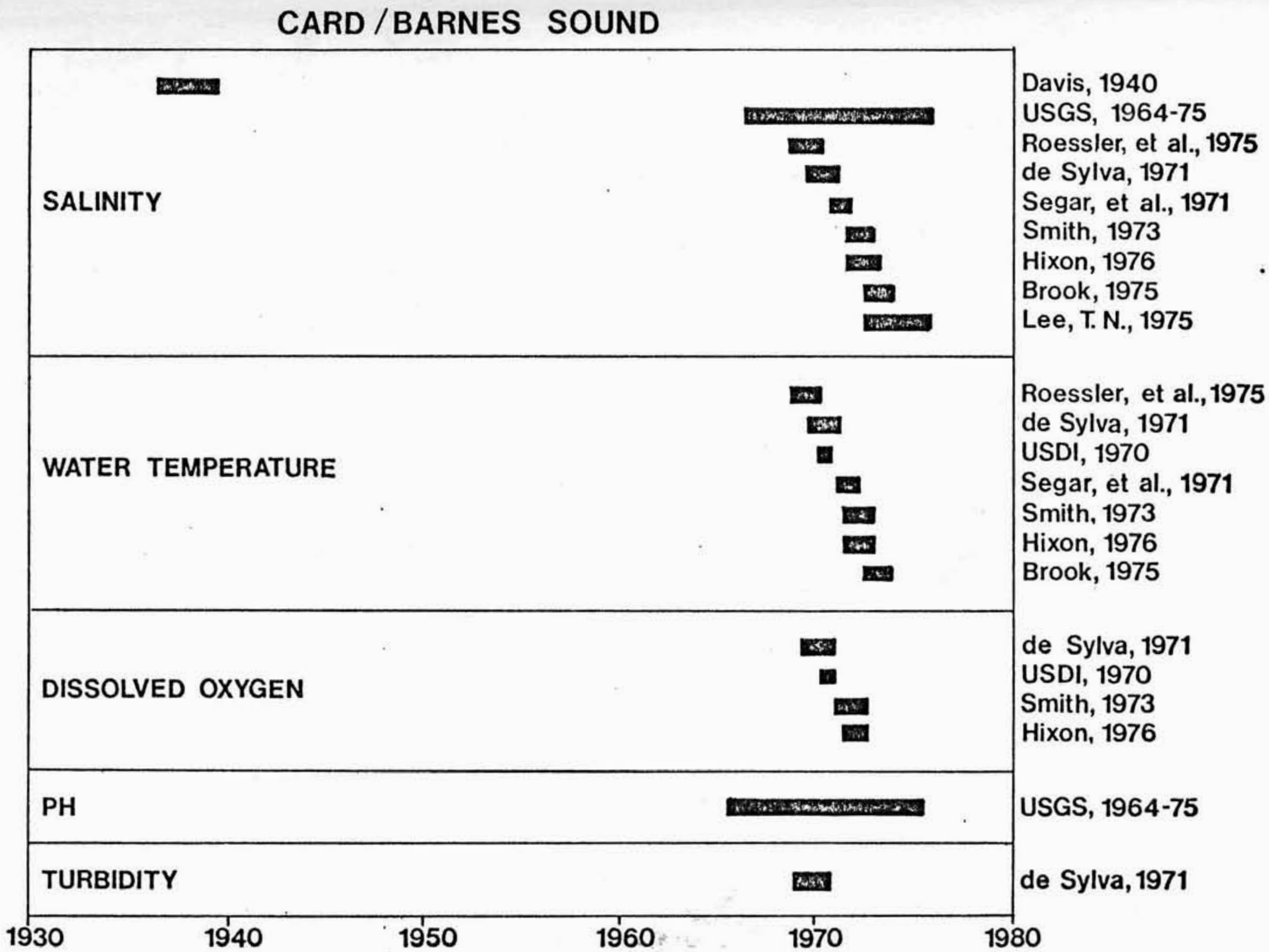

Figure 9. Summary of Card/Barnes Sound Water Quality Studies

Figure 10. Map of Card-Barnes Sound showing historical water quality stations.

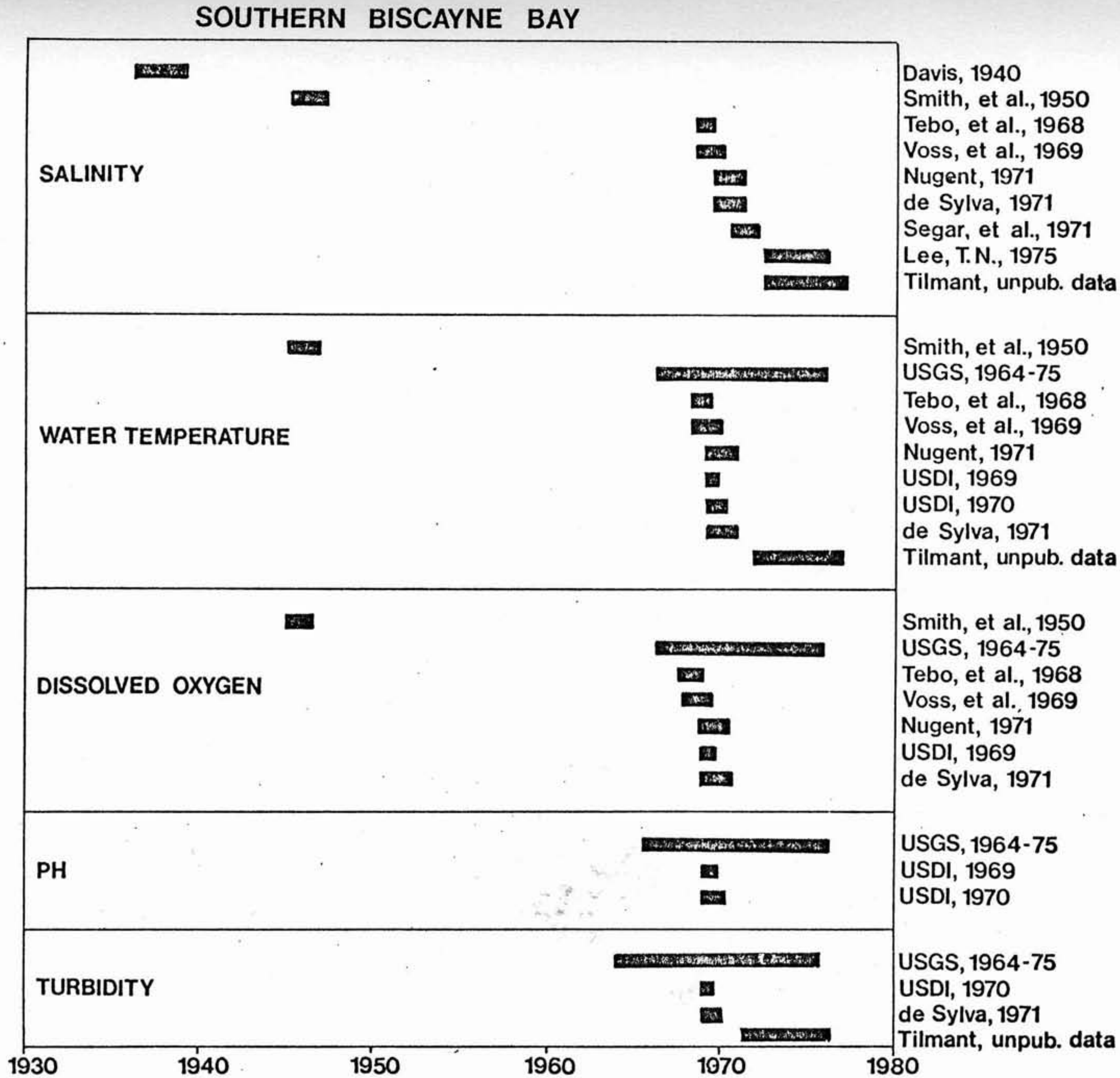

Figure 11. Summary of Southern Biscayne Bay Water Quality Studies

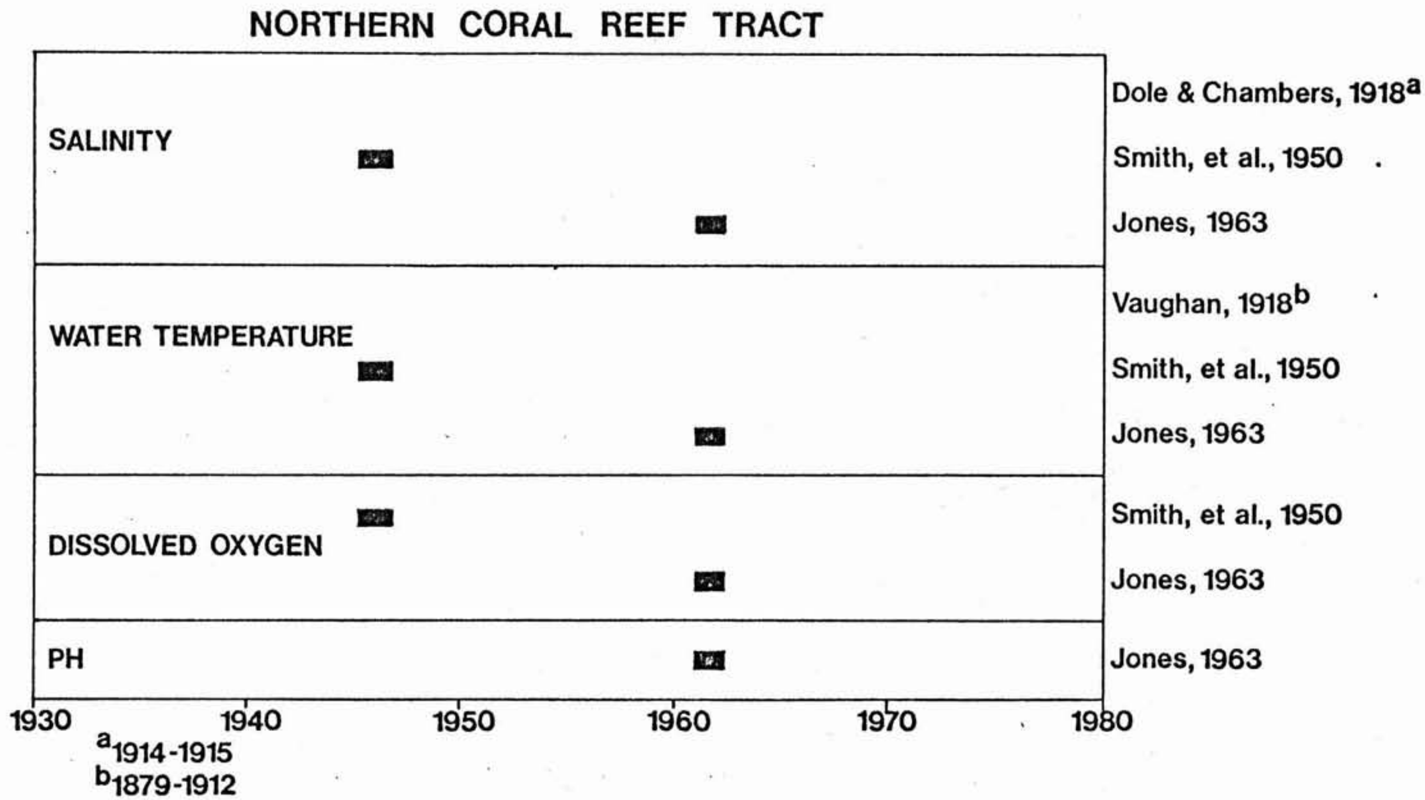

Figure 12. Summary of Northern Coral Reef Tract Water Quality Studies

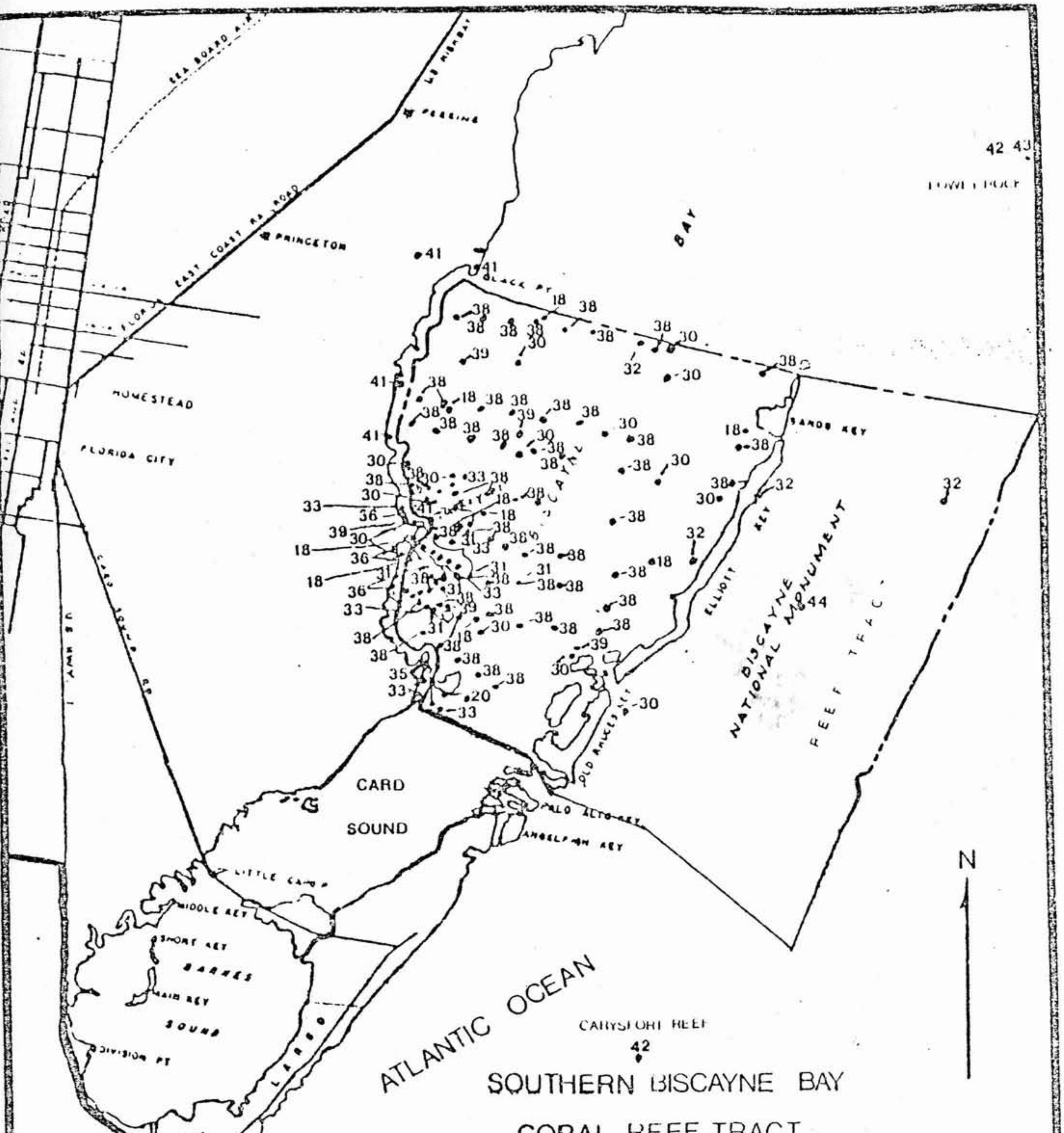

Figure 13. Map of southern Biscayne Bay and northern coral reef tract showing historical water quality stations.

Table 1. Key to historical water quality station locations on Figures 3, 5, 7, 8, 10 and 12.

Station Code	Source
1.	Beardsley, 1967
2.	Tabb, et al., 1974
3.	Odum, 1971
4.	Tabb and Dubrow, 1962
5.	Davis and Hilsenbeck, 1974
6.	Clarke, 1971
7.	Rouse, 1970
8.	Tabb and Kenny, 1967
9.	Roessler, 1970
10.	Lindall, et al., 1973
11.	Jannke, 1971
12.	Davis, 1940
13.	Ginsburg, 1956
14.	McPherson, 1970 and USGS
15.	Lee, 1969
16.	Goodell & Gorsline, 1961
17.	Finucane & Dragovich, 1959
18.	Tebo, et al., 1968
19.	Tabb, et al., 1959
20.	Brook, 1975
21.	Hixon, 1976
22.	Smith, 1973
23.	Lynts, 1966
24.	Davis and Williams, 1950
25.	Costello, et al., unpublished data
26.	Lloyd, 1964
27.	Creamer, unpublished data
28.	McCallum and Stockman, 1959
29.	Patty and Coleman, unpublished data
30.	de Sylva, 1971
31.	USDI, 1969
32.	Smith, et al., 1950
33.	Segar, et al., 1971
34.	Tabb, unpublished data
35.	Roessler, et al., 1975
36.	Nugent, 1972
37.	Schmidt, unpublished data
38.	Tilmant, unpublished data
39.	Voss, et al., 1969
40.	Marshall and Jones, unpublished data
41.	USGS
42.	Vaughan, 1918
43.	Dole and Chambers, 1918
44.	Jones, 1963
45.	Hudson, et al., 1970
46.	Holm, 1975
47.	Tabb, et al., 1967

Table 2.

A summary of Water Quality measurements reported from the Big Cypress Estuary (Chokoloskee Bay to Broad River) in Everglades National Park

Date	Salinity (o/oo)	Water Temp. (^{o}C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
1936-1938	3.8-28.8	---[a]	---	---	---	---	13	26	Irregular	Davis,1940
Jan-Feb 1948-1948	0.6-23.2	---	---	---	---	---	13	14	Monthly	Davis and Williams, 1950
May-Mar 1954-1957	0.1-40.2	15.3-33.5	---	7.2-8.3	---	(b)	11	361	Weekly Monthly	Finucane and Dragovitch, 1959
Apr-Mar 1962-1967	0.0-40.0	---	---	---	---	---	24	700	Monthly	Marshall and Jones, unpublished data
1966-1967	---	---	---	---	1.0-13.0	---	1	14	Irregular	USGS
May-Feb 1971-1972	3.5-40.3	19.5-30.3	---	---	---	---	11	11	Quarterly	Lindall, Jr., et al., 1973
1966-1969	0.0-44.8	15.0-32.2	---	---	---	---	7	---	Irregular	Rouse, 1970

[a]Dashes (---) indicate data not reported.

[b]Data summarized in Table 8.

Table 3.

A summary of Water Quality measurements reported from The Everglades Estuary (Whitewater Bay, Shark Slough Estuary and Buttonwood Canal) in Everglades National Park

Date	Salinity (o/oo)	Water Temp. (°C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
1937-1938	26.9-27.5	---[a]	---	---	---	---	---	6	Irregular	Davis, 1940
Mar-May 1955-1957	14.0-40.82	19.0-33.0	---	---	---	(b)	4	187	Weekly Monthly	Finucane and Dragovitch, 1959
Aug-Jun 1957-1959	0.0-43.8	14.4-34.0	1.47-6.90	7.47-9.45	---	---	26	772	Monthly	Tabb, et al., 1959
Sep-Feb 1957-1962	0.0-39.8	16.0-32.5	0.0-6.39	7.7-8.3	---	---	25	559	Monthly	Tabb and Dubrow, 1962a Tabb and Dubrow, 1962b
Apr-Mar 1962-1967	0.0-40.0	---	---	---	---	---	44	1,209	Monthly	Marshall and Jones, unpublished
Jan-Jun 1963-1964	15.5-45.2	15.8-34.0	---	---	---	---	1	89	Bi-monthly	Roessler, 1970
Jun-Jun 1964-1965	22.0-51.5	14.0-31.1	---	---	---	---	1	145	Weekly	Beardsley, 1967
1964-1975	0-28	15.5-33.0	4.3-10.4	6.4-8.5	0.0-27.0	(b)	9	158	Irregular	USGS and McPherson
Oct-Sep 1965-1966	0.0-30.3	14.8-32.2	---	---	0.7-9.6	---	17	---	Monthly	Tabb, et al., 1974
Jan-Dec 1966-1967	23.5-37.4	16.4-31.8	---	---	---	---	1	66	Weekly	Jannke, 1971
Dec-Feb 1966-1967	0.0-16.8	---	1.3-6.8	---	---	---	22	132	Monthly	Tabb and Kenny, 1967

Table 3 (Continued)

Date	Salinity (o/oo)	Water Temp. (^{o}C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
Oct-Dec 1967-1968	0.0-27.4	---	---	---	---	---	3	12	Monthly	Odum, 1971; Heald, 1971
Sep-Nov 1968-1969	2.6-30.9	15.9-32.1	5.0-9.0	---	---	---	8	135	Monthly	Clark, 1971
May-Feb 1971-1972	18.0-36.9	21.0-29.9	---	---	---	---	6	236	Quarterly	Lindall, et al., 1973
Oct-Sep 1973-1974	0.1-41.6	13.2-31.8	0.0-9.5	5.8-8.5	0.4-41.0	---	26	416	hourly Monthly	Davis and Hilsenbeck, 1974
1966-1969	0.0-50.8	13.7-35.5	---	---	---	---	5	42	Irregular	Rouse, 1970

[a]Dashes (---) indicate data not reported.

[b]Data summarized in Table 8

Table 4.

A summary of water quality measurements reported from Florida Bay in Everglades National Park

Date	Salinity (o/oo)	Water Temp. (^oC)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
1936-1938	26.7-39.2	---[a]	---	---	---	---	36	26	Irregular	Davis, 1940
1947-1948	5.01-29.09	---	---	---	---	---	18	29	Irregular	Davis and Williams, 1950
Oct 1953 Dec 1953 Jul 1954	30 20-30 15-36	15.0-40.0	---	---	---	---	16 17	11 16	Monthly	Ginsburg, 1956
Mar-May 1955-1957	34.4-70.0	15.0-33.2	---	7.9-8.4	---	(b)	8	266	Weekly Monthly	Finucane and Dragovitch, 1959
Dec-Feb 1956-1958	5.9-57.8	---	---	---	---	---	75	826	Bi-monthly	McCallum and Stockman, 1959
Jan-Nov 1958	11.4-39.4	18.0-31.2	---	---	---	---	32	54	Monthly	Lloyd, 1964
Jan-Aug 1960	2.02-44.94	18.4-33.0	0.96-6.41[c]	---	---	---	3	24	Hourly	Goodell and Gorsline, 1961
1959-1962	19.0-47.7	15.0-32.5	2.02-6.05	7.6-8.6	---	---	10	77	Monthly	Tabb and Dubrow, 1962a
1959-1962	---	---	---		---	---	9	132	Irregular	Tabb and Dubrow, 1962b
1957-1959	25.3-46.3	15.0-36.3	---	---	---	---	11	162	Monthly	Tabb, et al., 1959
1964-1968	27.8-49.6	17.5-32.2	---	---	---	---	1	36	Monthly	Hudson, et al., 1970
1966-1968	25.4-44.8	15.7-33.7	---	---	---	---	21	190	Monthly	Costello, et al., unpublished data
1964-1976	---	20.5-31.0	5.3-10.0	7.5-8.5	5-58	(b)	2	23	Irregular	USGS

Table 4 (Continued)

Date	Salinity (o/oo)	Water Temp. (^oC)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
Aug-Feb 1962-1963	25.3-40.8	19.5-32.4	---	6.9-8.9	---	---	19	76	Irregular	Lynts, 1966
Apr-Jul 1965-1966	0.0-67.7	---	---	---	---	---	44	510	Bi-monthly.	Tabb, unpublished data
Feb-Mar 1967	0.0-28.4	---	---	---	---	---	12	77	Irregular	Tabb, et al., 1967
Feb-Mar 1966-1966	23.4-31.6	---	---	---	---	---	---	---	Monthly	Lee, C.C., 1969
1972-1974	---	---	---	---	---	---	---	---	Monthly	Griffin, unpublished data
Apr-Sep 1973-1976	1.7-66.6	11.9-34.0	1.1-15.2	5.8-9.8	0.3-72.0	---	49	1.914	2X/Month to Monthly	Schmidt, unpublished data
1973-1975	---	---	---	---	---	---	---	---	Monthly (continuous)	Lee, unpublished data
Jan-Aug 1977-1977	2-4	---	---	---	---	---	32	---	Monthly	Patty and Coleman, unpublished
Jan-Mar 1977-1977	25.2-36.1	---	---	---	---	---	8	32	Irregular	Creamer, unpublished data
1975-1976	---	---	---	---	---	---	1	---	---	Halley, unpublished data

[a] Dashes (---) indicate data not reported.

[b] Data summarized in Table 8.

[c] ml/l

Table 5.

A summary of water quality measurements reported from Card and Barnes Sound, Florida[a]

Date	Salinity (o/oo)	Water Temp. (°C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
1936-1938	24.9-38.7	---	---	---	---	---	7	17	Irregular	Davis, 1940
Jan.-Jun. 1966-1975	29.2-41.0	---	4.9	7.3-7.5	---	(b)	1	4	Irregular	USGS, 1967-1976
July-May 1968-1971	4.5-44.4	13.4-38.8	---	---	---	---	20	1,960	Monthly	Roessler, et al., 1975
Sept.-May 1970-1971	30-42.1	17.5-28.9	---	---	---	(b)	62	629	Monthly	Segar, et al., 1971
Jan. 1970	---	15.5-21.9	7.7-11.5	---	---	---	10	20	Hourly Monthly	USDI, 1970
Jun.-Sept. 1969-1970	24.3-40.9	15.0-31.3	4.4-7.9	---	0.7-7.6	---	5	295	Monthly	deSylva, 1971
1971-1972	30.5-41.5	20.2-33.4	3.7-8.4	---	---	---	5	131	Monthly	Smith, 1973
Oct.-Oct. 1971-1972	24.1-36.9	20.2-34.1	4.1-8.4	---	---	---	5	130	Monthly	Hixon, 1976
1972-1973	30.3-40.9	19.0-32.8	---	---	---	---	1	13	Monthly	Brook , 1975
Jan.-Jun. 1972-1975	30-47	---	---	---	---	---	---	---	Monthly (continuous)	Lee, T.N. 1975
1972-1974	---	---	---	---	---	---	---	---	---	Manker, 1975

Table 5 (Continued)

Date	Salinity (o/oo)	Water Temp. (°C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
1972-1974	---	---	---	---	---	---	---	---	---	Martin, 1975
1972-1974	---	---	---	---	---	---	---	---	---	Griffin, unpublished data
1973-1975	---	---	---	---	---	---	---	---	Monthly (continuous)	Lee, T.N., unpublished data

[a]Dashes (---) indicate data not reported.

[b]Data summarized in Table 8.

Table 6.

A summary of water quality measurements reported from Southern Biscayne Bay in Biscayne National Monument

Date	Salinity (o/oo)	Water Temp. (°C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
1936-1938	21.9-37.8	---[a]	---	---	---	---	---	9	Irregular	Davis, 1940
Jul-Jun 1945-1946	33.71-39.26	18.25-32.0	2.97-4.92	---	---	(b)	3	71	Irregular	Smith, et al., 1950
1966-1975	---	27.0-30.0	6.7-18	7.3-9.4	0-30	(b)	8	42	Irregular	USGS
Apr-Aug 1968-1968	23.8-38.5	20.5-36.1	3.69-9.65	---	---	---	6	1,328	Daily	Tebo, et al., 1968
Jul-Jun 1968-1969	6.0-35.5	16.0-35.5	3.2-8.5	---	---	---	5	50	Monthly	Voss, et al., 1969
Feb-Jan 1969-1970	15.3-31.2	19.4-36.4	3.61-6.63	---	---	---	5	840	Irregular	Nugent, 1972
Feb-May 1969-1969	---	23.0-24.0	3.9-7.6	7.6-8.1	---	---	5	26	Monthly	USDI, 1969
Dec-Jul 1969-1970	---	15.5-34.1	---	7.8-8.0	1.8-4.8	---	5	20	Monthly	USDI, 1970
Dec-Sep 1969-1970	16.1-41.7	11.6-41.7	1.4-9.0	---	0.7-9.6	---	13	505	Monthly	de Sylva, 1971
Sep-May 1970-1971	27.6-44.4	14.5-35.9	4.1-8.6	---	---	(b)	55	330	Monthly	Segar et al., 1971

Table 6 (Continued)

Date	Salinity (o/oo)	Water Temp. (°C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
Jan-Jun 1972-1975	20-44	---	---	---	---	---	---	---	Monthly (continuous)	Lee, 1975
1972-1974	---	---	---	---	---	---	---	---	---	Valleau, 1977
1972-1976	5.2-40.0	11.0-34.4	---	6.2-8.4	.1-26.1	---	60	1,878	Monthly	Tilmant, unpublished data
1973-1975	---	---	---	---	---	---	---	---	---	Lee, T.N., unpublished data
Mar-July 1973-1974	36.0-40.4	17.2-41.1	---	8.0-8.9	---	---	8	708	Monthly, Weekly, Hourly	Holm, 1975
1977	---	---	---	---	---	---	---	---	---	Wang & Lee (current)

[a] Dashes (---) indicate data not reported.

[b] Data summarized in Table 8.

Table 7.

A summary of water quality measurements reported from the Northern Reef Tract in Biscayne National Monument

Date	Salinity (o/oo)	Water Temp. (^{o}C)	Dissolved Oxygen (ppm)	pH	Turbidity (JTU)	Chemical Data	# of Stations	# of Samples	Frequency of Measurement	Sources
Mar-Dec 1879-1912	---[a]	15.6-31.2	---	---	---	---	2	24,810	Daily	Vaughan, 1918
Mar-Oct 1914-1915	34.16-39.04	---	---	---	---	---	1	388	Daily	Dole and Chambers, 1918
Jul-Jun 1945-1946	35.2-36.5	24.3-29.8	3.7-4.4	---	---	(b)	1	21	Irregular	Smith, et al., 1950
Aug-May 1961-1962	36.8-37.3	22-30.5	3.8-5.9[b]	7.6-8.2	---	(b)	1	---	Hourly for 3 days on a quarterly basis	Jones, 1963
Oct 1977 (current)	---	---	---	---	---	---	1	---	Continuous	Hudson, unpublished data

[a]Dashes (---) indicate data not reported.

[b]Data summarized in Table 8.

Table 8. Summary of chemical water quality data collected in the estuarine and marine waters of South Florida National Park Service areas, 1945-1975[a]

General Category	Compound	Total Range	Unit Size
Pesticides			
Chlorinated			
	Aldrin	ND[b]	ug/l
	Dieldrin	0.00 - 0.05	"
	Endrin	ND	"
	Chlordane	ND	"
	Lindane	ND	"
	DDD	0.00 - 0.01	"
	DDE	0.00 - 0.01	"
	DDT	0.00 - 0.02	"
	Silvex	ND	"
	Toxaphene	ND	"
	2, 4-D	0.00 - 0.05	"
	2, 4, 5-T	ND	"
	Heptachlor	ND	"
	Heptachlor Epoxide	ND	"
Non-Chlorinated			
	Ethion	ND	"
	Trithion	ND	"
	Methylitrithion	ND	"
	Malathion	ND	"
	Diazinon	0.00 - 0.01	"
	Methyl Parathion	ND	"
	Parathion	0.00 - 1.00	"

General Category	Compound	Total Range	Unit Size
Carbonate System			
	Calcium Carbonate ($CaCO_3$)	11 - 315	mg/l
	Bicarbonate (HCO_3^-)	104 - 439	"
	Carbonate ($CO_3^{=}$)	0 - 17	"
	Carbon dioxide (CO_2)	1.2 - 23	"
	(Total inorganic carbon)	16.8 - 72	"
Nutrients			
Nitrogen			
	NH_3	0.00 - 2.8	mg/l
	NO_2^-	0.00 - 7.0	"
	NO_3^-	0.00 - 39	"
	NO_2^- and NO_3^-	0.00 - 6.3	"
	Organic N	0.36 - 8.4	"
	Total N	0.02 - 9.3	"
	Kjeldahl N	0.23 - 2.0	"
Phosphorous			
	Total ortho P	0.00 - 1.1	mg/l
	Total P	0.00 - 1.4	"
	Dissolved PO_4^{-3}	0 - 6.9	"
	Total PO_4^{-3}	0 - 15.5	"
	Total ortho PO_4^{-3}	0.07 - 1.3	"
	Inorganic PO_4^{-3}	0.00 - 3.5	"
	Dissolved PO_4^{-3}	0.01 - 0.10	"

General Category	Compound	Total Range	Unit Size
Carbon			
	Organic Carbon	0 - 61	mg/l
	Total C	49 - 104	"
Silicon			
	SiO_2	0.00 - 20	mg/l
	SiO_4^{-2}	0.00 - 7.0	"
Metals			
Dissolved			
	Fe (Iron)	0.00 - 810	ug/l
	Mg (Magnesium)	1.1 - 1800	mg/l
	Sr (Strontiun)	0.2 - 9500	ug/l
	Na (Sodium)	8.6 - 14000	mg/l
	K (Potassium)	0.2 - 14000	mg/l
	As (Arsenic)	0 - 10	ug/l
	Al (Aluminium)	0.8 - 40	"
	Mn (Manganese)	0 - 80	"
	Pb (lead)	0 - 5	"
	Zn (Zinc)	3 - 40	"
	Cu (Copper)	2 - 40	"
	Co (Cobalt)	ND	"
	Cr (Chromium)	0 - 1	"
	Cd (Cadmium)	ND	"
	Ca (Calcium)	7.3-1910	mg/l

General Category	Compound	Total Range	Unit Size
Particulate			
	Pb (lead)	0 - 8	ug/1
	Mn (Manganese)	0 - 70	"
	As (Arsenic)	1	"
	Cd (Cadmium)	ND	"
	Cr (Chromium)	10	"
	Co (Cobalt)	ND	"
	Cu (Copper)	ND	"
	Zr (Zirconium)	10	"
Total			
	Al (Aluminium)	2 - 210	ug/1
	As (Arsenic)	0 - 12	"
	Cd (Cadmuim)	0 - 10	"
	Hg (Mercury)	0.1 - 5.6	"
	Fe (Iron)	0 - 3100	"
	Mn (Manganese)	0 - 280	"
	Pb (Lead)	0 - 24	"
	Ni (Nickel)	0 - 47	"
	Cr (Chromium)	0 - 10	"
	Co (Cobalt)	0 - 5	"
	Li (Lithium)	0 - 0.15	"
	B (Boron)	1.1 - 6.0	"
	Cu (Copper)	0 - 10	"
	Zn (Zinc)	1.5 - 60	"

General Category	Compound	Total Range	Unit Size
Non-Metals			
	SO^{-2} (Sulfate)	0 - 3870	mg/l
	Cl^{-4} (Chloride)	13 - 25000	"
	F^{-} (Fluorine)	0 - 1.8	"
	Total Br (Bromine)	0 - 66	"
	Total I (Iodine)	0 - 0.25	"
Miscellaneous Parameters			
	PCB	0.00 - 0.00	ug/l
	Dissolved Solids residue @ 180°C	161 - 41400	mg/l
	Dissolved solids calculated	0.168 - 40200	"
	Dissolved Solids Sum of Constituents	139 - 45400	"
	Dissolved solids	.2 - 35.0	kg/m^3
	Dissolved solids	0.57	ton/day
	Oil and grease	0 - 15	mg/l
	Color	5 - 160	Platinum Cobalt units
	Biochemical Oxygen demand	0 - 7.4	mg/l
	Hardness Ca, Mg	105 -8700	mg/l
	Hardness (non-carbonate)	4 - 8600	mg/l
	Na^{+} Absorption ratio	1.0 - 48	
	Protein	0.0 - 18.5	
	Carbohydrates	0.0 - 15.4	

[a]Sources of data included in this table are: Smith, et al., (1950), Finucane and Dragovitch (1959), Jones (1963), U.S. Geological Survey (1964-75) and Segar, et al., (1971).

[b]not detected.