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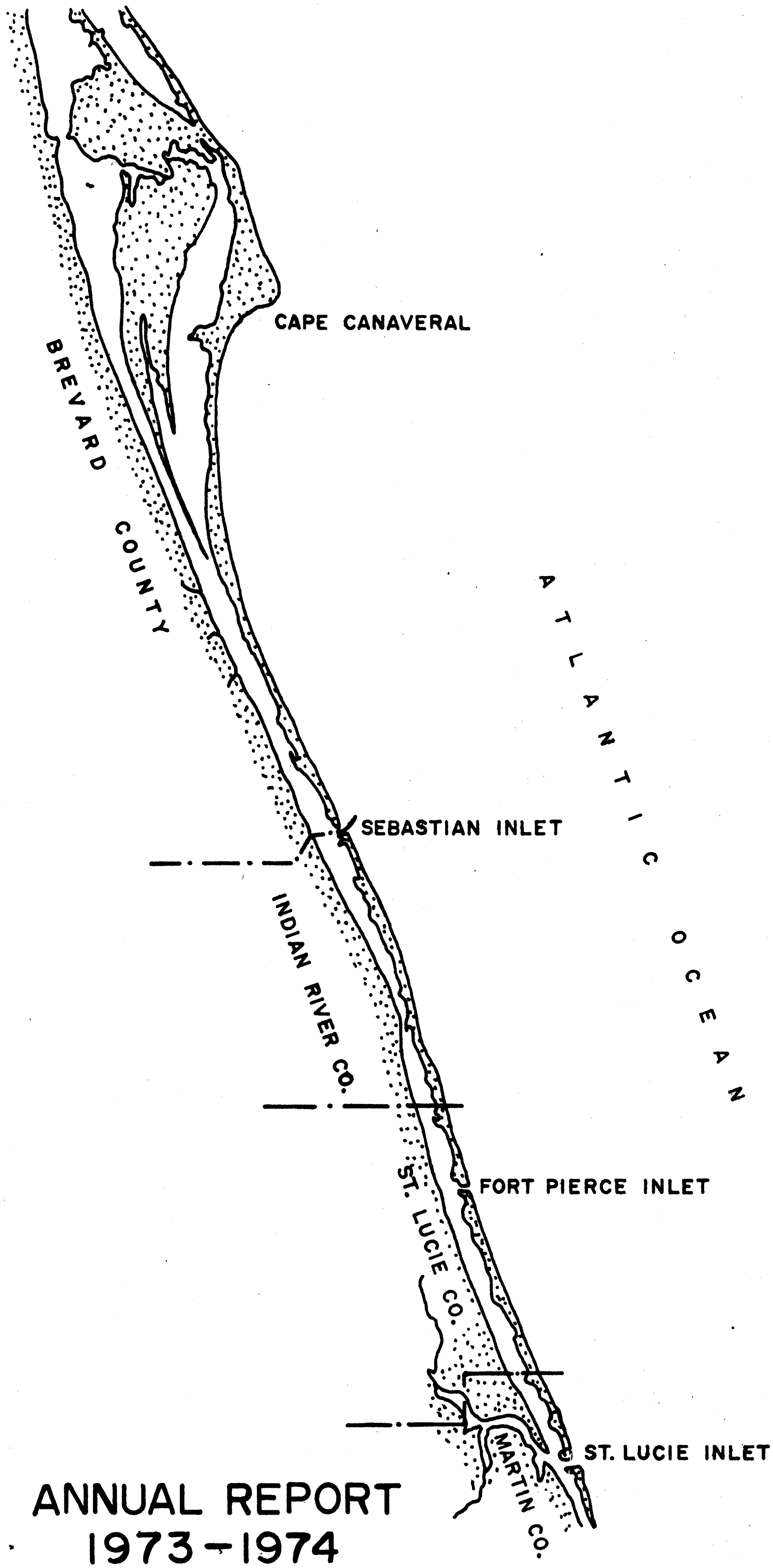

INDIAN RIVER STUDY

ANNUAL REPORT 1973-1974

VOLUME 1

KAREN A. STEIDINGER

H A R B O R   B R A N C H   C O N S O R T I U M

North Old Dixie Highway
RFD 1, Box 196
Fort Pierce, Florida 33450

Harbor Branch Foundation

Smithsonian Institution

Link Foundation

Woods Hole Oceanographic Institution

INDIAN RIVER STUDY

by

David K. Young
Robert M. Avent
Lawrence I. Briel
Nathaniel J. Eiseman
Robert H. Gore
Robert S. Jones
George A. Kerr
Harry H. Seibert
Ortwin vonZweck
J. Ross Wilcox

H. Adair Fehlmann - Principal Investigator

FIRST ANNUAL REPORT

A report on research and progress ending October 1974.

Cover by Michael Laffey. Map of the Indian River region from St. Lucie Inlet to Mosquito Lagoon.

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FOREWORD

The Indian River Study was initiated in September 1973 by a grant from the Atlantic Foundation to the Smithsonian Institution in support of a proposal for a three-year study entitled, "The distribution, ecology and systematics of the fishes and decapod crustaceans of the Indian River in relation to selected environmental factors". Dr. H. Adair Fehlmann was the principal investigator of this study. The proposed research was to build upon a survey of the fishes and decapod crustaceans begun in November 1971, directed by Dr. Robert H. Gore, and supported jointly by the Harbor Branch Foundation and Smithsonian Institution.

During the past year, increasing cooperative overlap of staff, facilities and equipment between the Harbor Branch Foundation and Smithsonian Institution has resulted in the expansion of scope and productivity of the Indian River Study. Although the first year's grant support of the Study will terminate as of 31 December 1974, support by both the Harbor Branch Foundation and Smithsonian Institution will continue during 1975.

Therefore, this document represents the terminal report by the Smithsonian Institution to the Atlantic Foundation for grant support of the Study, as well as the first annual report of progress by the Indian River Study under joint sponsorship of the Harbor Branch Foundation and Smithsonian Institution. The work reported herein represents results of research as of October 1974.

The major project goals of the Indian River Study are as follows:

(1) Inventory - to obtain baseline information on the diversity of organisms and quality of the environment in the Indian River region, particularly as related to effects of pollution.

(2) Data Acquisition - to establish a computerized data bank permitting a rapid and efficient storage and retrieval capability for environmental information concerning the Indian River region.

(3) Prediction - to gain a predictive capability of both short and long-term effects of natural and man-induced changes to the Indian River ecosystem.

The philosophic basis and rationale for the Indian River Study were presented to the Trustees of the Atlantic Foundation during their annual meeting at Link Port, 7 December 1973, as follows:

> "The guiding philosophy of the Indian River Study is that natural ecosystems should be investigated using a holistic approach, that is, as much information should be concurrently obtained by as many different means as possible to provide a thorough understanding of the operational characteristics of an ecosystem. A central concept to the study of an ecosystem is that all components of the environment, both living (biotic) and nonliving(abiotic), interact in an interdependent manner. Much of our understanding of an ecosystem depends on man's ability to define the interactions and cause-effect relationships between the biotic and abiotic components. This is critically important today when pollution is increasingly affecting natural ecosystems.
>
> Any multidisciplinary approach that is uncoordinated will result in piecemeal answers, providing little if any understanding of the functioning of an ecosystem as a whole. In contrast, the Indian River Study will, through an integrated field and laboratory approach, gather physical, chemical and biological data in one coordinated program. A common data format will be used by which correlations between variables and extrapolations with regard to space and time can be readily made by computer.
>
> The Indian River Study is designed to define, examine and clarify environmental problems of the coastal zone from Jupiter Inlet in the south to Ponce de Leon Inlet in the north, but the main area of concentration will be from St. Lucie Inlet northward to the Banana River and the Mosquito Lagoon. Environmental concerns of the coastal zone include physical destruction of the environment, such as by dredge and fill operations, and changes of

natural ecosystems by man-produced or man-influenced pollution. Oil, pesticides, heavy metals, sewage and turbidity represent some of the different types of pollution caused by man.

The National Environmental Policy Act, or so-called NEPA, of 1969, provides guidelines by which any proposed manipulation of the environment by man has to be supported by an Environmental Impact Statement. Such a Statement has to provide, among other things, scientific evidence which indicates whether the effects of the proposed manipulation will have harmful, neutral or beneficial effects upon the environment. Studies to provide such information, by their very nature, have to be short term and site-specific. Most commonly, previous baseline information about a specific area to be studied is lacking, so data on seasonal fluctuations and annual variations are not available. In addition, information on species present in an affected area is incomplete regarding occurrence and distribution of all life history stages of the organisms. Tolerances of these species to the effects of the proposed manipulation are not usually known. Most importantly, the biological information is usually not coupled with physical and chemical information, so probable effects upon the ecosystem cannot be accurately predicted, particularly with regard to those areas adjacent to the specific site studied.

The Indian River Study will approach those voids not usually filled by research supporting Environmental Impact Statements. The Study will be unique in its approach to obtaining long-term information about a natural ecosystem over a large geographic area.

An inventory will be made of the Indian River with regard to species of flora and fauna as well as selected chemical and physical variables. Chemical variables, such as major nutrients, heavy metals and pesticides have been selected for study as probable pollutants of the ecosystem. Physical variables such as currents and tide have been selected for study as deemed necessary to determine the residence time and transport of potential pollutants. The presence or absence of certain species of flora and fauna will indicate probable effects of pollutants on natural communities of the ecosystem.

Information about the ecosystem of the Indian River will be efficiently collected by a highly mobile field unit operating mainly from the barge facility at Link Port. The heart of the inshore effort will be a 36-foot houseboat which is specifically modified as a research vessel with a capability for _in situ_ measurements of many environmental variables. Shallow draft skiffs and field vehicles will be used to collect samples in grassflat and mangrove areas. Collections using the R/V GOSNOLD will provide information about offshore populations of marine organisms, particularly the commercially and recreationally important crustaceans and fishes. These data will be used to gain further insight into the onshore-offshore migrations of species which spend their critically important early life histories within the Indian River.

All data will be analyzed by computer to determine seasonal and long term trends. Initially, because of the large geographic area and great numbers of variables to be studied, some specificity will be sacrificed for more general information. It is expected that specificity and predictive capabilities will increase with time and with an increase of understanding of the operational characteristics of the ecosystem. This deductive approach will be highly heuristic and will undoubtedly uncover new and important aspects of the ecosystem which should be more intensively studied. In this respect, the Study will be important to both basic and applied science and should be a model for investigations of other geographic areas in addition to the Indian River."

The individual chapters of this document are the responsibilities of the supervisors in each research or support area. In most cases, the chapters represent drafts of manuscripts that have been prepared for publication in journals or technical reports. Therefore, the individual style and format of presentation in the chapters have been been preserved. Due credit is given where individual sections or appendices within a given chapter were written or contributed by research assistants and technicians.

In addition to these chapters authored by research staff, special thanks are due Captain Harry Seibert who contributed a chapter on the use of ships and small boats by the Indian River Study. In particular, thanks are due Mr. Russell "Slim" Floyd, the operator of the R/V CASA AQUA, for his help in field work as well as maintenance of the barge laboratory.

Much of the specialized field gear and laboratory apparatus reported in this document has been designed and built by Mr. John Holt of Research and Development, Engineering Laboratory, Harbor Branch Foundation. Mr. Holt donated much time after working hours and during weekends in liaison between Science and Engineering.

Mr. Michael Laffey, chemistry technician with the Indian River Study, prepared many of the figures and drawings. Mr. William Davenport, Photographic Services-Science Laboratory, did all photography. Ms. Karen Wright, secretary of the Indian River Study, typed the final manuscript.

The open cooperation of the staffs of the several institutions at Link Port contributed to the Indian River Study in many ways, too numerous to mention here. All is sincerely appreciated.

David K. Young
Program Manager

November 20, 1974

CHAPTER 1

Ship and Small Boat Operations for the Indian River Study

Capt. H. H. Seibert

R/V GOSNOLD

Since arrival on 5 November, 1973, the R/V GOSNOLD, which was leased from Woods Hole Oceanographic Institution, operated from Link Port for a total of 329 days during which time 41 cruises (G207-G248) and 726 stations were made. A total of 227 scientists and technicians were aboard during these cruises. The cruises resulted in a broad and comprehensive coverage of biological and physical oceanographic stations of the continental shelf and upper continental slopes of East-Central Florida (see Figures 1 and 2).

The past year's operation of the R/V GOSNOLD was highly successful for the initial "Inventory" phase of the Indian River Study. Refer to the following chapters for descriptions of scientific results of cruises for purposes of the Indian River Study.

It is noted that GOSNOLD provided a stable platform and was able to remain at sea and continue working safely, with winds to about 35 knots and seas running five to eight feet. However, two problems arose. One was the problem of towing nets and dredges. They were best towed over the stern; but GOSNOLD had problems due to her high stern and having no winches astern. Second, the problem of too many crew members aboard GOSNOLD. A minimum of seven men were required while at sea, so when the vessel was in port, there was no opportunity to curb expenses by using these men in other positions.

I believe we could operate a smaller vessel, of not less than sixty feet. Fewer men would be required for a crew, less fuel would be consumed because of the size, and more speed would be possible because of design. The proper vessel would have the ability to tow over the stern, be air-conditioned for comfort and have the facilities to remain at sea for about five to seven days. It would, of course, be the property of

Figure 1. Stations of water column samples from the R/V GOSNOLD, including those of the Indian River Study (figure prepared by G. Kulczycki and L. Becker, photographed by W. Davenport).

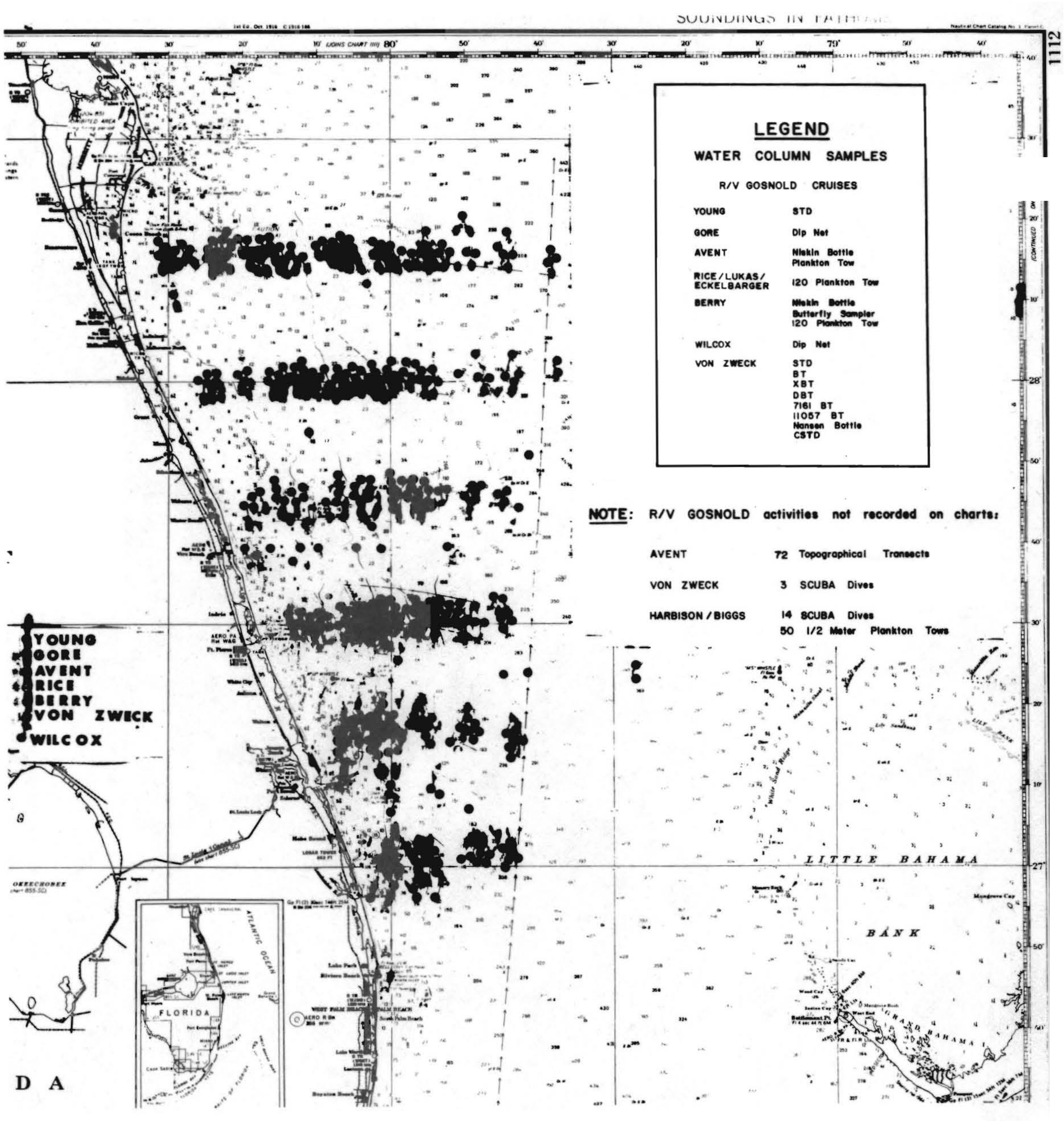
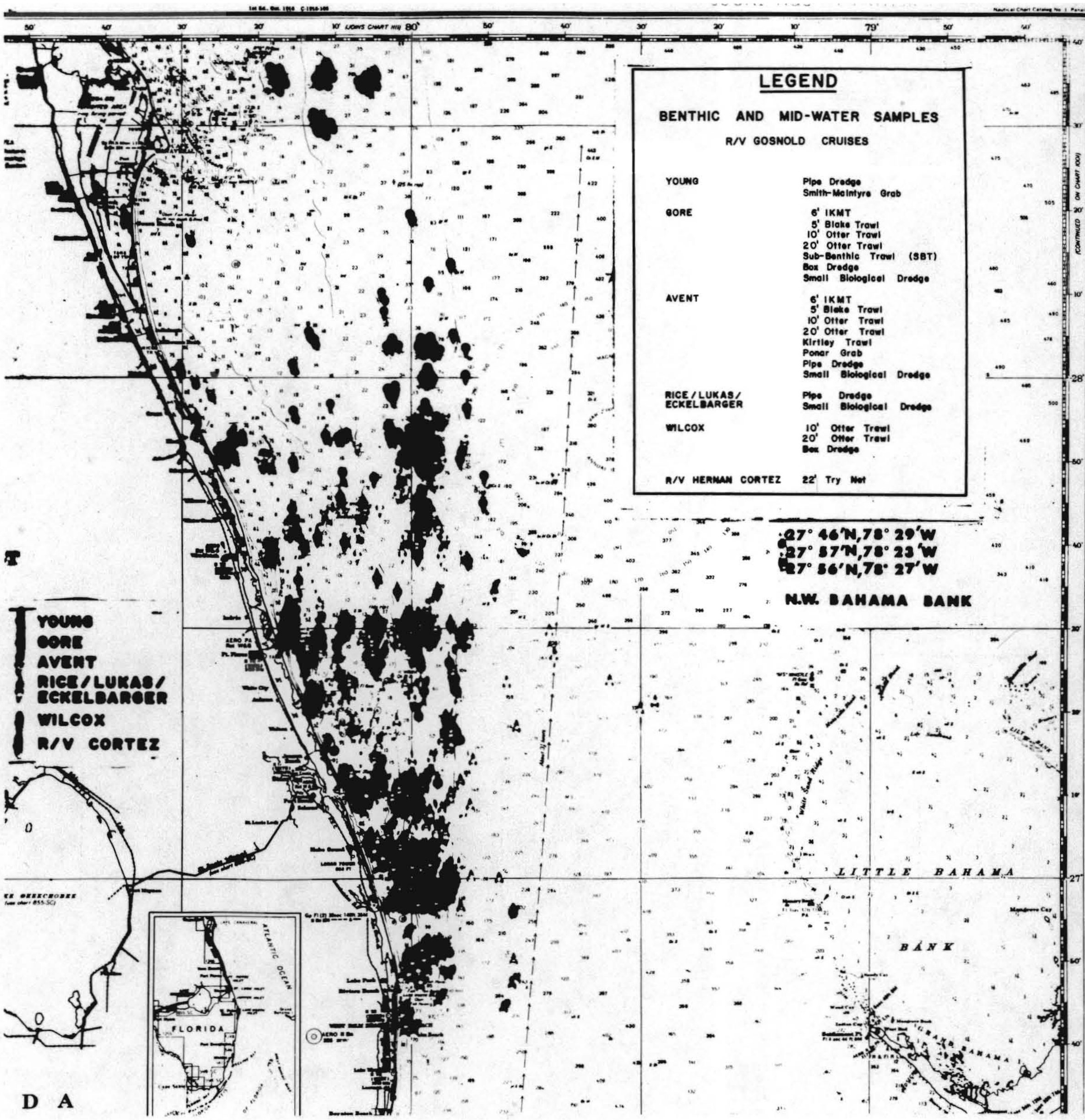

LEGEND
WATER COLUMN SAMPLES
R/V GOSNOLD CRUISES
YOUNG STD
GORE Dip Net
AVENT Niskin Bottle Plankton Tow
RICE/LUKAS/ ECKELBARGER 120 Plankton Tow
BERRY Niskin Bottle Butterfly Sampler 120 Plankton Tow
WILCOX Dip Net
VON ZWECK STD BT XBT DBT 7161 BT 11057 BT Nansen Bottle CSTD
NOTE: R/V GOSNOLD activities not recorded on charts:
AVENT 72 Topographical Transects
VON ZWECK 3 SCUBA Dives
HARBISON / BIGGS 14 SCUBA Dives 50 1/2 Meter Plankton Tows
YOUNG
GORE
AVENT
RICE
BERRY
VON ZWECK
WILCOX
LITTLE BAHAMA
BANK
FLORIDA
ATLANTIC OCEAN
D A
1112
80°
79°
28°
27°

Figure 2. Stations of benthic and mid-water samples from the R/V GOSNOLD, including those of the Indian River Study (figure prepared by G. Kulczycki and L. Becker, photographed by W. Davenport).


LEGEND
BENTHIC AND MID-WATER SAMPLES
R/V GOSNOLD CRUISES
YOUNG
Pipe Dredge
Smith-McIntyre Grab
GORE
6' IKMT
5' Blake Trawl
10' Otter Trawl
20' Otter Trawl
Sub-Benthic Trawl (SBT)
Box Dredge
Small Biological Dredge
AVENT
6' IKMT
5' Blake Trawl
10' Otter Trawl
20' Otter Trawl
Kirtley Trawl
Ponar Grab
Pipe Dredge
Small Biological Dredge
RICE/LUKAS/ECKELBARGER
Pipe Dredge
Small Biological Dredge
WILCOX
10' Otter Trawl
20' Otter Trawl
Box Dredge
R/V HERNAN CORTEZ
22' Try Net
27° 46'N, 78° 29'W
27° 57'N, 78° 23'W
27° 56'N, 78° 27'W
N.W. BAHAMA BANK
YOUNG
GORE
AVENT
RICE/LUKAS/ECKELBARGER
WILCOX
R/V CORTEZ
LITTLE BAHAMA
BANK
FLORIDA
ATLANTIC OCEAN
80°
79°
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D A

Harbor Branch and would not have to be stripped after each trip as a chartered or leased vessel would require.

R/V CASA AQUA

Since the arrival of the 36-foot "Sea Rover" houseboat at Link Port on 1 January, 1974, a 9 x 14 foot laboratory space has been completed aboard and instrumentation has been installed. Refer to the chapter by L. Briel (this report) for description of the on-board instrumentation. The houseboat, recently named the R/V CASA AQUA, completed 19 scientific cruises by 17 October, 1974, including four combined chemistry-biology cruises over the length of the Indian River from St. Lucie Inlet to the Mosquito Lagoon at Haulover Canal.

The R/V CASA AQUA has surpassed expectations in the wealth of data achieved by this mobile laboratory-vessel system as well as in the economy of the operation. CASA AQUA operates about two weeks out of every five. While on cruises an on-board generator powers all electricity however, CASA AQUA normally moors during the evening at marinas at selected sites along the Indian River.

She requires a Boatman, Mr. Russell Floyd, for that period on cruises and to maintain the vessel in running condition.

Other Small Boats

Many small boats are available for use by scientists with the Indian River Study, including the recently acquired diesel-powered inboard, R/V BLUE FOX, operated by Mr. Carl Tomica. In particular, the Mullet Smasher is currently being outfitted for use by the Indian River Study.

Radio contact with the R/V CASA AQUA and the R/V BLUE FOX while they are at sea is now being maintained through a receiving station aboard the Barge laboratory facility at Link Port. Currently the small boat program is handled by three personnel, who under the current usage of boats, should be able to maintain the boat fleet in reliable running condition.

CHAPTER 2

STUDIES OF THE EAST FLORIDA CONTINENTAL SHELF

R. M. Avent

M. E. King

ABSTRACT

A total of eighty topographic transects were made off the coast of central Atlantic Florida, between November, 1973, to September, 1974, aboard R/V Gosnold. Regions of rocky prominences were studied most intensively.

Profiles obtained with a Gifft Depth Recorder confirmed the presence of continuous and discontinuous structures on the continental shelf and on the shelf-slope break. Most conspicuous is a string of "spikes" and benches running north from Fort Pierce to Cape Canaveral, Florida. These lie under the western edge of the Florida Current in 80 meters of water and at longitude 80°W. South of Fort Pierce these structures almost disappear. Other shallower features of low profile are seen in depths of 30 to 60 meters. The origin, structure, and morphology of diverse geological features are discussed on the basis of available topographic and geological evidence.

Biological dredgings demonstrate the existence of a diverse invertebrate and fish fauna associated with rocky structures off eastern Florida.

INTRODUCTION

The marine environment is a continuous system of waters of which the most obvious characteristic is its salt content. Authors have variously described and redescribed its integral components (estuary, continental shelf, continental slope, and deep sea) largely on the premise that compartimentalization is a necessary (if sometimes an undesirable prerequisite for practical investigations and reports. It is obvious to most observers, however, through myriads of studies, that the several marine regimes are neither static nor independent. Biologically, chemically, physically and geologically, components of the environment are connected; physically via tidal, geostrophic and wind driven currents; biologically via migrations, energetics, larval development, and competition, and geochemically via dissolution, dilution, concretion, and precipitation. Each environmental regime is a product of its several sources.

The oceanographer's view is that the interdisciplinary approach is most productive in marine investigations. He considers marine habitats as interconnecting and interrelated, yet separately definable entities. With this approach in mind, the Biological Oceanography section has devoted itself to a series of investigations which have dovetailed into the inventory phase of the Indian River Study scientifically and philosophically. To date our efforts have fallen into two major categories:

1) Biological Inventory of the Continental Shelf

In cooperation with Smithsonian and Harbor Branch Foundation scientists (especially Dr. Robert H. Gore), we have attempted to collect invertebrate and fish fauna from the continental shelf for taxonomic identification (see Appendix A for details). This endeavor has met with great success. Numerous faunal range extensions have been found as a result of these cooperative efforts. About 250 to 300 species each of decapod crustaceans and fishes have been listed for the Indian River region and the adjacent continental shelf (see chapters by R. Gore and R. Jones in this report).

2) Topographic and Physiographic Studies of the Central East Florida Continental Margin

A series of studies designed to describe offshore topographic features and associated sedimentary, thermal and faunal distributions was initiated in November 1973 on the first HBFL cruise of R/V Gosnold (G-207). These studies are being expanded in several directions, to include qualitative and quantitative benthic photography, sediment and rock descriptions, quantitative faunal collecting, and hydrographic investigations. Much of the future work envisioned will be accomplished with the aid of a unique research tool, the Johnson-Sea-Link submersible. Presently we are completing the initial topographic study based on numerous continuous sonic depth recordings from R/V Gosnold operations. The bulk of this report is devoted to these findings.

Topographic and Physiographic Studies of the Central East Florida Continental Margin

The structure of animal communities and distribution of marine organisms is dependent upon a myriad of physico-chemical and biotic factors. Among the most important and obvious parameters, with which benthic ecologists must deal are temperature, salinity, eH, dissolved oxygen, substrate type, water current, light intensity, inter- and intra-specific competition, food recources, and "lebensraum". It is not always possible to identify and ascribe limiting factors to animal existence in the natural environment. Yet it is often experimentally demonstrable that each organism has its "preference" for certain sets of conditions. Eurybiotic organisms (those living in, and adapted to widely fluctuating conditions) seem to be the exception, rather than the rule in nature. Perhaps the two most important physical conditions which must be met for benthic animal existence are optimal substrate type and temperature regime.

The primary objective of this series of studies is to describe as completely as practical, the offshore environment from which animals have been collected, giving emphasis to substrate and temperature variations in our geographic study area. Of special interest has been the location and description of rocky promotories, reefs, ledges, and ridges. These topographic structures, especially linear reef systems, often form water mass, current and sedimentation boundaries, and provide unique hard-substrate habitats for fishes and invertebrates. They provide a wide variety of physical niches for boring and cryptic forms. There is usually a higher species and biomass diversity associated with these structures than that of continental shelf, smooth, sandy bottom.

Numerous studies of the sediments, structure, evolution, and morphology of the Atlantic continental margin of the United States over the past 20 years, have made this submarine region by far the most extensively studied. (See, e.g., Drake and Ewing, 1968; Emery, 1966, 1968; Emery and Zarudski, 1967; Hurley, et al., 1962; Menzies, et al., 1966; Pilkey, 1964; Pratt, 1966; Moe, 1963; Struhsaker, 1969; Uchupi, 1963, 1966, 1968, 1969; and Uchupi and Emery, 1968.)

Study area-setting

The study area off central eastern Florida includes parts of the continental shelf, upper continental slope (Florida-Hatteras slope) and floor of the Straits of Florida, between latitudes 26°30'N and 28°30'N.

The continental shelf in the area of study varies in width from 2 km off Palm Beach to 50 km off Cocoa Beach, and encompasses about 1500 km^2 of ocean bottom. Sediments reflect its past biogenic (biologically-derived) conditions of deposition. From the Cape Hatteras region, south, including the study area, the continental shelf is characterized by quartzose and calcareous sands, gravels and silts. Cores in depths of 20 m and less off Ft. Pierce show five types of carbonate strata in various stages of fragmention, weathering and induration (Meisburger and Duane, 1971). Carbonate concentration increases southward and seaward (Pilkey, 1964). The 50% carbonate isopleth lies near the landward edge of the Florida current and matches the shelf-edge closely. The transition is abrupt from calcareous sand on the outer shelf to virtually 100% calcareous silt and sand on the upper slope. Mollusc shells, echinoid and bryozoan debris, barnacle plates, and other skeletal remains predominate on the shelf; and foraminiferan tests, echinoid spines, sponge spicules and pteropod ooze predominate on the Florida-Hatteras slope. The abundance of relict (Tertiary) calcareous sediments indicates that more recent sedimentation has been low over most of the continental margin south of Cape Hatteras. Presently the continental shelf contributes little detrital material to the slope (Bond, 1970).

The continental shelf from Palm Beach to Cape Canaveral is believed to be a depositional feature, although some subsurface reflection profiles off Cape Canaveral (Meisburger and Duane, 1969) and some features south of Palm Beach such as Pourtales Terrace and Miami Terrace (Jordan, et al., 1964; Koford and Malloy, 1965) were caused by faulting.

The shelf-slope break is almost always topographically distinct from Cape Hatteras southward to Palm Beach and is often marked by a series of hills, ridges and reefs of coral and algal origin which lie approximately parallel to the coast (Menzies, et al., 1966, Moe, 1963; Struhsaker, 1969; Macintyre and Milliman, 1970). These features lie 2 to 75 km offshore, in depths of 35 to 100 m respectively (south to north). Continental shelf reefs vary in age from approximately 7000 to 20,000 yr. depending upon Pleistocene and Holocene reaches of sea level at the time they were formed. Off central Florida, the 80 m Oculina reefs date 13,000 to 14,000 yr. B.P. (Macintyre and Milliman, 1970). Shallower coquinoid reefs, exist along the east coast of Florida, notably in 20 to 34 m of water off Palm Beach (Emery, et al., 1970) and in 40 to 50 m of water off Sebastian and Melbourne. Many other small, reef-like features have been reported by Moe (1963) and Struhsaker (1969) in the study area. Most of these reef-like structures possess both actively growing and relict materials (corals, algae, etc.) but evidently have not survived rises in sea level. Evidence from topographic surveys and dredged samples indicates that shelf-edge reefs off North Carolina (Menzies et al., 1966), in the northern Gulf of Mexico (Ludwick and Walton, 1957) and off eastern Florida (Macintyre and Milliman, 1970) have much in common, morphologically and structurally.

The continental slope south of Cape Hatteras is broken by a broad platform, the Blake Plateau. Encompassing an area of 180,000 km^2 it lies at depths of 700 to 1100 m, and is bound on the south by the Little Bahama Bank. Blake Plateau sediments are mostly foraminiferan sand and silt of Tertiary origin. At the western margin of the Blake Plateau is the Florida-Hatteras Slope, which continues southward meeting the floor of the Straits of Florida at its seaward edge. The eastern boundary of the Blake Plateau is the precipitous Blake Escarpment which grades into the Blake Basin and Hatteras Abyssal Plain at about 5000 m. The Straits of Florida which begins off the Florida Keys (24°30'N) in depths of 860 m, shallows northward and grades into the southern and western extension of the Blake Plateau in depths of 740 m. The Straits of Florida and the Blake Plateau are swept by waters of the Florida Current moving swiftly northward. Pratt (1966) likened the Gulf Stream (Florida Current) to a graded river which moves water and sediment to the north, neither eroding nor agrading the Straits. The presence of sand ripples and exposed manganese encrustations and Miocene limestone supports his view. Hurley, et. al., (1962) believes that the hyperbolic topography in the northern Straits off central Florida represents rugged rock outcroppings which are swept of recent sediments.

The Straits, then, seem to result, not from faulting, but from balanced erosion under the Florida Current and from differential up-building of its margins (Florida Plateau to the west, and the Bahamas to the east), (Uchupi, 1966, 1968, 1969).

Materials and Methods

Topographic transects were made aboard R/V Gosnold in depths from 30 m to 750 m over the eastern Florida continental margin. Latitudinal limits of our operation were Cape Canaveral (28°30') to the North and Palm Beach to the South (26°30'N). The area of major interest was a geographic triangle formed by 28°30'N, the east coast of Florida and 79°50'W (the approximate location of the 200 m isobath). A cumulative distance of 3200 km has been traversed in the course of this investigation.

In all cases ship speed (over the bottom) was from 3 to 9 knots (usually 5 to 6 knots). Loran-A positions were taken routinely at the beginning and end of transects and every 1/2 hour while underway; USC&GS chart 1112 was used for Loran radar and visual navigation in local waters. East-west orientation was difficult to achieve on occasion because of high winds and heavy seas. Heavy ship roll and wave noise occasionally resulted in partially obscured depth records and minor inaccuracies, (± 0.5 to 1.0 m). Depths recorded are based on an assumed sound velocity of 1500 m/sec. No slope corrections have been applied.

The profiler employed was a model 4100 Gifft Depth Recorder (GDR) interfaced with protected and unprotected, 12kHz, Edo-Western transducer heads. The GDR was routinely programmed for a 150 m scale range (19" chart), standardized paper feed rates, and transmit-receive schedules. Transducer and receiver gain and pulse length were varied as needed to obtain clean depth traces, line darkness, and resolution. Except times when chart rolls were changed or GDR maintenance was required, bottom profiles were continuous. Many surface water temperatures and salinities were taken while underway except in unusually heavy seas. Recorder charts were marked every 10 to 20 minutes with cruise number, date, time, heading, speed, depth, scale, temperature and pertinent notes (see Appendix B). These records added to Loran-A fixes from ships logs has produced a high density, three-dimensional view of the bottom. On the average, transects occur about every 2 mi (3.7 km) from north to south, and in no instance is a point on the chart (over 30 m deep) farther than 5.5 mi (10.2 km) away from the nearest transect. These records are not intended for navigational uses. Rather, they were taken in hopes of producing a morphologically informative view of the central east Florida continental margin.

GDR data were transferred to proforma sheets (Appendix B) for later computer analysis (Appendix C). Records include all above mentioned data and descriptive topographic notes. All data have now been corrected and key punched, and are awaiting the completion of computer programming for analysis, and final tape storage at the Information

Systems Division, Smithsonian Institution, Washington, D.C. Figure 1 shows geographic coverage of computerized transects.

At least three computer programs are anticipated:

1) Linear interpolation of Loran positions. The computer will add interpolated positions to each available depth entry. (Program now in final stages of correction).

2) Retrieval program.
The computer will retrieve on demand all or part of the available data (e.g. all topographic notes, temperatures for the month of July, or latitude and longitude for all depths between 46 m and 48 m).

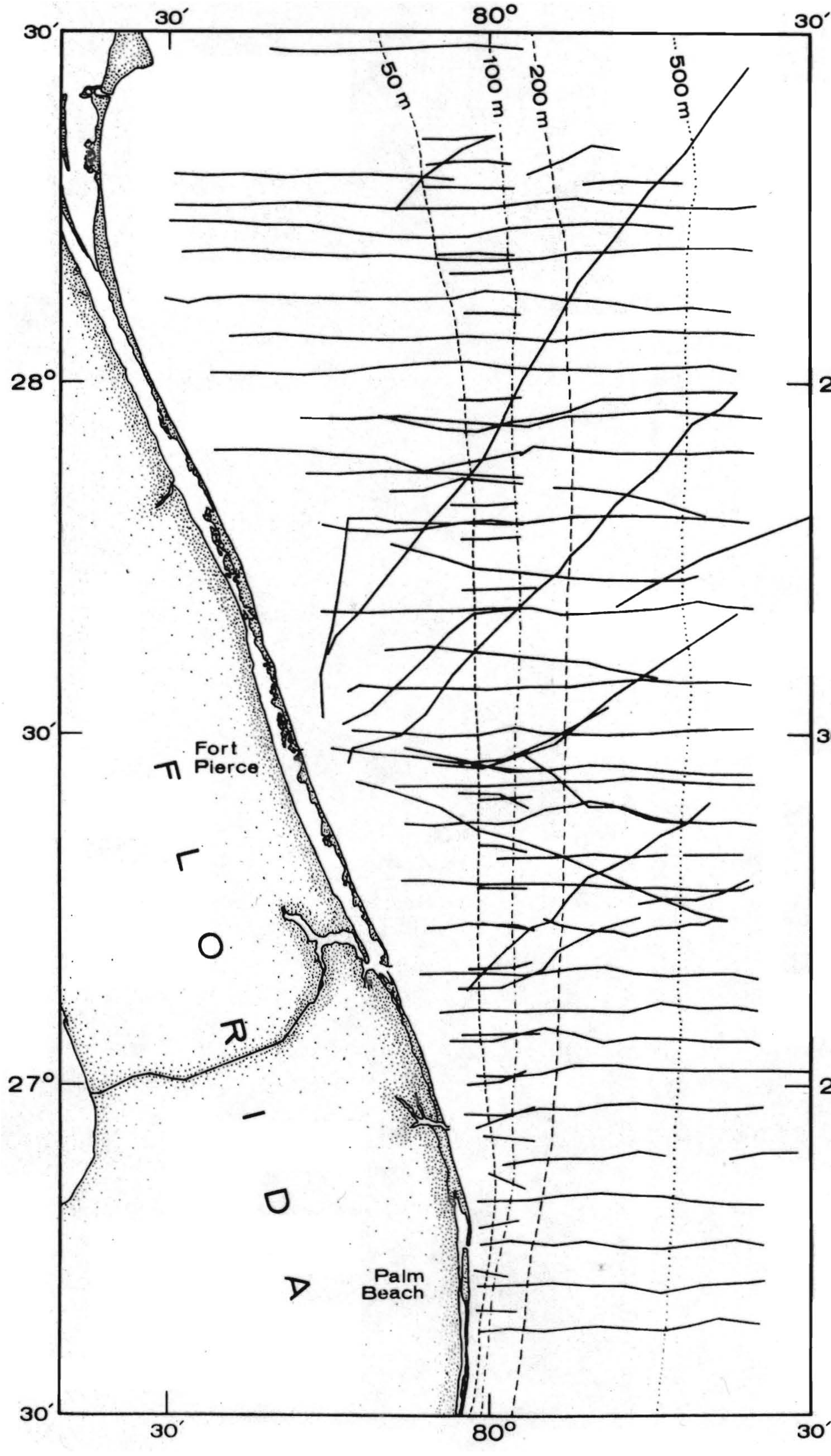
3) Contour plotting (CALCOMP plotters).
Upon completion of (1) and (2) above the computer will derive an x-y regional chart with depth contours, topographic features, and scale marks. These charts will be compared to existing ones to determine if short term bathymetric changes have occurred.

The writer expresses his gratitude to Captain Harry H. Seibert and his crew for their outstanding cooperation and service aboard R/V Gosnold. For assistance in data management, transcription and correction, he thanks Mr. George Kerr and Mr. Douglas Cochrane.

Results and Discussion

Between Cape Canaveral and Palm Beach, Florida (26°40'N and 28°30'N inclusive) the continental shelf and Florida-Hatteras Slope takes on several distinct morphological patterns. North of Ft. Pierce (27°30'N) to Cape Canaveral (28°30'N) shelf-edge reef topography is characterized

Figure 1: Topographic transects taken aboard R/V GOSNOLD, November, 1973 to June, 1974.



30′
80°
30′
50 m
100 m
200 m
500 m
28°
30′
Fort Pierce
F
L
O
R
I
D
A
27°
Palm Beach
30′
80°

by hills and pinnacles or "spikes" up to 25 m above the otherwise relatively smooth bottom. South of Fort Pierce to Jupiter Inlet the shelf edge is comparatively smooth with the exception of a distinct hammock off St. Lucie Inlet (27°07' to 26°12'N), and rare spikes. From Jupiter Inlet to Palm Beach the continental shelf is narrow. Here the shelf-slope break is abrupt and the slope is unusually steep.

Both continuous and discontinuous shelf structures exist along Florida's central Atlantic coastline. Table 1 and Figures 2 to 4 show the morphology, location and depth of specific features.

Major shelf-edge features are described below in detail starting at Cape Canaveral and proceeding southward. Transects have been labeled individually (A to ZZ, Figure 3 and Table 1; ZZ to zzz, Figure 4) for reference. Altogether 55 transects are pictured from north to south, each of which is a direct tracing of an original GDR profile. All transects were aligned on 80°W longitude. Proper latitudinal juxtaposition of the transects was accomplished by placing the point at which the transect crossed 80°W on the corresponding latitude scale to the left. Circles and triangles indicate depths of 50 and 100 m respectively. Figure 6 shows a sample GDR record of the continental margin (27°48'N) in perspective.

Shelf-edge Structures

The shelf-edge is marked conspicuously by a reef system between 28°28.8'N to 27°36.8'N. Height as of the forereef above surrounding bottom varies from 3 m to 25 m, and averages 11 m. The northern transects (A-V) show that the reefs are usually best developed ("spikes") at their seaward extension with a series of irregular mounds or benches 3 to 9 m high, lying 1 to 5 km landward of the forereef. The reef system varies from

Table 1. Position, depth, and time of crossing of shelf-edge topographic structures seen in Fig. 3.

TRANSECT	GOSNOLD CRUISE NO.	DATE	TIME	POSITION OF FOREREEF*		DEPTH** (M)	SHIP COURSE (°)
				Lat. (N)	Long. (W)		
A	236	6-VI-74	0040	28°28.8'	80°00.8'	91	270
B	239	21-VI-74	0131	28°21.2'	80°00.4'	81	90
C	239	20-VI-74	2348	28°19.1'	80°00.4'	81	270
D	239	20-VI-74	2305	28°16.9'	79°59.1'	87	90
E	236	6-VI-74	0849	28°15.3'	80°00.0'	81	90
F	225	20-VI-74	1142	28°12.9'	79°59.9'	75	265
G	239	20-VI-74	2153	28°11.2'	79°59.9'	77	275
H	239	20-VI-74	2009	28°09.5'	79°59.9'	77	90
I	225	20-III-74	2033	28°07.8'	79°59.4'	86	85
J	239	20-VI-74	1954	28°06.0'	79°58.7'	91	270
K	236	7-VI-74	0435	28°08.9'	79°59.6'	78	90
L	225	21-III-74	0502	28°01.5'	79°59.6'	78	275
M	239	20-VI-74	1748	27°58.9'	79°59.1'	77	90
N	236	7-VI-74	1308	27°56.5'	79°59.0'	74	275
O	207	6-XI-73	1835	27°56.2'	79°59.1'	73	85

*Seaward - most extension of shelf-edge structures
**Depth at junction of reef and slope

Table 1. (cont'd.)

TRANSECT	GOSNOLD CRUISE NO.	DATE	TIME	POSITION OF FOREREEF*		DEPTH** (M)	SHIP COURSE (°)
				Lat. (N)	Long. (W)		
P	225	21-III-74	1249	27°53.8'	79°58.2'	81	80
Q	236	7-VI-74	1820	27°52.0'	79°57.9'	93	95
R	207	6-XI-73	1339	27°51.4'	79°57.8'	96	275
S	239	20-VI-74	1526	27°49.6'	79°57.7'	97	270
T	236	7-VI-74	2000	27°48.2'	79°57.8'	86	270
U	228	9-IV-74	2235	27°47.7'	79°51.2'	90	270
V	239	20-V(-74	1502	27°46.9'	79°58.3'	80	90
W	207	6-XI-73	0654	27°43.8'	79°58.3'	78	100
X	239	2-VI-74	1325	27°42.5'	79°58.4'	84	270
Y	228	10-IV-74	0426	27°40.7'	79°58.5'	85	90
Z	207	6-XI-73	0236	27°36.7'	79°59.0'	79	275

*Seaward - most extension of shelf-edge structures
**Depth at junction of reef and slope

Figure 2: Positions of transects crossing shelf-edge reef shown in Figures 3-4.

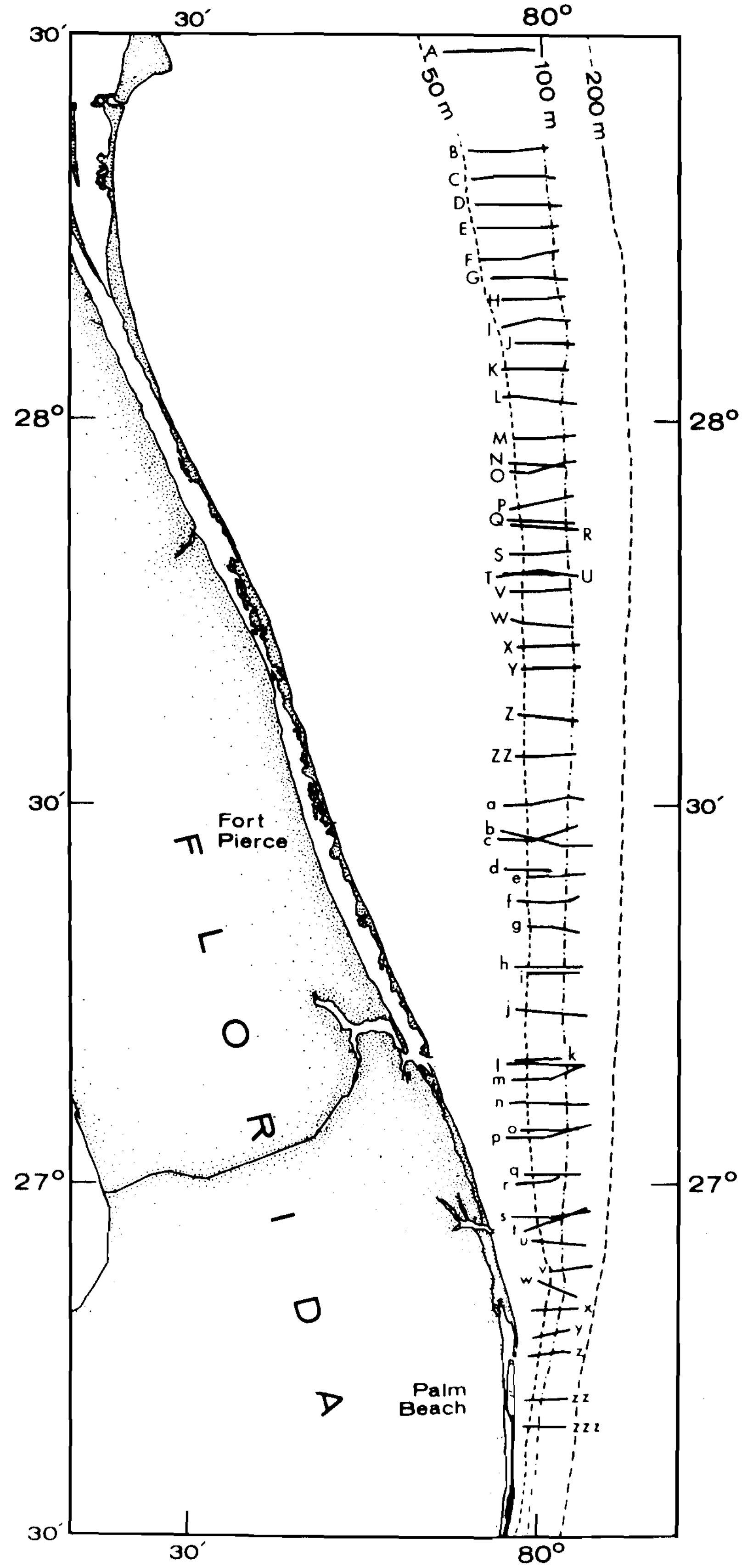
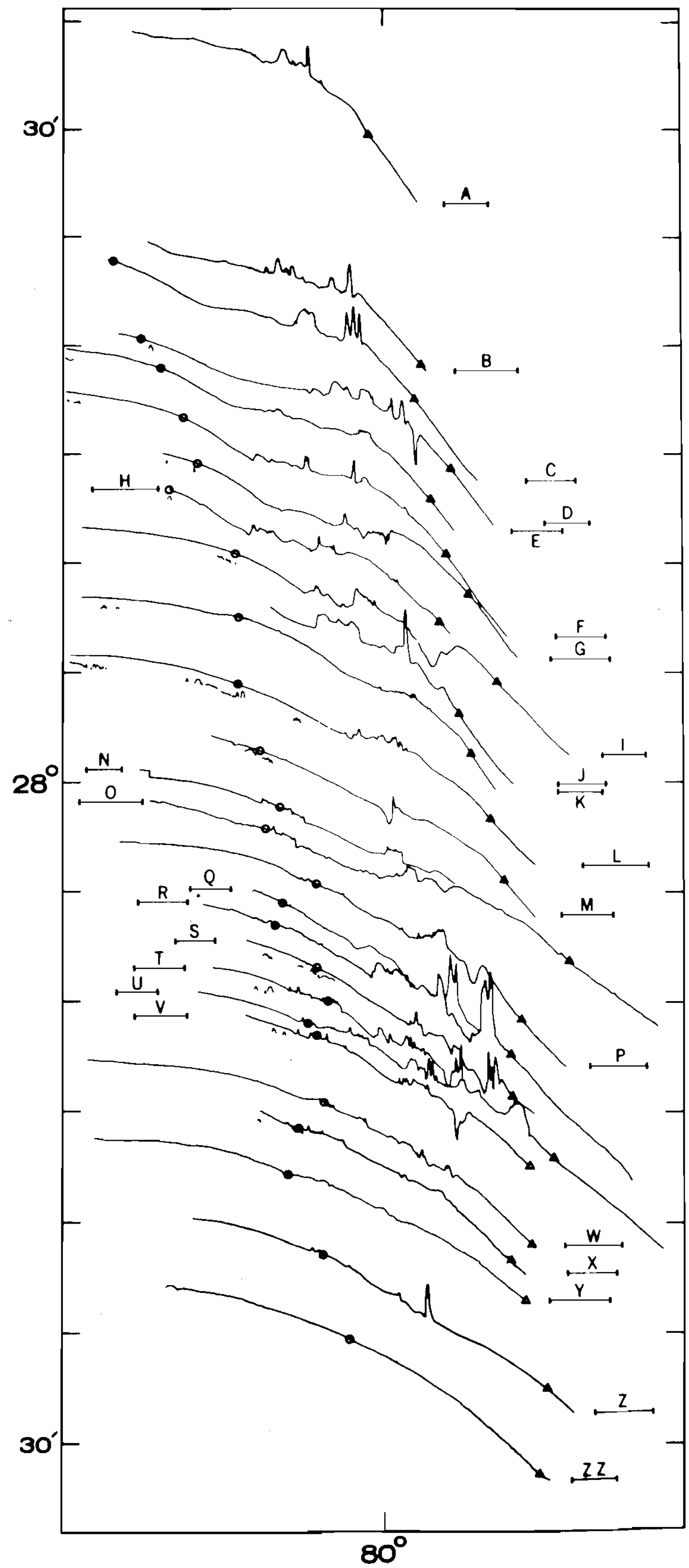
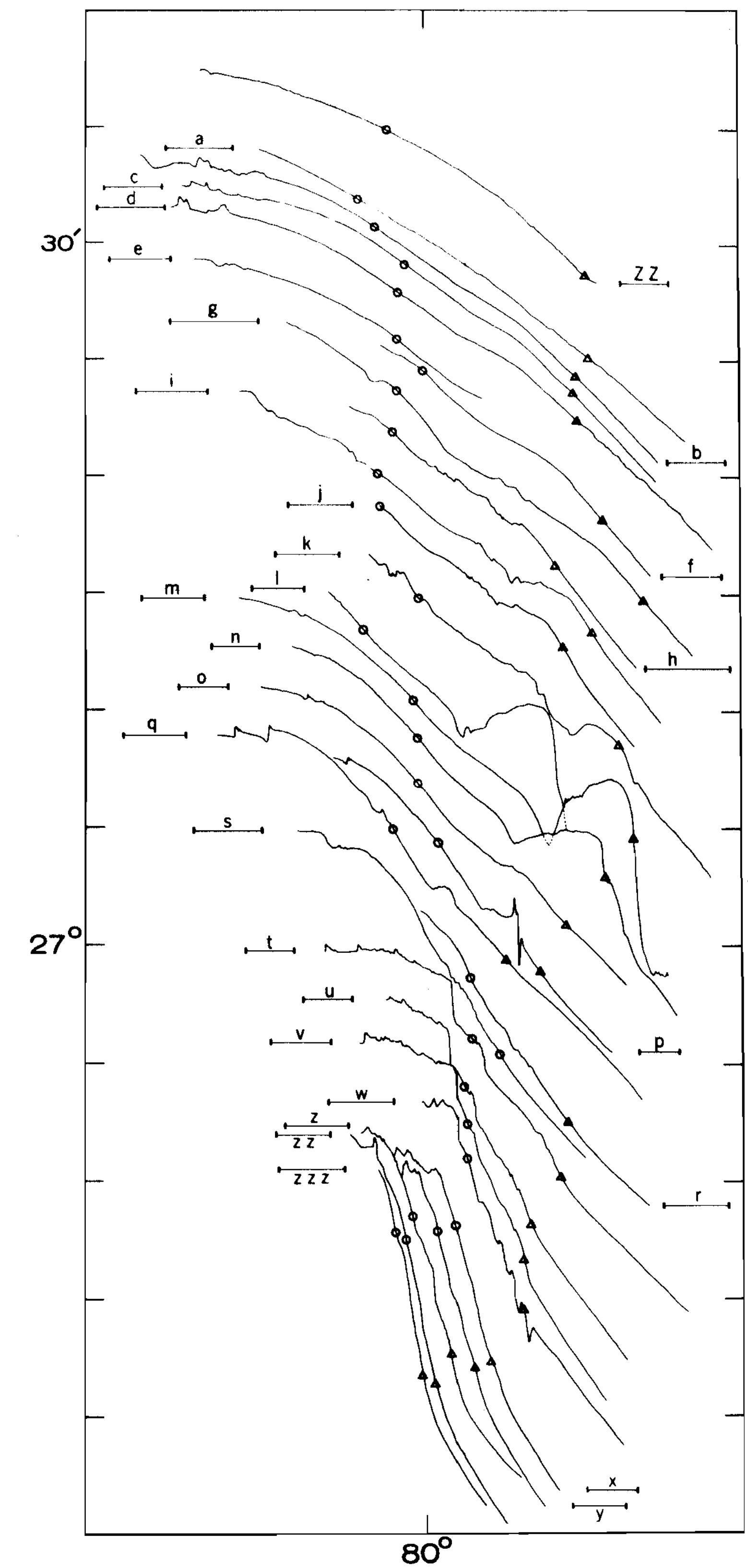

30′
80°
30′
28°
28°
30′
30′
27°
27°
30′
30′
80°
50 m
100 m
200 m
Fort Pierce
FLORIDA
Palm Beach

Figure 3: Shelf-edge structures,
Cape Canaveral to Fort Pierce (see text for details).



30′
28°
30′
80°
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
Z
ZZ

Figure 4: Shelf-edge structures,
Fort Pierce to Palm Beach (see text for details).



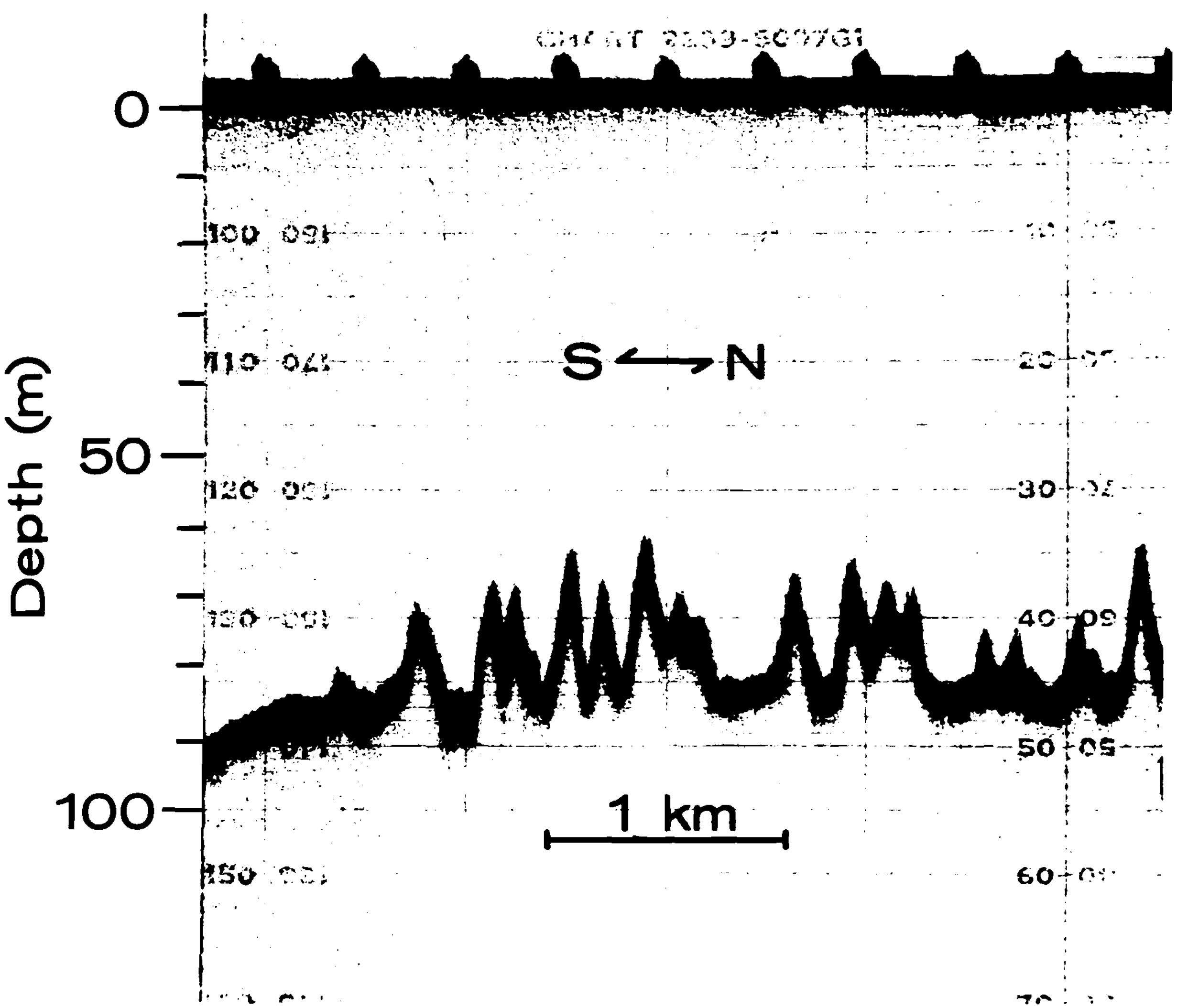
30′
27°
80°
a
c
d
e
g
i
j
k
l
m
n
o
q
s
t
u
v
w
z
z z
z z z
Z Z
b
f
h
p
r
x
y

3 to 5 km wide. The tops of the backreef benches lie at approximately the same depth as the tops of the forereef spikes (about 60 m) suggesting that they are of the same age (trans. A to D., F to L, Q, R, T, U). Shallow troughs or depressions exist landward of the backreefs suggesting little seaward flow of shelf sediments or terrigenous deposition.

North of 27°36'N, every transect (A-Z) shows some evidence of reefs. In a few transects (K, V-Y) shelf-edge reef development is poor. In some areas reef structures seem to bifurcate or join (backreef benches, trans. A-D) or are nearly identical (trans. K-L, N-O, Q-R). Usually, however, adjacent profiles bear only slight or moderate resemblance to each other. It seems certain then that the system itself is continuous but that individual prominences are often distinct and separate. Several north-south GDR and fathometer traces show this to be true. Figure 5, a fathometer recording taken while drifting north (longitude 79°58'W between 27°48' and 27''50'N) shows distinct peaks from 100 to 300 m wide at the base and from 5 to 20 m in height. Similar traces have been obtained in other areas of the reefs but they are not usually so pronounced or rugged. It is obvious from the small size of the peaks and the relatively wide transect spacing that most of them have gone undetected.

Reef prominences reach their maximum in height, number,and diversity from 27°47' to 27°52'N, a north-south distance of about 9 km. This area (about 35 km^2) is characterized by high, sharp pinnacles on the forereef and backreef, often with multiple spikes and deep intermittent depressions or valleys. Dredgings from this area show that *Oculina* coral (living and dead), *Oculina* rubble and well-worm pelecypod shells and hash are the dominant bottom materials. Miscroscopic examination of

Figure 5: North-south transect taken over shelf-edge structures with fathometer (latitude 27°48' N to 27°52' N, longitude 79°58' W).



Depth (m)
0
50
100
S ⟷ N
1 km

gravel and coarse sand fractions indicates that these elements are also calcareous. Several large rocks covered with living and dead corals, sponges, bryozoans, worm tubes and attached pelecypods have been dredged. Internal structure of some of these rocks reveals coquinoid limestone or oolitic limestone, frequently in alternating layers. Fracture faces and shapes of these rocks indicate that distinct ledges exist, having somewhat different attached faunal assemblages on upper and lower surfaces. The microrelief of such materials and the quantitative description of hard substrate communities will be the source of more intense future investigations. It is abundantly evident that the shelf-edge reefs harbor diverse animal communities.

From Fort Pierce (27°34'N) south to 27°24'N the shelf-edge reefs disappear. A smoothly-rounded bottom profile, sloping increasingly steeper seaward, remains to indicate the shelf-slop junction (trans. ZZ to f).

However, further south (27°22' to 27°17', trans. g-j) small (5m) protuberances exist between 60 and 85 m, possibly as a southern remnant of the reefs farther north. More likely, these low features are related to more southerly mounds, hummocks, and valleys. Transects g-n show a transition from smooth bottoms to large hummocks built immediately seaward of the shelf-slope break and from a gradual to a more precipitous seaward slope. This system of hummocks (trans. k-o) reaches its maximum development at 27°09.5'N directly off St. Lucie Inlet. United States Coast and Geodetic Survey's Hydrographic Survey Chart No. 8783 clearly shows this structure which extends seaward as a delta-shaped fan, the outer edges of which drop rapidly onto the Florida-Hatteras slope. It is enticing to speculate that it represents an ancient fluviatile delta, but no supporting data are immediately available.

Proceeding southward from St. Lucie Inlet to Palm Beach, the shelf narrows from 17 km to less than 3 km, and the shelf-slope break becomes increasingly pronounced. In this region, the Florida Current sweeps near shore, bathing a shallow series of shelf-edge reefs 30 to 35 m deep. Few indications of more northerly shelf-edge reefs remain. Transects p-v show scattered small peaks less than 3 m high and one isolated spike with a backreef bench in depths from 55 to 90 m. Dredge hauls contain coral fragments, algal balls and shell hash. Judging from depth, it is likely that these structures are of similar age and etiology as the reef system north of Fort Pierce.

Shallow continental shelf features

In his review of eastern Florida continental shelf fishing grounds, Moe (1963) described numerous small scale promontories in depths from 10 to 75 m in addition to the prominent shelf-edge habitat. These open-shelf features are referred to by Struhsaker (1969) as "live bottom habitat". The most landward shallow features were not detected in the present investigation because shoals and small boat traffic presented a navigational hazard to R/V Gosnold. On the continental shelf from Cape Canaveral to Palm Beach, low-relief coquinoid ledges and living or dead coralline rock compose the major fraction of small scale features, but shipwrecks and artificial reefs (automobile bodies, ships' ballast, etc.) are occasionally detected by sonic profilings. The shallow-most structures are often partially or totally obscured by biogenic sand and gravels. The inshore fishing grounds off Melbourne (13 - 38 m) bounded by latitudes 27°59'N and 27°23'N, and longitudes 80°07'W and 80°19'W, are characterized by scattered coral rocks, reefs and ledges with vertical profiles up to 5m high over the surrounding hard sand-gravel bottom. Farther south off Fort Pierce and Stuart another group of reef structures exist which are probably continuous with the Melbourne grounds. Bound by latitudes 27°02'N and 27°43'N and longitudes 80°01'W to 80°10'W, these features lie in depths of 13 to 49 m and are similar to the fishing grounds off Melbourne in structure. A distinct series of three coral rock reefs parallel the coast off Stuart in depths of 10 m, 20 m, and 40 m. Farther south between Juno Beach and Lake Worth similar structures exist between 23m and 50m on the narrow shelf and upper slope. Their occurrence on or near the abrupt shelf-slope break does not denote continuity with more northerly, deeper, and more pronounced shelf-edge features.

All of the above shallow prominences are probably less than 10,000 years old (see e.g. Emery, et al., 1970) and were formed in recent times during relatively high stands of sea level.

A nearly continuous, 75 km long, string of reef-like features lies in 45 to 55 m depth from 27°37'N to 28°17'N north of Fort Pierce. These structures rise above the open shelf bottom as much as 7 m in the area of maximum development of the shelf-edge reef off Sebastian. They lie immediately seaward of the numerous shallow reef features and 2 to 8 km landward of the backreef benches (trans. D-Z). North of 27°57'N they are invariably covered with several meters of shelf sediment, but are still detected on 12 kHz GDR profiles (trans. D-M). The 45 m to 55 m reefs occur only sporadically south of Fort Pierce (trans. k and q). The shallower structures seen in trans. b-d are of unknown affinity.

Florida-Hatteras Slope

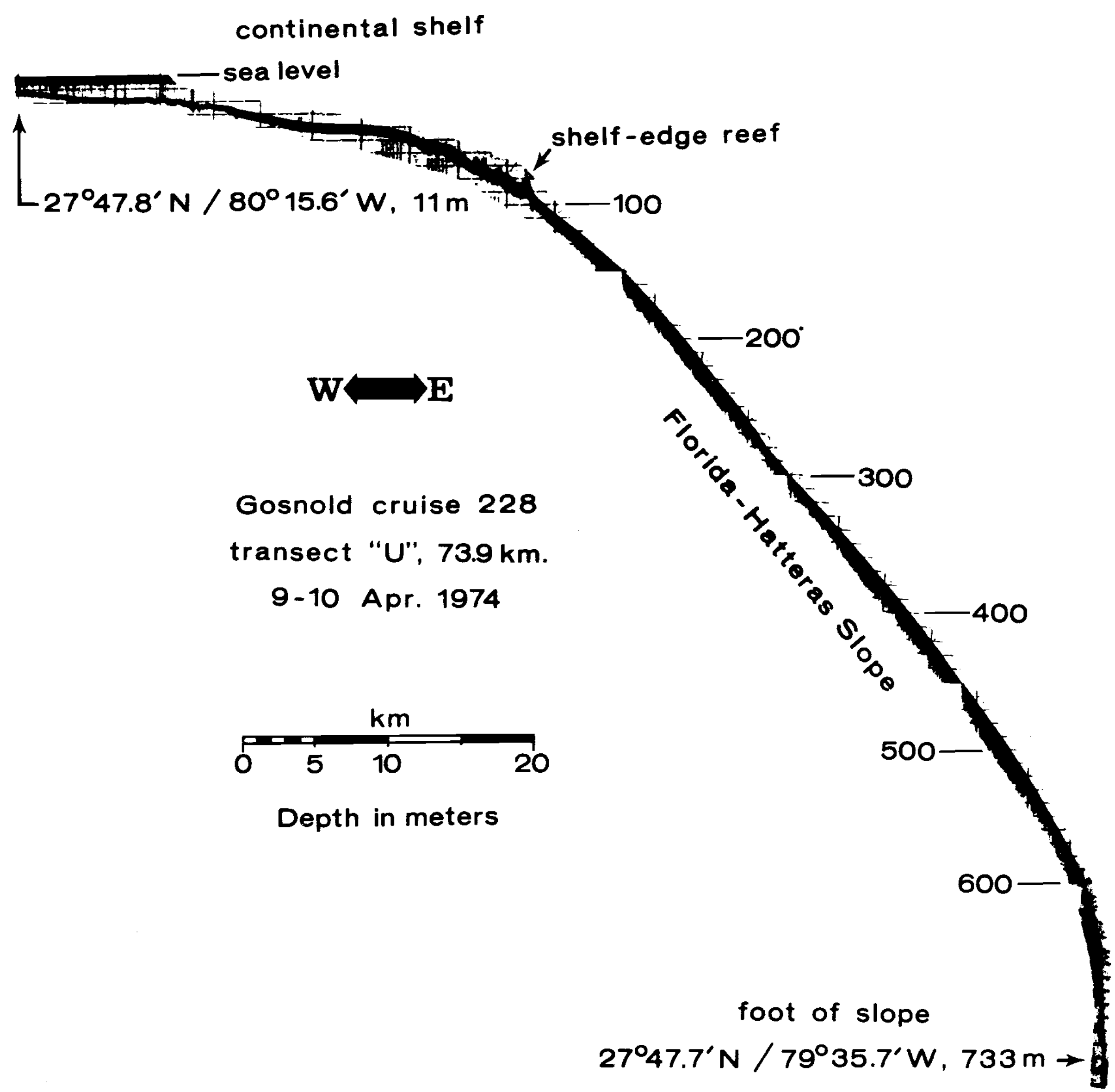
The continental slope profiles we have taken in the area of investigation conform well with the descriptions of other authors (e.g. Uchupi, 1969). Downward inclination varies from 12m/km (parts per thousand) at the upper slope to 18 ppt between 500 and 600m. At the bottom of the slope in depths greater than 600 m declivity reaches a precipitous 81 ppt or more. (For purposes of comparison, the continental shelf averages about 2 ppt). The eastern foot of the Florida-Hatteras slope is as abrupt if not more than its western break (Figure 6).

Our dredging in depths of 300 to 450 m indicate that mid-slope sediments are predominantly well-sorted fine sand and silt with an abundance of foraminiferal and pteropod remains.

The western floor of the Florida Straits which abuts the slope is exceptionally rough. Typically, hyperbolic bottom reflections indicate the close proximity of high, sharp prominances. Side and multiple reflections always obscure the bases of these peaks but average height and width are estimated at 20 and 300 m respectively. Hurley, et al. (1962) believe that these peaks are rock outcroppings swept by currents and thus devoid of sediment. Often a deep valley or depression is seen at the foot of the slope, bottoming out immediately landward and 20 to 40 m deeper than the depth of the seaward floor. We surmise this to be an erosional feature produced by swift currents flowing northward, approximately under the axis of the Florida Current.

The abrupt transition from high slope declivity to the rugged floor of the Straits of Florida suggests that little unconsolidated sediment exists at their junction. An accidental lowering of an Isaccs-Kidd midwater trawl to the floor of the Straits revealed the existance of a rich community of attached soft corals and sponges and absence of large motile forms.

Figure 6: East-west profile of east Florida continental margin off Sebastian 27°48' N. Vertical exageration 77 X.


continental shelf
sea level
27°47.8′ N / 80°15.6′ W, 11 m
shelf-edge reef
100
200
300
400
500
600
Florida-Hatteras Slope
W E
Gosnold cruise 228
transect "U", 73.9 km.
9-10 Apr. 1974
km
0 5 10 20
Depth in meters
foot of slope
27°47.7′ N / 79°35.7′ W, 733 m

Summary

1. Numerous bottom reflection profiles confirm the existence of reef systems on the continental shelf off central eastern Florida. These structures are believed to have formed within the last 20,000 years as sea-level rose from a minimum stand of -130 m.

2. The most prominent structures occur between latitudes 27°48' and 27°52' on the edge of the continental shelf north of Fort Pierce in about 80 m of water. Dredgings confirm that the dominant structural materials are oolitic limestone, coquinoid limestone non-hermatypic corals (mostly _Oculina_ sp.) and coral rubble. A rich temperate-subtropical invertebrate community inhabits the reef. Typically the reef is about 3 km wide and shows "spikes" up to 25 m high at its seaward margin and lower benches at its landward margin. Poorly defined prominences south of Fort Pierce at the same depth suggest the southern extension of a continuous north-south reef system.

3. Landward of the shelf-edge reefs lie several systems of rocky prominences usually having a vertical profiles of 5 m or less. The most notable of these is a series of structures in 50 m depth, assumed to have formed at higher stands of sea level than did the deeper structures. These and other shallower features are reported to have living coral growth and a diverse invertebrate assemblage, and to attract large populations of commerically important, demersal and pelagic fishes. Near Palm Beach the continental shelf narrows to a few km and the shelf slope break is shallower (about 30 m). The shelf edge reefs here are not continuous with more northerly, deeper shelf edge structures,

but show an affinity with northerly, inshore, low profile prominences.

Future Investigations

Future research efforts are seen by this investigator as logical extensions of the work reported herein. They will be guided by the same philosophical considerations as have been stated in the "General Introduction" of this chapter (viz., productivity of the multidisciplinary approach).

The interpretation of topographic transects depends largely on assumptions made by the reader. Depth recordings are mere "shadows" of the water-sediment interface, giving only indirect morphological hints of the composition or origin of the structures detected. Three-dimensional accuracy is determined by the density of soundings and the reader's guess work. Without accessory information he is often unsure whether a "depression" is simply that, or a valley cross section. It is virtually impossible to detect all small spurs, bifurcations, pinnacles, and depressions with conventional sonic hardware. Additional means, such as side-scan sonar, *in situ* submersible studies and bottom dredging give a more precise picture of benthic structures. Our transects have been made in the highest practical density in regions of specific interest (less than 4 km apart on the average over the shelf-slope break) and in lower density over most of the continental slope and inner shelf. With the assistance of the *Johnson-Sea-Link* submersible we will attempt to make a more detailed *in situ* survey of prominent features beyond the practical depth limits of SCUBA, eventually to a depth of 250 m (about 800 feet).

The following regions will be of particular interest:

1) Continental shelf reefs (30 m to 60 m), especially off Grant, Florida. These are highly productive fishing areas and harbor a diverse fauna.

2) Shelf-edge reefs (70 to 100 m) especially off Sebastian, Florida in the region of maximum development.

3) Directly off Fort Pierce in depths of 30 to 100 m, where reefs are covered or non-existent.

4) Directly off St. Lucie Inlet between 75 and 250 m depth on the offshore hummocks or "delta".

5) Off Riviera Beach (30 m to 200 m) in an area of rapid drop-off and narrow shelf.

6) At selected locations on the inner shelf and upper slope, to depths of 250 m to make estimates of faunal abundance and behavior of dominant forms (e.g. Cancer borealis and Rochinia crassa).

The list of ecological investigations which can be made in the above areas is limited only by the ingenuity of the investigator. Highest priority will be given to the following types of studies on the Florida continental shelf reefs:

1) Inventory of animal distribution abundance and diversity.

2) Description of animal habitat, including micro-relief, temperature, and current structure.

3) Animal behavior and interspecific interaction on deep reefs.

Photographic surveys will be made over large areas with the Johnson-Sea-Link using an externally mounted, remote control, Edgerton camera. Photographs and visual observations will allow a more extensive study of large motile animals which are difficult to collect quantitatively with conventional devices. Cameras have been used effectively by Menzies to locate sources of pollutants and to determine their effects on animals in studies of Atlantic deep-water dump (DWD) sites. He was not only able to determine the lethal effects of dumped toxins on *Phormosoma placenta* (Echinoidea) but he was able to locate the pollution source exactly via dead/live ratios and knowledge of current directions. Cameras have been used extensively in quantitative counts of benthonic species, and in geological studies (see, e.g. Hollister and Heezen, 1971).

Quantitative collections of invertebrates will be made by lockout divers using *in situ* devices to give an almost unprecedented accuracy in hard-substrate community definition. All studies will be aided by judicious *in situ* monitoring of habitat conditions. Current meters will be deployed in strategic locations and SBT and CSTD equipment will be used extensively. These data will build upon that obtained in 1973 and 1974 (see chapter by O. von Zweck in this report).

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Appendix A. RESULTS OF OFFSHORE CRUISES (R/V GOSNOLD)

Cruise #	Departure Date	Days	Accomplishments: Biological Stations**					Topo transects/km		Hydro-casts
			OT	Blake	SBT	Dredge	IKMT	# Trans.	Length	
G-207	5-XI-73	3				3		6	416	3
G-210	25-XI-73	4	5	5						2
G-215*	7-01-74	5						4	118	
G-217	21-01-74	6	10	3		14	5	5	185	1
G-219	5-II-74	4		1	3			3	74	2
G-225	19-III-74	4	4			6		6	379	
G-228	9-IV-74	4						11	518	1
G-233	30-IV-74	3						9	564	
G-236	5-VI-74	4						9	574	5
G-238	12-VI-74	3						17	159	
G-239	20-VI-74	2						10	139	
G-246	3-IX-74	3	1	2		14				
G-248*	17-IX-74	3	10			7				
	TOTAL	48	30	11	3	44	5	80	3126	14

* - Avent participated, but not as chief scientist

** - Successful stations: OT - Otter trawl (10' and 20'), Blake - 5' Blake trawl, SBT - small biology trawl, dredge - includes box, pipe, Kirtley, and other dredges, IKMT - Isaacs-Kidd midwater trawl.

APPENDIX B. Proforma sheet.

1st record RMa-MK
CHECK MK-DC
RECHECK MK-RMa

IRS-OFFSHORE TOPOGRAPHIC SURVEY

DATE 1-6	TIME 7-10	DEPTH 11-13	LATITUDE 14-19	LONGITUDE 20-25	HEAD 26-28	TEMP. 29-32	CRUISE 33-36	TRANS.# 37-38	* 39	NOTES 40-80
061173	0120	283	-	-	265	-	G207	02		
	0125	266	-	-		-				
	0130	249	2736.0	7951.0		21.4				
	0135	233	-	-		-				
	0140	217	-	-		-				
	0145	204	-	-		-				
	0150	189	-	-	↓	-				
	0155	175	-	-	265	-				
	0200	162	27364	7954.8	260	-				
	0205	144	-	-		-				
	0210	120	-	-		-				
	0230	087	2736.7	7958.5		-				
	0235	080	-	-		-				
	0237	060	-	-	↓	-			*	TRIPLE HILL. MAX HEIGHT 18 m.
	0240	070	-	-	275	-				
	0241	065	-	-		-			*	3 m scarp
	0245	064	-	-		-				
	0250	060	-	-		-			*	1 m hill
	0255	048	-	-		-			*	2 m hill
	0300	044	2737.1	8001.7		-				
	0305	039	-	-		-				
	0310	037	-	-		-				
	0320	034	-	-		-				
↓	0325	032	-	-	↓	-	↓	↓		

GIFFT DEPTH RECORDER

CRUISE G- 207 DATE 26 XI 73 TIME 0130
HEADING 265 SPEED 6.5 k
DEPTH 249 m SCALE 150 - 300 m
BUCKET TEMP. 21.4 °C SALINITY - 0/00
NOTES Fix at 0130. Heavy seas 6'-10'.

Appendix C. Computer print-out.

DATE	TIME	DEPTH	LATITUDE	LONGITUDE	HEAD	TEMP	CRUISE	TRAN NO	NOTES
61173	1.92	175	2736.34	7954.17	265	.0	G207	2	
61173	2.00	162	2736.40	7954.80	260	.0	G207	2	
61173	2.08	144	2736.45	7955.42	260	.0	G207	2	
61173	2.17	120	2736.50	7956.03	260	.0	G207	2	
61173	2.50	87	2736.70	7958.50	260	.0	G207	2	
61173	2.58	80	2735.77	7959.03	260	.0	G207	2	
61173	2.62	60	2735.39	7959.24	260	.0	G207	2	* 3 HILLS, HEIGHT 18 M MAX.
61173	2.67	70	2734.84	7959.57	275	.0	G207	2	
61173	2.68	65	2734.64	7959.68	275	.0	G207	2	* SCARP, HEIGHT 3 M.
61173	2.75	64	2733.90	8000.10	275	.0	G207	2	
61173	2.83	60	2732.96	8000.64	275	.0	G207	2	* HILL, HEIGHT 1M
61173	2.92	48	2732.03	8001.16	275	.0	G207	2	* HILL, HEIGHT 2M
61173	3.00	44	2731.10	8001.70	275	.0	G207	2	
61173	3.08	39	2732.02	8002.33	275	.0	G207	2	
61173	3.17	37	2732.93	8002.96	275	.0	G207	2	
61173	3.33	34	2734.76	8004.21	275	.0	G207	2	
61173	3.42	32	2735.67	8004.84	275	.0	G207	2	
61173	3.50	29	2736.59	8005.47	275	.0	G207	2	
61173	3.58	22	2737.50	8006.10	275	.0	G207	2	* REEF, HEIGHT 4M.
61173	3.67	24	2737.40	8006.90	275	.0	G207	2	
61173	3.72	20	2737.34	8007.38	275	.0	G207	2	* HILL, HEIGHT 4M
61173	3.83	21	2737.20	8008.50	275	.0	G207	2	
61173	3.92	19	2737.10	8009.30	275	.0	G207	2	
61173	4.00	18	2737.00	8010.10	275	.0	G207	2	
61173	5.50	20	2746.20	8009.40	110	.0	G207	3	* BEGIN T:3
61173	5.58	22	2746.03	8008.76	110	.0	G207	3	* HILL, HEIGHT 10M.
61173	5.67	25	2745.86	8008.12	110	.0	G207	3	
61173	5.75	29	2745.70	8007.48	110	.0	G207	3	

CHAPTER 3

PHYSICAL OCEANOGRAPHIC STUDIES OF THE INDIAN RIVER REGION

O. vonZweck
D. Richardson
N. Szuchy
G. Adragna

INTRODUCTION

During 1974, physical oceanographic and hydrographic investigations were directed and planned towards the following three aspects of the Indian River Study.

1. Hydrographic investigation of the Fort Pierce Inlet.

This investigation was initiated beginning 1974. The object of this study was the determination of the motion and distribution of the various water masses encountered within the Fort Pierce Inlet and harbor area. This was done in order to determine the possible distribution and mixing patterns of waters from various sources within this area. The importance of such an investigation rests on the fact that inlets, such as the Fort Pierce Inlet, form a link between the Indian River and the ocean. Processes occurring within these inlets may, as a consequence, affect large portions of the Indian River system.

2. Hydrography of Continental Shelf Water.

Since very little is known about the hydrography and dynamics of the shelf waters off Florida's central east coast, a hydrographic investigation of these waters was initiated in order to determine the distribution and motion of these waters.

For this purpose, the following hydrographic cruises were undertaken with the R/V GOSNOLD:

Cruise 218	28 January - 1 February 1974
Cruise 227	25 March - 28 March 1974
Cruise 231	23 April - 26 April 1974
Cruise 240	24 June - 28 June 1974
Cruise 244	19 August - 22 August 1974

The area under investigation extended north from Hobe Sound to

Cocoa Beach. About 50 stations on 6 transects, extending from 5 miles offshore to the western edge of the Florida Current were repeatedly occupied.

3. Near Shore Current Velocity Measurements.

This particular investigation which was in its development stage, has been deferred in favor of a more comprehensive study of the Indian River between the Fort Pierce Inlet and Link Port.

Current measurements had been scheduled to begin in early 1975 and were to be performed in conjunction with the hydrographic investigation of the shelf water.

Instrumentation to carry out this investigation has been ordered and has been partially received. During 1974, work on the design of the instrument mooring in the ocean and data reduction and analysis computer programs had been carried out.

No work or planning is presently in progress for this investigation.

With the exception of the summer months, this work was carried out on a part-time basis. The Principal Investigator, Dr. O. vonZweck, was assisted by two part-time employees of HBFL, Mr. David Richardson and Mr. Nicholas Szuchy, (3 months only). Mr. Gregory Adragna, an undergraduate student of Physical Oceanography at Florida Institute of Technology, volunteered his services during the summer of 1974. Undergraduate students of the Oceanography and Ocean Engineering Department of F.I.T. volunteered about 100 man days on the R/V GOSNOLD cruises.

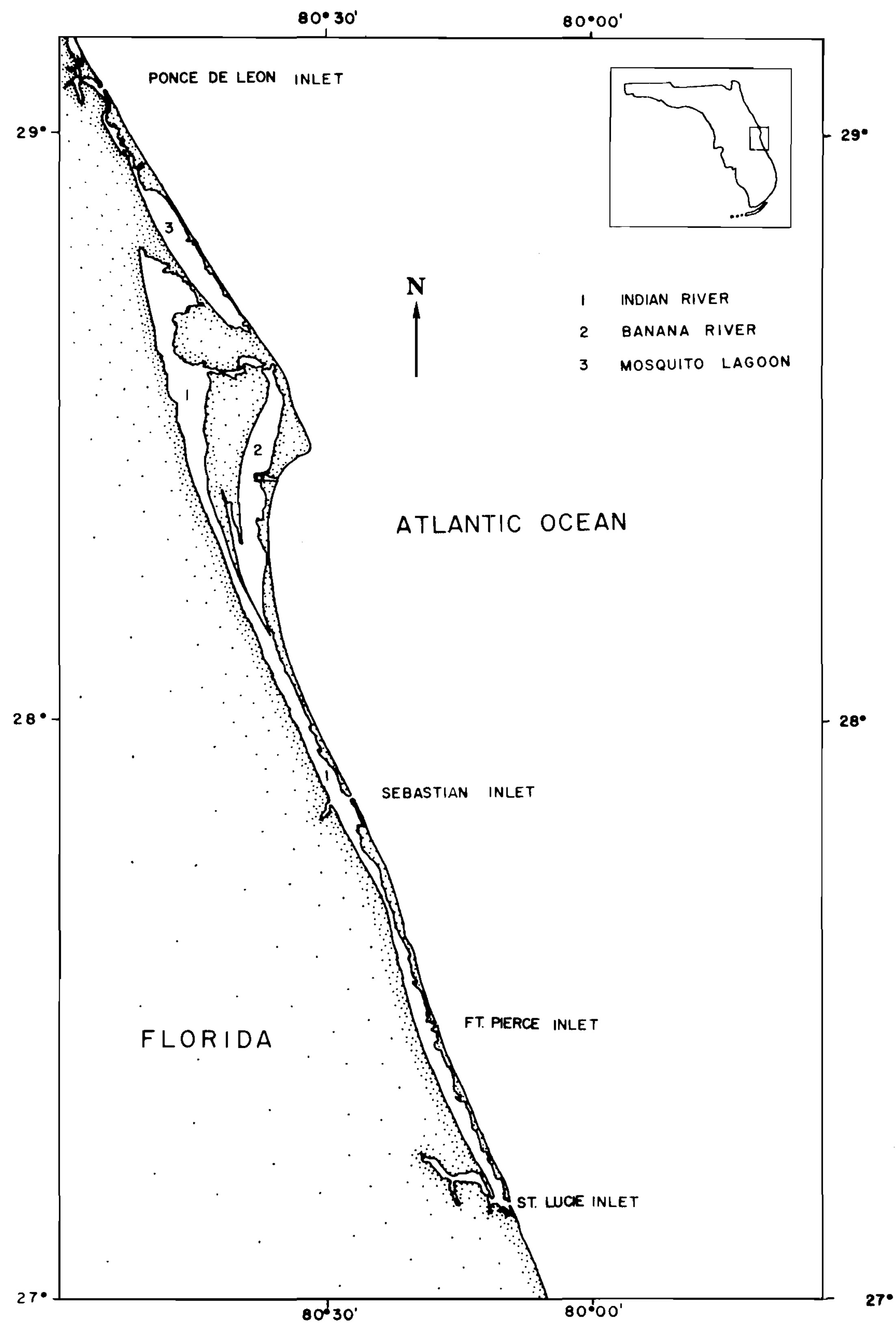


FIG. I LOCATION OF AREA UNDER INVESTIGATION

SUMMARY OF RESULTS

A. Fort Pierce Inlet Hydrography

1. Introduction

Barrier beaches on Florida's central east coast form a lagoonal system part of which are known as Mosquito Lagoon, Banana River and the Indian River.

Of these, the Indian River, which is part of the intracoastal Waterway, is the longest, stretching from its southern terminus, Jupiter Inlet (Fla.) to north of Titusville (Fla.) a distance of about 210 km. (Fig. 1).

The St. Lucie, Fort Pierce and Sebastian Inlets allow free communication between the southern half of the Indian River and the Ocean. Considerable tidal flows passing through these inlets impart an estuarine character to parts of the Indian River in the vicinity of these inlets.

The estuarine character of these inlets is further enhanced by the addition of fresh water from creeks emptying into the Indian River within the areas directly affected by the tidal flows.

The circulation and mixing of water masses within the inlet areas have a definite effect upon large parts of the Indian River. In order to understand these processes in the Fort Pierce area a hydrographic investigation of the Fort Pierce Inlet and harbor area was undertaken primarily during the summer of 1974.

2. Background

The area under consideration in this investigation encompasses the Fort Pierce (Florida) inlet and harbor area as well as some of the adjacent parts of the Indian River shown in figure 2. A topographic

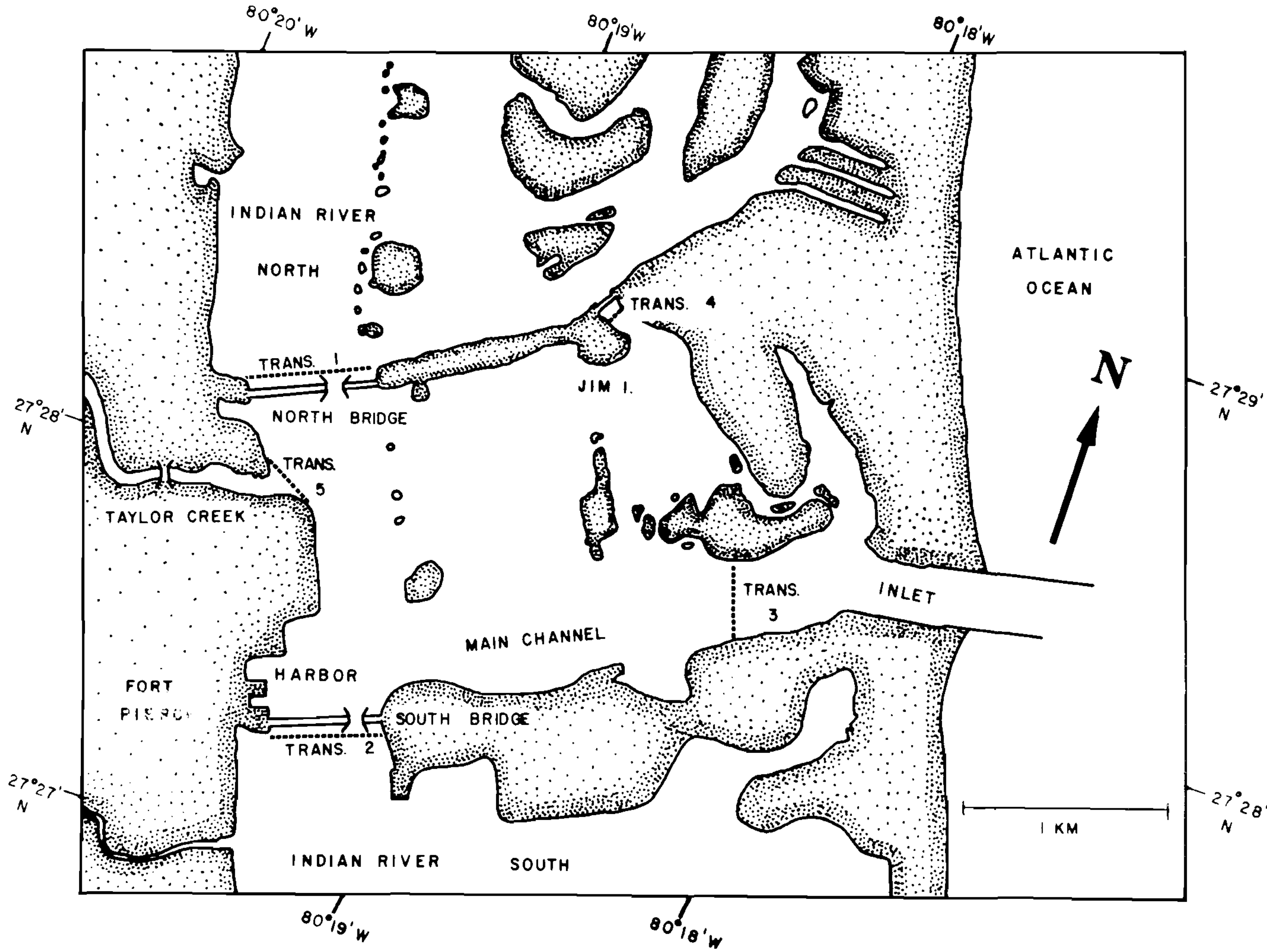


FIG. 2 MAP OF AREA UNDER INVESTIGATION.

chart of this area based on C & GS chart 582 and additional depth soundings are shown in figure 3.

For the purposes of this study the inlet and harbor areas is defined as the area which is bounded by the northern and southern causeways and bridges and the western end of the inlet proper, as shown in figure 2. In this study, the portion of the Indian River north of the Northbridge is referred to as the northern branch, while that south of the Southbridge is referred to as the southern branch of the Indian River.

The man-made Fort Pierce inlet, harbor and shipping channel (which intersects the Intracoastal Waterway which runs through the Indian River) was constructed in 1921 as replacement for a filled in natural inlet which was located a few miles north of the present inlet. The inlet, harbor and shipping channel is maintained at a minimum depth of 21 feet (6.4m), by periodic dredging. The dredge spoil is presently used to replenish the eroding beach south of the southern inlet jetty which extends into the ocean.

The different waters encountered in the harbor area largely stem from the Indian River and the ocean. Taylor Creek, which is part of a land drainage system, is connected to Lake Okeechobee and constitutes a major source of fresh water in the inlet area. Since Taylor Creek is partially controlled by locks its flow is variable and large unpredictable.

Moore Creek and the Fort Pierce sewage outfall, both of which are located in the southern branch of the Indian River contribute small amounts of fresh water to the system.

In a preliminary investigation of the Fort Pierce inlet, Sedwick (1973) determined an 80% reduction in the mean tidal range between the

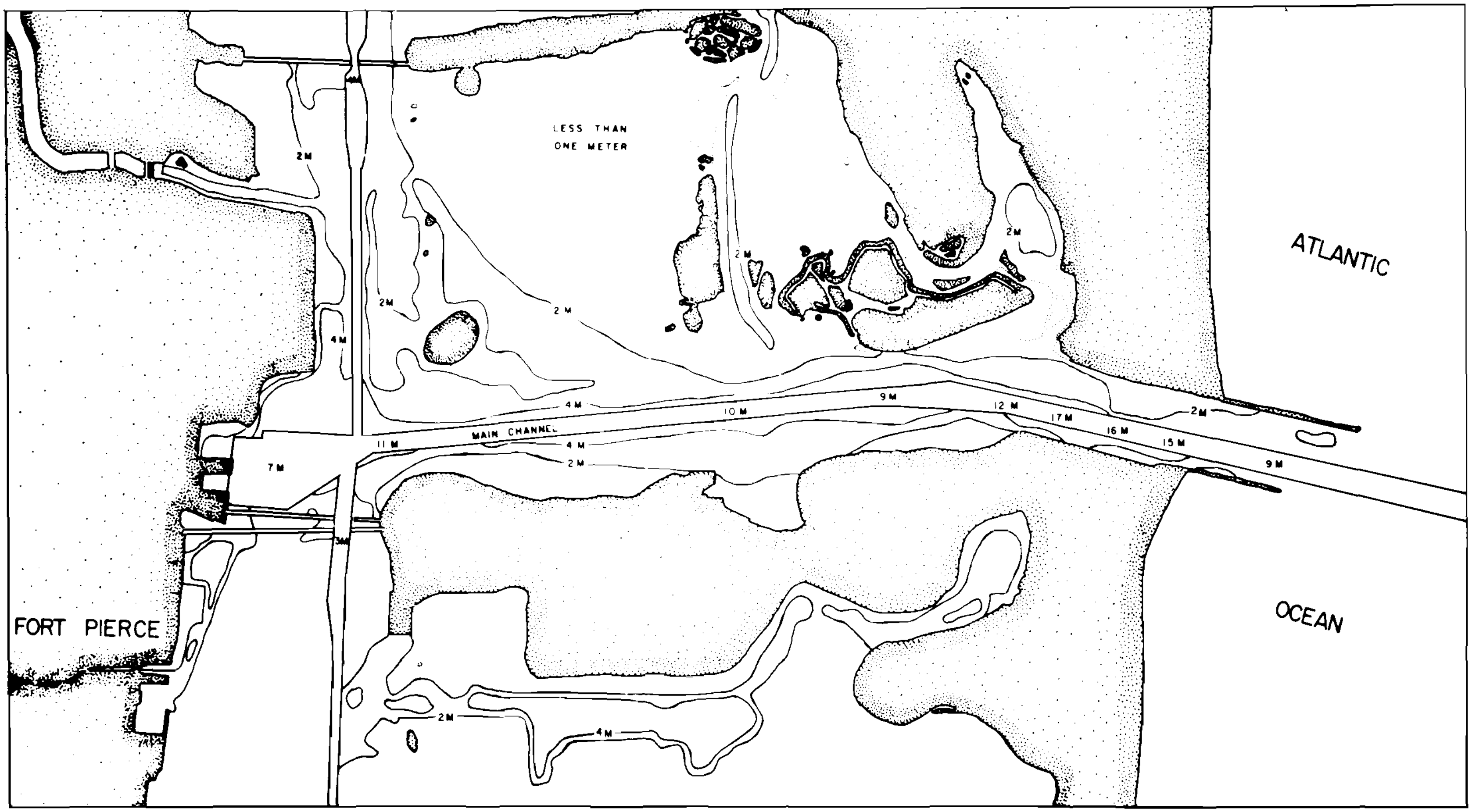


FIG. 3 BOTTOM TOPOGRAPHY OF AREA UNDER INVESTIGATION

ocean and the Fort Pierce city dock. Sedwick further found that the slack water times predicted for the Inlet by the Tidal Current Tables (NOS 1974) lagged actual observations of slack water by as much as 20 minutes (Sedwick 1973).

3. Observations

3.1. Tides and Currents

During the summer of 1974 measurements of water current velocities were performed throughout the inlet and harbor area using neutrally buoyant surface floats, drogues and an on-deck readout current meter.

Tidal current measurements were obtained on 13-hour anchor stations, located next to the waterway on transects 1 through 3 (Figure 2), on 26, 27 and 28 August 1974. In addition, vertical velocity profiles were obtained on transects 1 through 5 at times of predicted maximum tidal flows.

Results of the anchor station on transect 3, indicate agreement between the observed slack water time and that predicted by the Tidal Current Tables (NOS 1974).

This contrasts, however, with an observation of 9 September 1974, when the low slack water time in the inlet preceded the predicted time by about 40 minutes. The magnitude of the latter difference falls within the statistical variations of predicted slack water times as discussed in the NOS Tidal Current Tables.

Between 26 - 28 August 1974, slack water time at the Northbridge was observed to lag behind the predicted times (for the inlet) by about 40 - 50 minutes (for high and low slack water). Out of a total of 6 observations of slack water times at the Southbridge four agreed with their predictions, while two observed slack water times lagged the predicted times.

Ratios of observed maximum current velocities vectors on 26-28 August 1974 to the maximum ebb or flood predicted for the inlet by the NOS tables for these dates are shown in figures 4 (4a for ebb, 4b for floqd) for surface measurements and 5 (5a for ebb, 5b for flood) for measurements at 1 m depth. For August 1974 the average predicted maximum ebb current is 3.2$\pm$ .6 knots, the average predicted maximum flood is 2.6$\pm$ .5 knots.

Aside from variations in current strength within the inlet and at the bridges, a comparison of the results indicated in figures 4 and 5 shows the relatively thin surface layer (.5m - 1m) of the Taylor Creek water outflow resting on a tidally driven lower layer.

Values of volume transport at times of predicted maximum flood or ebb currents were calculated from vertical velocity profiles obtained at Transects 1 through 5, (with the exception of Transect 1, where data were only obtained during the flood stage). The transport values and their percentages relative to the volume transport through the Inlet (Transect 3) are given in Table 1.

TABLE I

Volume transport (m^3/sec) and their percentage contribution at times of maximum currents predicted by NOS Tidal Current Tables.

	EBB (m3/sec)	%	FLOOD (m3/sec)	%
Transect 1 (Northbridge)	-	-	550	29
Transect 2 (Southbridge)	1100	78	1100	58
Transect 3 (Inlet)	1400	100	1900	100
Transect 4 (Jim Creek)	200	14	300	16
Transect 5 (Taylor Creek)	60	4	20	1
Sewage Treatment Plant	1-2*	.001	1-2*	.001

*Data supplied by the City of Fort Pierce

With an estimated error of ±50% for the above values it is not surprising that the volume transport does not balance. The difference in the values for ebb and flood conditions in the inlet may not be significant, while the different values in transport at the mouth of Taylor Creek may be attributed to the outflow of Taylor Creek water as indicated in figures 4 and 5.

A fairly large amount of volume transport (approximately 15% of the transport through the inlet) from and into the shallow regions to the east of the Intracoastal Waterway in the northern branch of the Indian River, appears to take place through Jim Creek.

Current flow patterns at a depth of 1.5 meters for the inlet area around the time of maximum ebb or flood currents are presented in figures 6a and 6b respectively. The numbers shown on these figures represent the observed current speeds normalized to the maximum ebb or flood currents predicted for the Fort Pierce Inlet by the NOS Current Tidal Tables.

The above flow patterns were derived from a compilation of drogue observations obtained over various days, within ±1 hour of the predicted maximum tidal currents. Variations in wind spped and direction between the various observations were small. The wind speed was generally from the southeast to southwest at 2 - 7 mph. With this windspeed and the limitation in fetch, encountered in this area, the effect of wind driven currents is quite small in relation to the tidal currents.

The pattern for the ebb flow (Fig. 6a) does not present any unexpected features and corresponds qualitatively to what may be expected on the basis of potential flow theory and bottom topography (figure 2). The confluence of water from the southern and northern branches of the Indian River in the main channel north of Causeway Island is generally

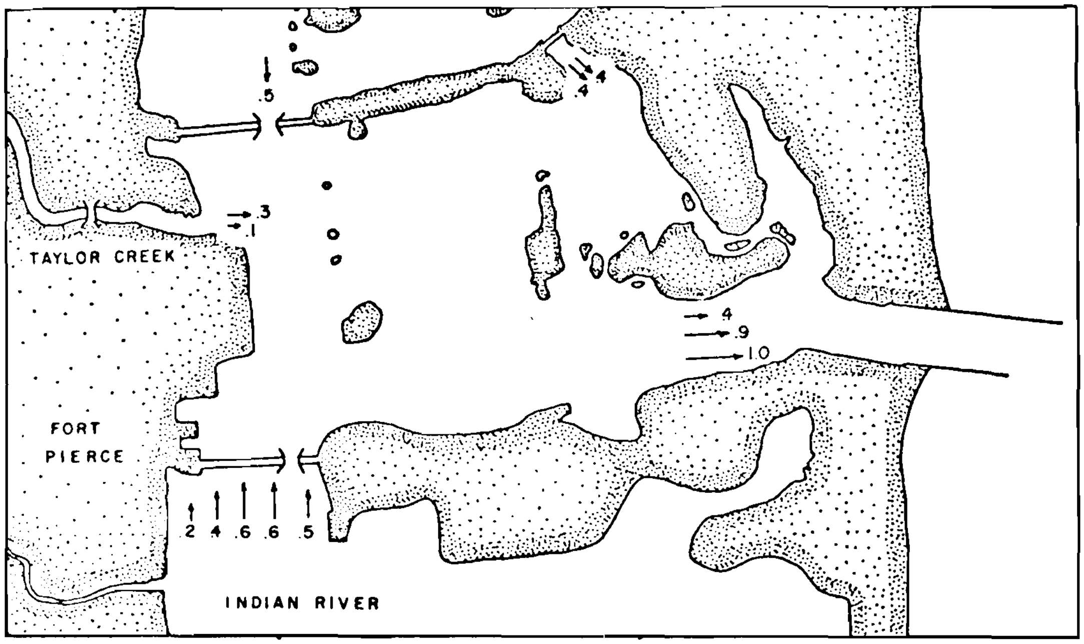


FIG. 4a SURFACE VELOCITY RATIOS FOR MAXIMUM EBB CURRENT

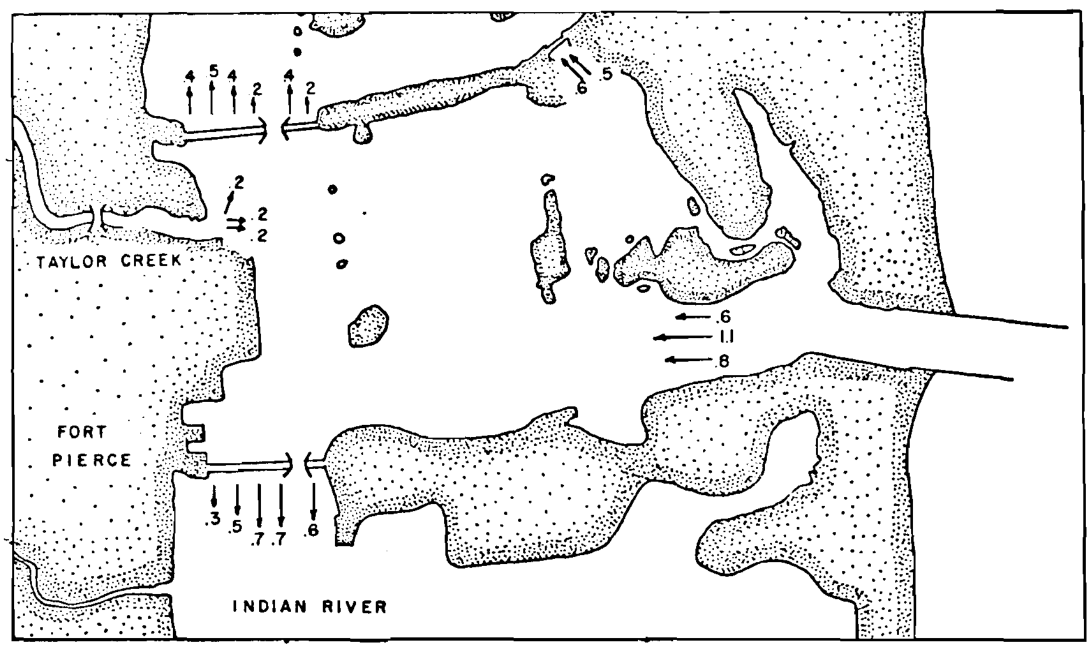


FIG. 4b SURFACE VELOCITY RATIOS FOR MAXIMUM FLOOD CURRENT

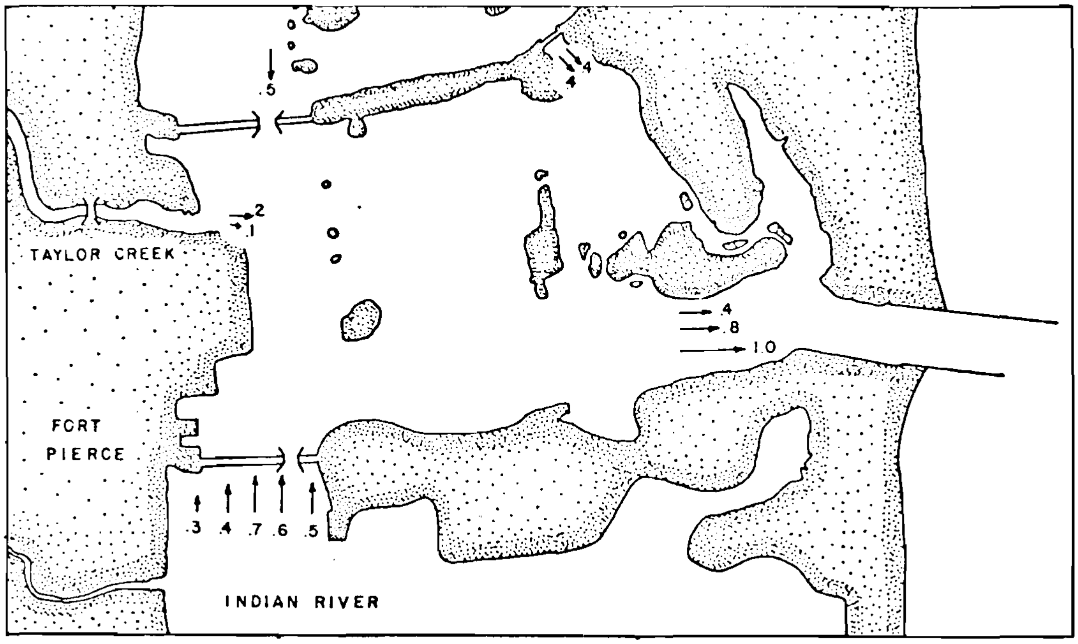


FIG. 5a VELOCITY RATIOS AT ONE METER FOR MAXIMUM EBB CURRENT

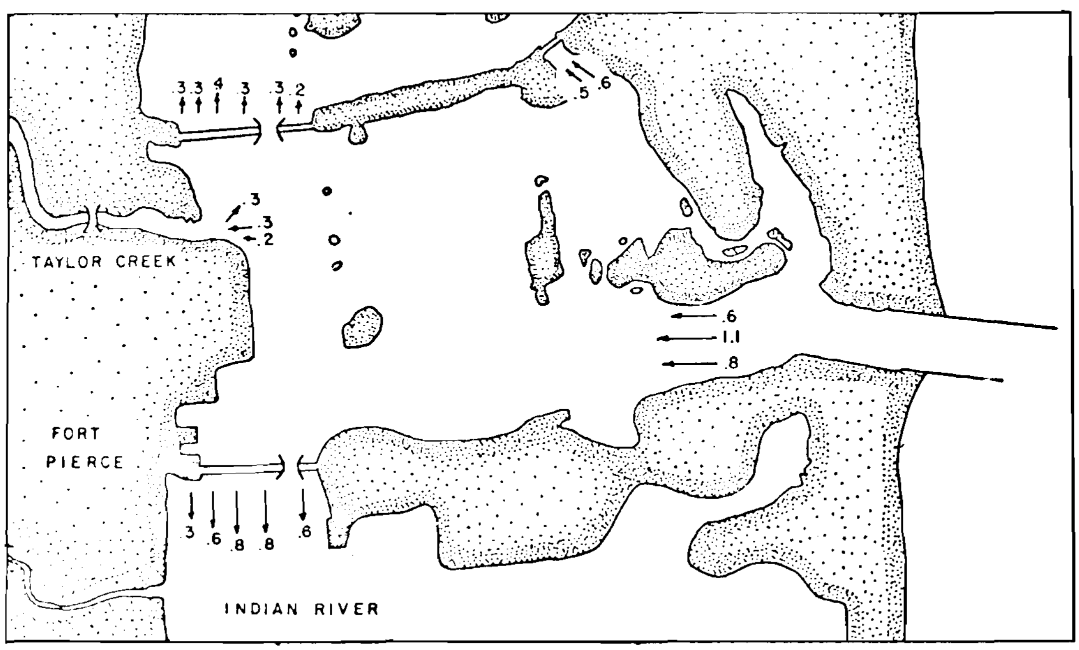


FIG 5b VELOCITY RATIOS AT ONE METER FOR MAXIMUM FLOOD CURRENT

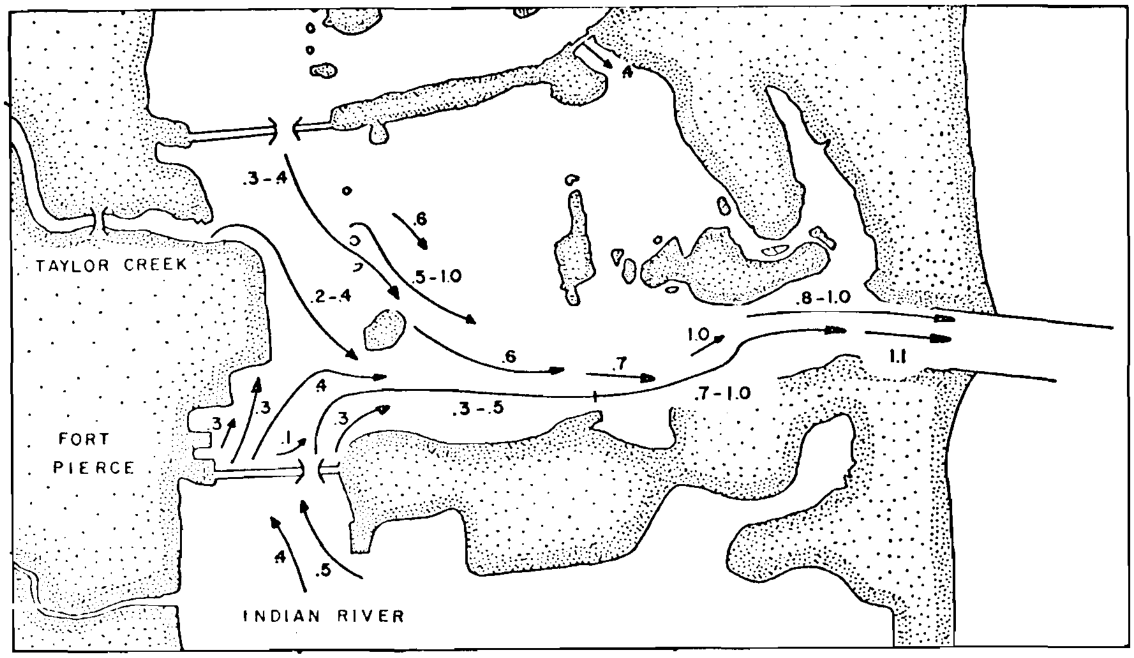


FIGURE 6A EBB CURRENT VELOCITY RATIOS AT 1.5 METERS

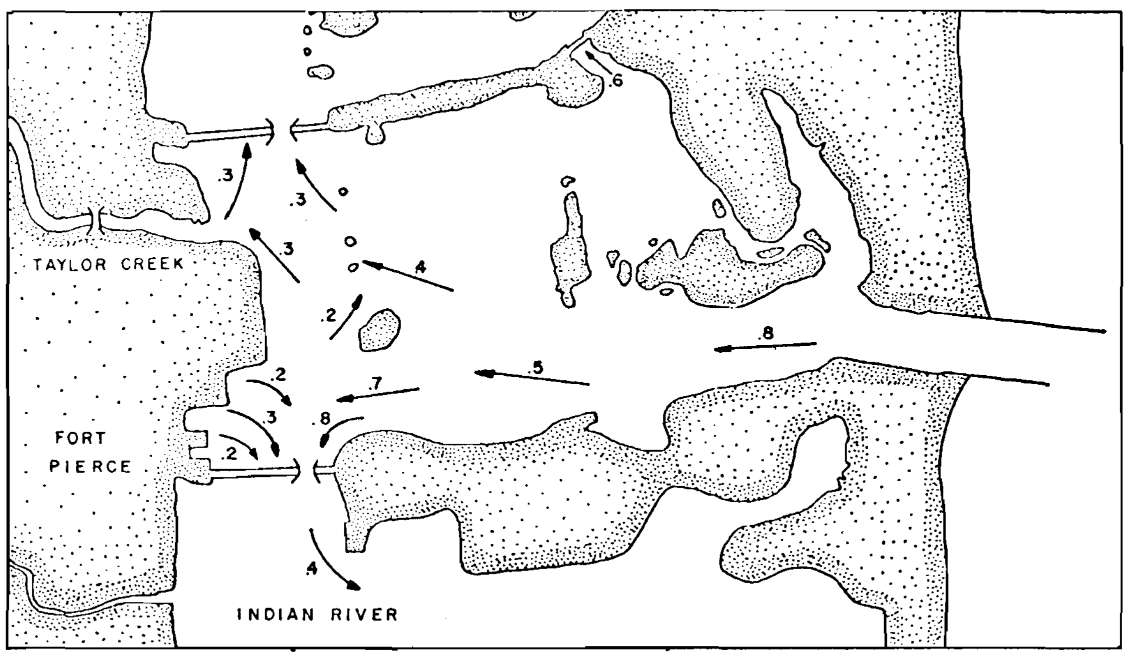


FIGURE 6B FLOOD CURRENT VELOCITY RATIOS AT 1.5 METERS marked by turbulence and mixing of the different waters.

The flow pattern for an incoming tide in general exhibits no surprising features with the exception of the Fort Pierce harbor area. The behavior of the current within this area is not clear at this time and requires further observation.

3.2. Salinity and Temperature

The salinity encountered in the Fort Pierce area and adjacent regions of the Indian River ranges from about 3 ppt at Taylor Creek to about 36 ppt for ocean water; its geographical distribution within the area depends to a large degree on the tidal state. Values of observed salinity ranges at various locations are given in Table II.

TABLE II

Approximate salinity (ppt ranges at various locations)

	EBB		FLOOD	
	Surface	2m depth	Surface	2m depth
Indian River - North	20 - 32	20 - 35	15 - 33	22 - 35
Indian River - South	24 - 35	27 - 35	24 - 35	24 - 35
Taylor Creek	3 - 12	24 - 33	7 - 14	26 - 31
Inlet	22 - 36	25 - 36	24 - 36	26 - 36

a) Indian River Water - Northern Branch

While all salinities encountered in the vicinity of the inlet vary tidally, the surface water in the northern branch of the Indian River was generally found to about 3 - 4 ppt fresher than the corresponding water in the southern branch.

Salinity measurements obtained over a tidal cycle at the North-bridge on 26 August 1974 show a variation of surface salinity from 15 to 33 ppt and vertical salinity gradients near the surface up to 7 ppt per meter. Similar data from 23 July 1974 show a gradient of 10 ppt per meter. These gradients were encountered in the top one meter, the water between 1 and 2 meter depth being more saline and homogeneous.

The existence of such large vertical salinity gradients may be explained by the contributions of the Taylor Creek water and will be discussed in a later section.

b) Indian River Water - Southern Branch

Surface salinity values collected on an anchor station at the South bridge on 27 August 1974 range from 24 to 35 ppt; the observed maximum vertical salinity gradient is of the order of 2 ppt/meter. As in the northern branch of the river, the water between 1 and 2 meters is quite homogeneous.

Results from a similar anchor station at the same site indicated a maximum gradient of 1 ppt/meter for that day.

The relative vertical homogeneity of the southern branch water is indicative of either a large degree of mixing, or the lack of any large input of a fresh water source. The lack of a known fresh water source in the southern branch of the Indian River in the vicinity of the Inlet and the relative homogeneity of the water compared to that of the northern branch, indicates a reduced influence of Taylor Creek water on the southern branch of the Indian River.

c) Taylor Creek

The salinity structures encountered at Taylor Creek indicate a mixture of fresh water and water of oceanic origin resting on a more saline deeper layer. These observations are in agreement with the understanding of the Taylor Creek outflow obtained from the current flow measurements.

Because of its low salinity, the Taylor Creek outflow water spreads horizontally over large areas. During flood tide, this water is carried into the northern branch of the river, thus generating the salinity characteristics of the Northern Indian River waters previously discussed.

d) Inlet

The large salinity range and the low salinities encountered at the western end of the Fort Pierce inlet proper (Transect 3) during ebb and flood tide may be explained as follows: during ebb tide the waters from the various sources meeting at the inlet are poorly mixed at this location, resulting in a large horizontal cross channel salinity gradient and salinity range.

At the beginning of the flood tide, the water remaining within the outer reaches of the inlet from the previous ebb cycle, as well as some outflow water which had entered the ocean, is returned to the river area through the inlet producing low salinity readings; towards the end of the flood cycle the inflowing water will be oceanic (coastal) water of salinity ranging between 34 and 36 ppt. The different waters thus tend to increase the total salinity range observed in the inlet.

Representative examples of the salinity distribution for the area under consideration at various depths and for flood and ebb tide are presented in Figures 7 and 8. These figures show the large influence of the Taylor Creek outflow on the water within the Fort Pierce Inlet and harbor area.

The water temperatures encountered in the area are less indicative of the motion and sources of the waters. Representative temperature distributions are shown in Figures 9 and 10.

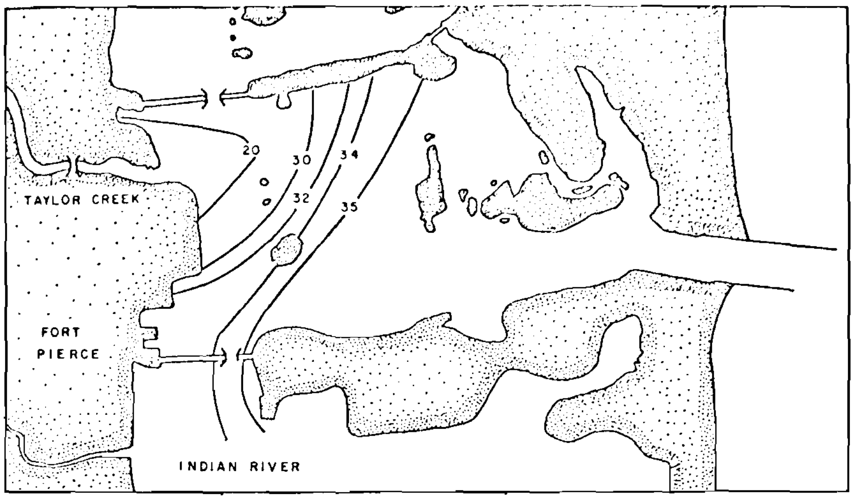


FIG. 7a, SALINITY DISTRIBUTION AT THE SURFACE FOR FLOOD TIDE.

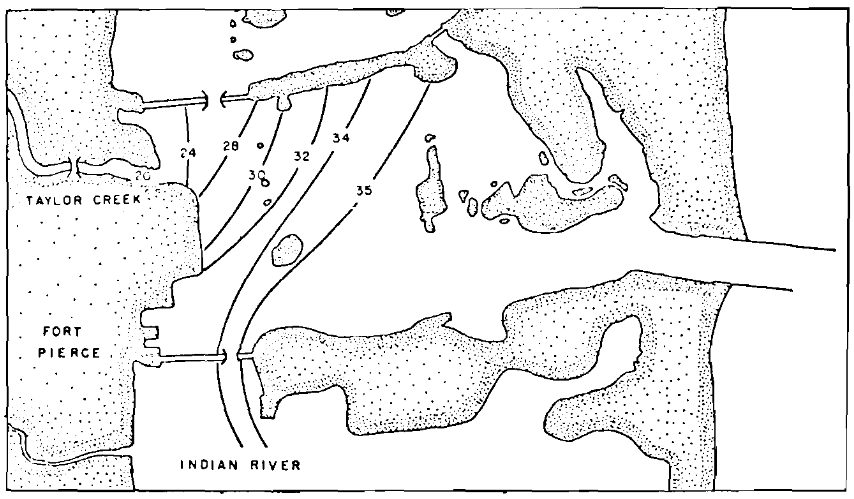


FIG. 7b, SALINITY DISTRIBUTION AT ONE METER FOR FLOOD TIDE.

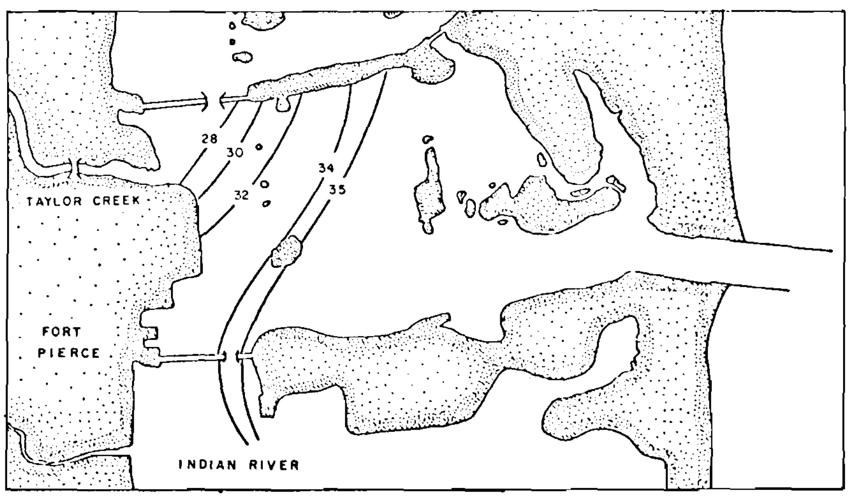


FIG. 7c, SALINITY DISTRIBUTION AT TWO METERS FOR FLOOD TIDE.

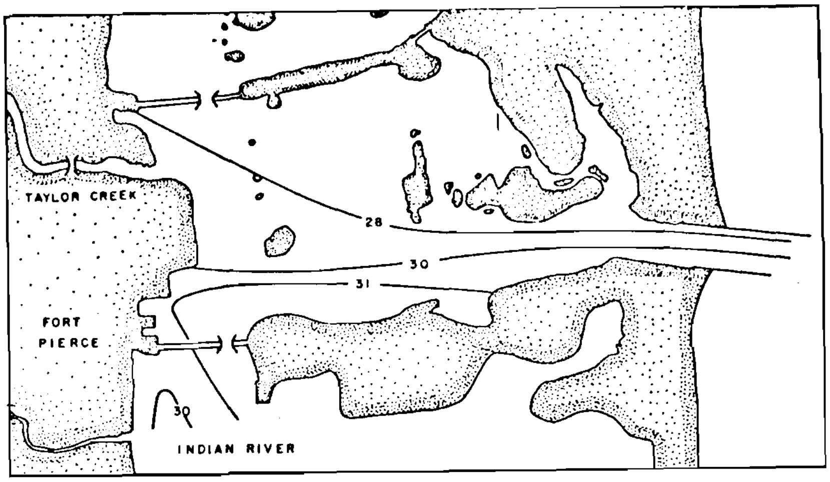


FIG. 8a SALINITY DISTRIBUTION AT THE SURFACE FOR EBB TIDE (PPT)

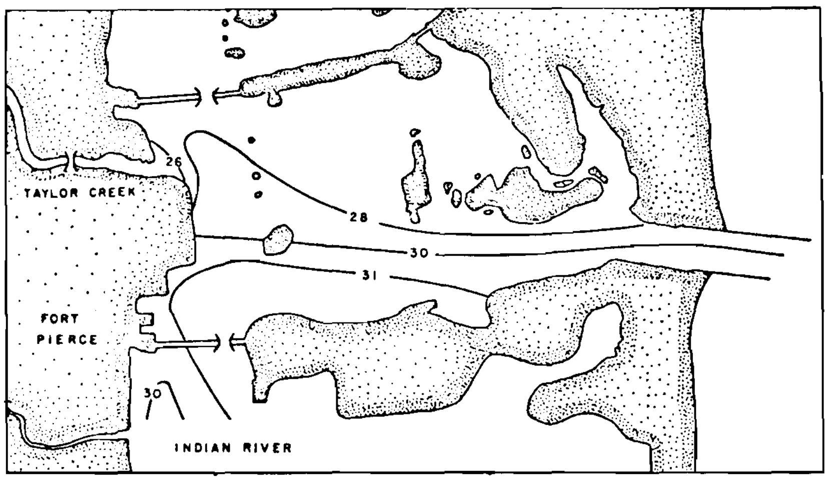


FIG. 8b SALINITY DISTRIBUTION AT ONE METER FOR EBB TIDE (PPT)

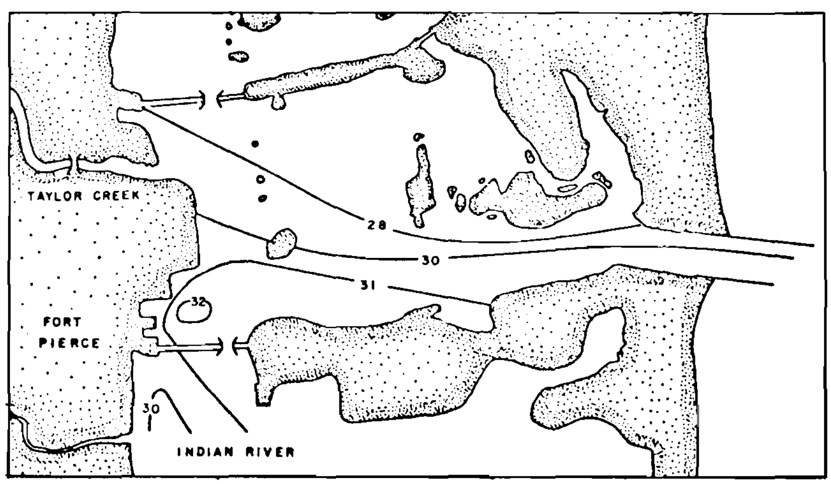


FIG. 8c SALINITY DISTRIBUTION AT TWO METERS FOR EBB TIDE (PPT)

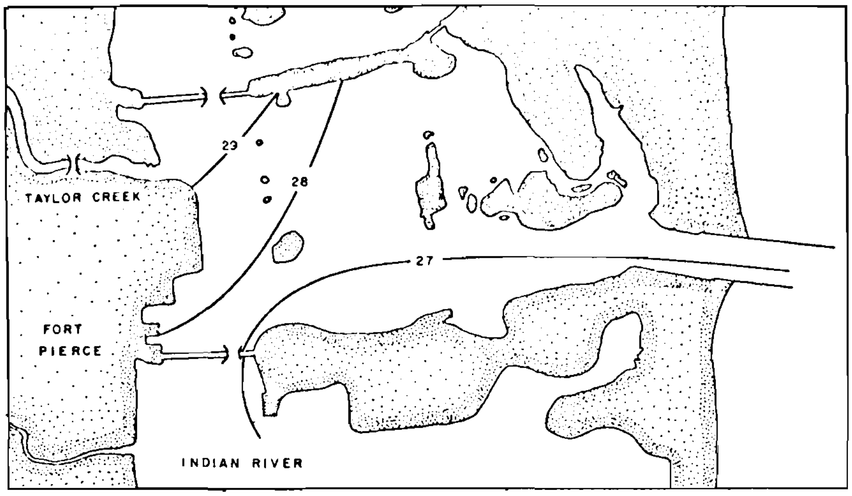


FIG. 9a, TEMPERATURE DISTRIBUTION AT THE SURFACE FOR FLOOD TIDE.

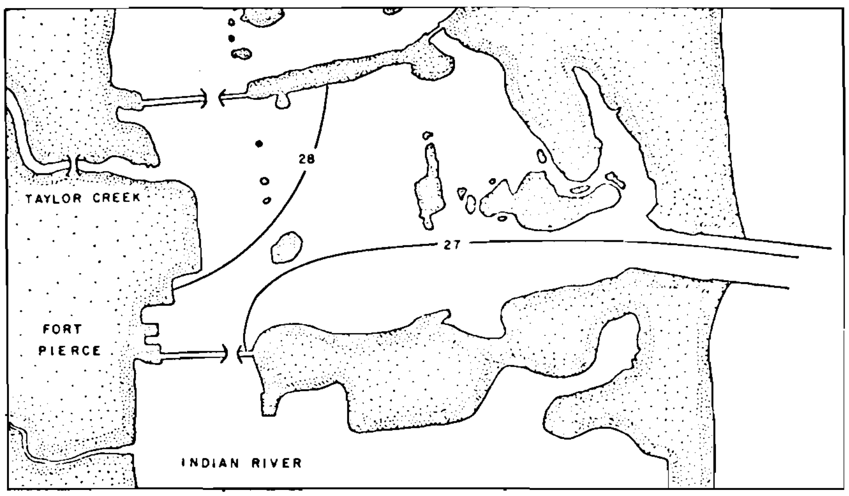


FIG. 9b, TEMPERATURE DISTRIBUTION AT ONE METER FOR FLOOD TIDE.

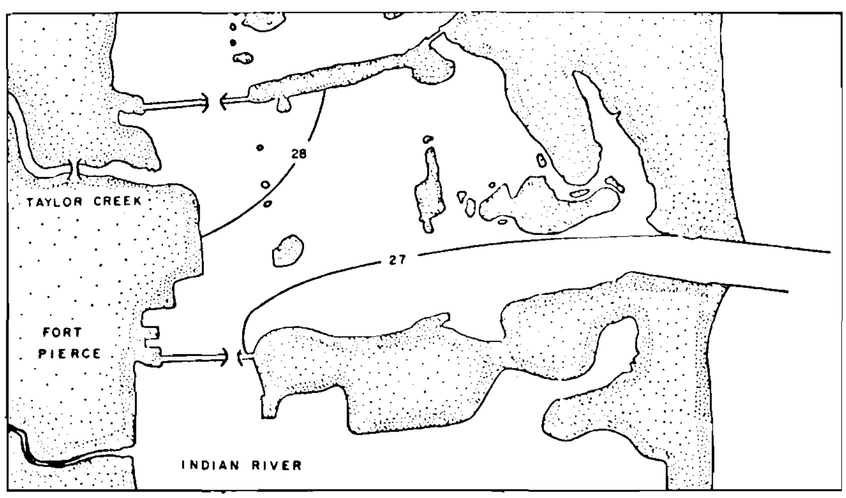


FIG. 9c, TEMPERATURE DISTRIBUTION AT TWO METERS FOR FLOOD TIDE.

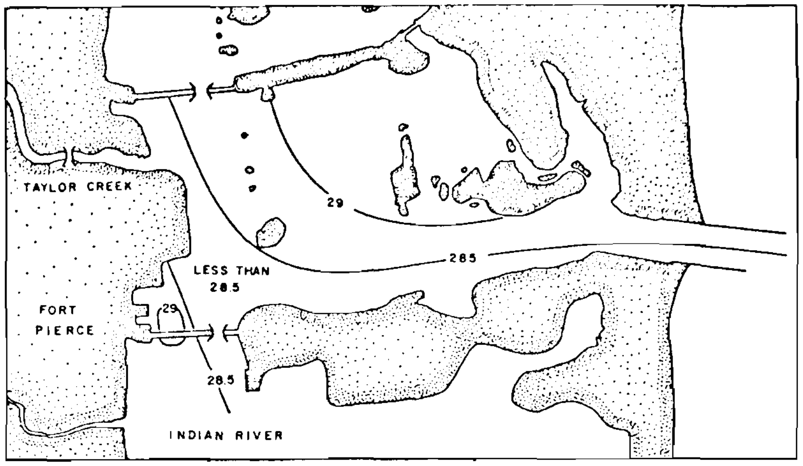


FIG. 10a TEMPERATURE DISTRIBUTION AT THE SURFACE FOR EBB TIDE (°C)

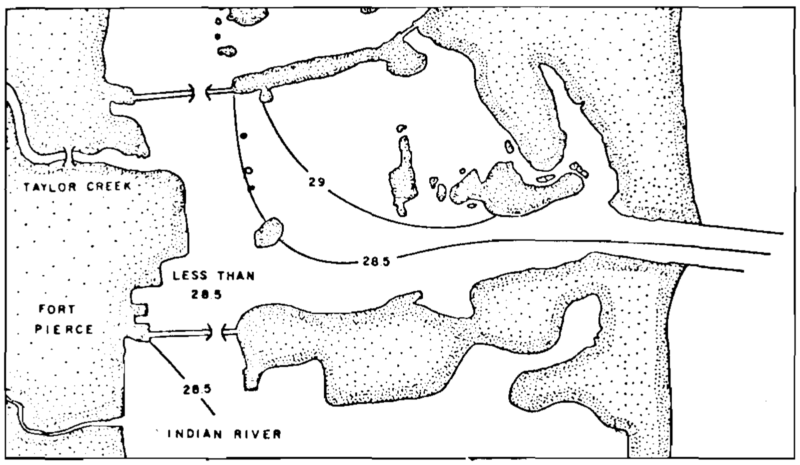


FIG 10b TEMPERATURE DISTRIBUTION ONE METER FOR EBB TIDE (°C)

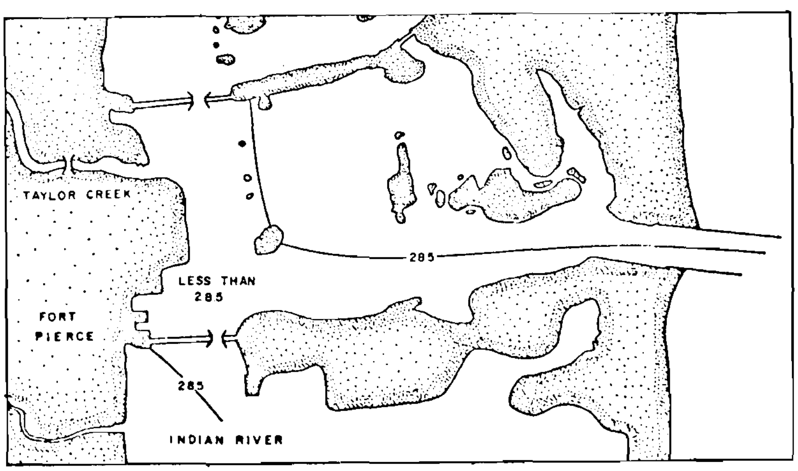


FIG. 10c TEMPERATURE DISTRIBUTION TWO METERS FOR EBB TIDE (°C)

e) Water Mass Distribution

For the purposes of this study the term "water mass" is not used according to the accepted definition but refers to waters which can be associated with geographical regions within the area of our study. The various "water masses" in this investigation can be differentiated from each other by means of salinity, however, their tidal and seasonal salinity variations overlap. Since the temperature variations of these waters are small and variable, it is not possible to define water masses in the oceanographic sense.

The water masses encountered in this study are: Northern Indian River water, which is found in the river area near the North bridge. Southern Indian River water, found in the river in the vicinity of the South bridge. Taylor Creek water and ocean water, named after their respective sources.

The various water masses can generally be distinguished visually by color and clarity. Interfaces between water masses are often sharply demarked by differences in color, clarity, salinity and sometimes by the accumulation of flotsam at the surface. The position, motion and diffusion of such interfaces for a representative day are shown in Figures 11 and 12. The distribution and motion of the water masses is discussed in detail in the following paragraphs.

At slack high water, oceanic (coastal)water covers a large portion of the Fort Pierce Inlet and harbor area in addition to encompassing the southern branch of the Indian River in the vicinity of the South bridge. Taylor Creek influenced water covers the area north of Taylor Creek and the North bridge. A mixture of river and ocean water extends over a portion of the area south of Taylor Creek as shown in Figure 11a.

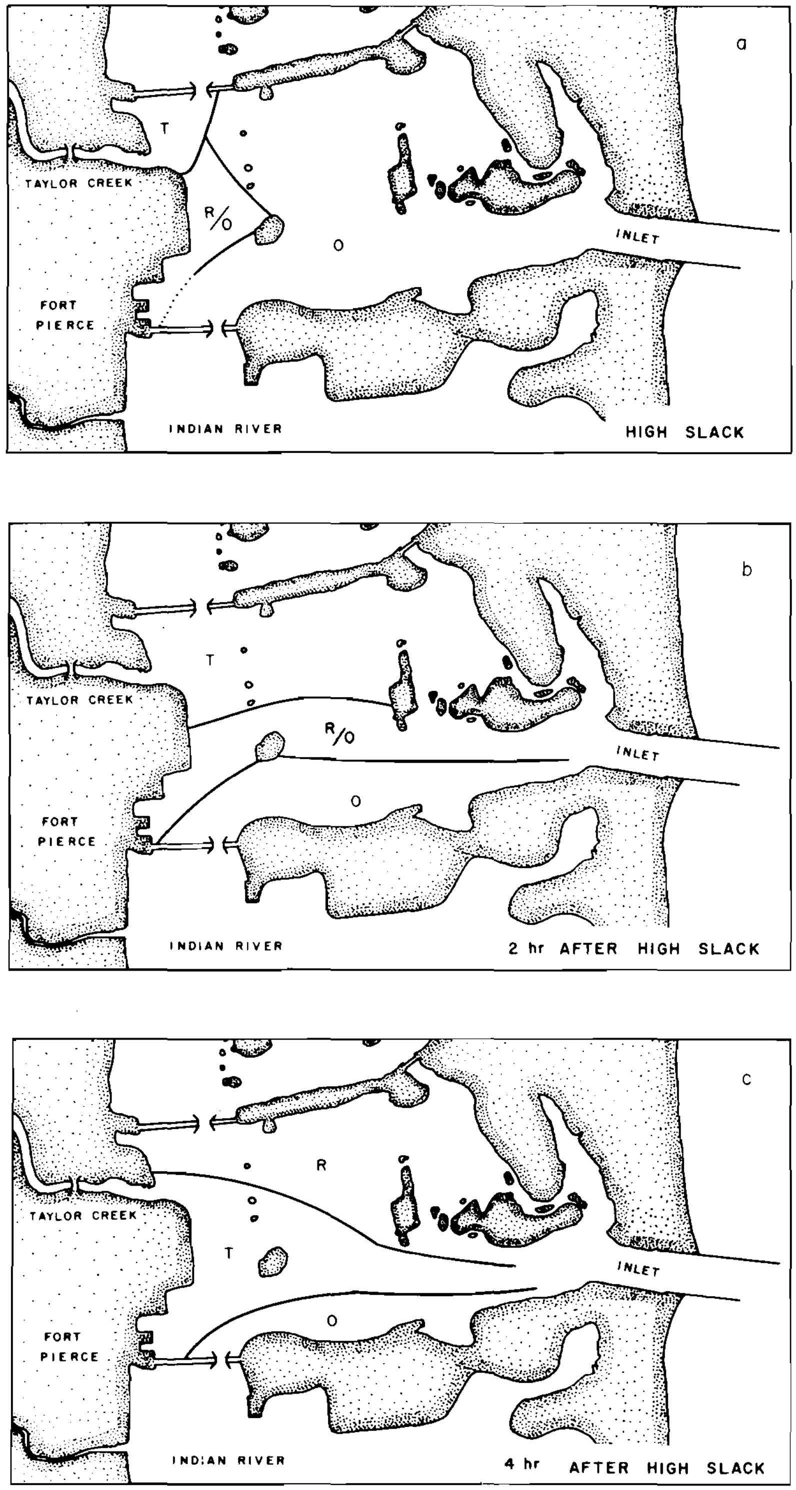
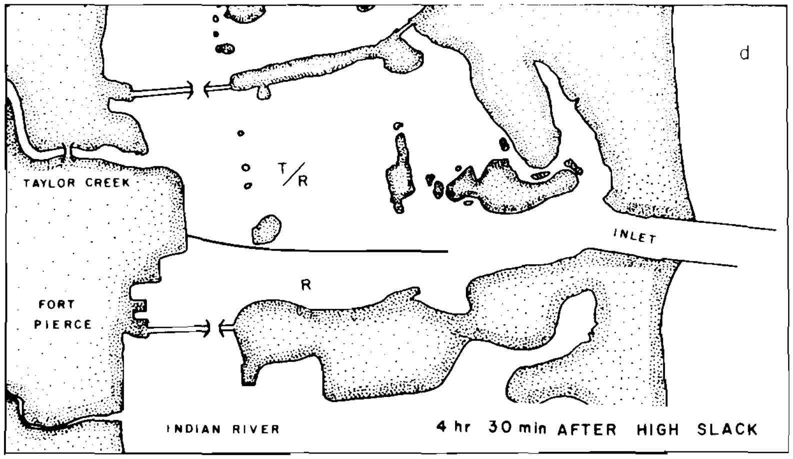
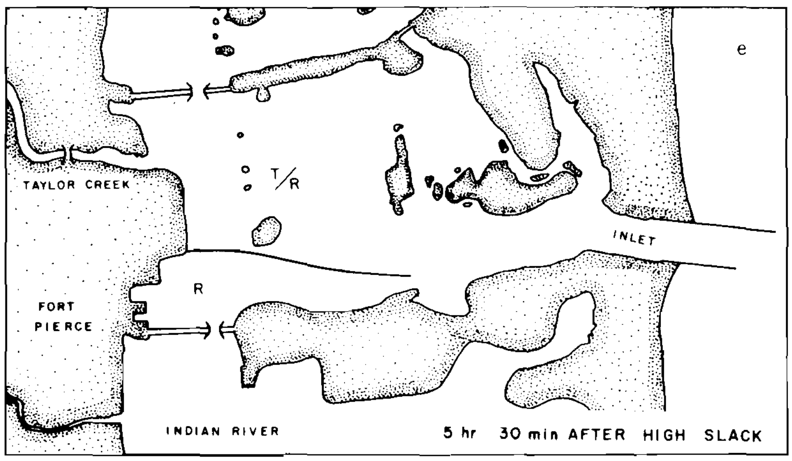


FIG. II a-c, WATER MASS DISTRIBUTION IN THE FORT PIERCE INLET AREA DURING EBB TIDE; T-TAYLOR CREEK WATER, R-RIVER WATER, O-OCEAN WATER, T/R-MIXTURE OF TAYLOR CREEK AND RIVER WATER, R/O-MIXTURE OF RIVER AND OCEAN WATER

——— SHARP INTERFACE ········ DIFFUSED INTERFACE.





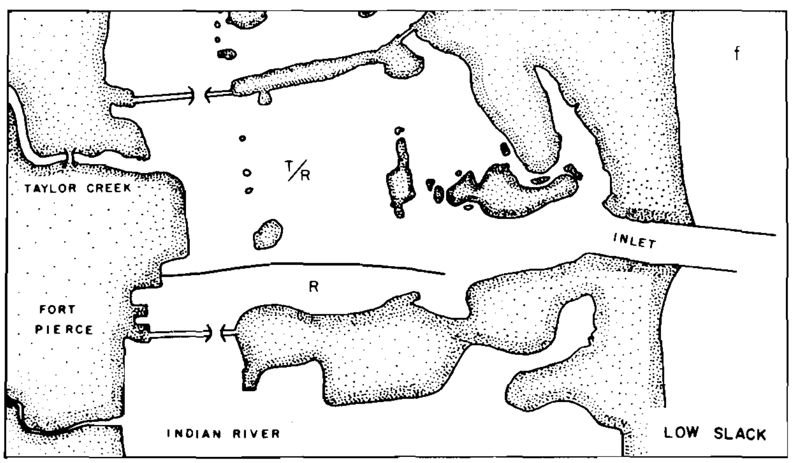


FIG. II d-f, WATER MASS DISTRIBUTION IN THE FORT PIERCE INLET AREA DURING EBB TIDE; T-TAYLOR CREEK WATER, R-RIVER WATER, O-OCEAN WATER, T/R-MIXTURE OF TAYLOR CREEK AND RIVER WATER, R/O-MIXTURE OF RIVER AND OCEAN WATER

——— SHARP INTERFACE ········ DIFFUSED INTERFACE.

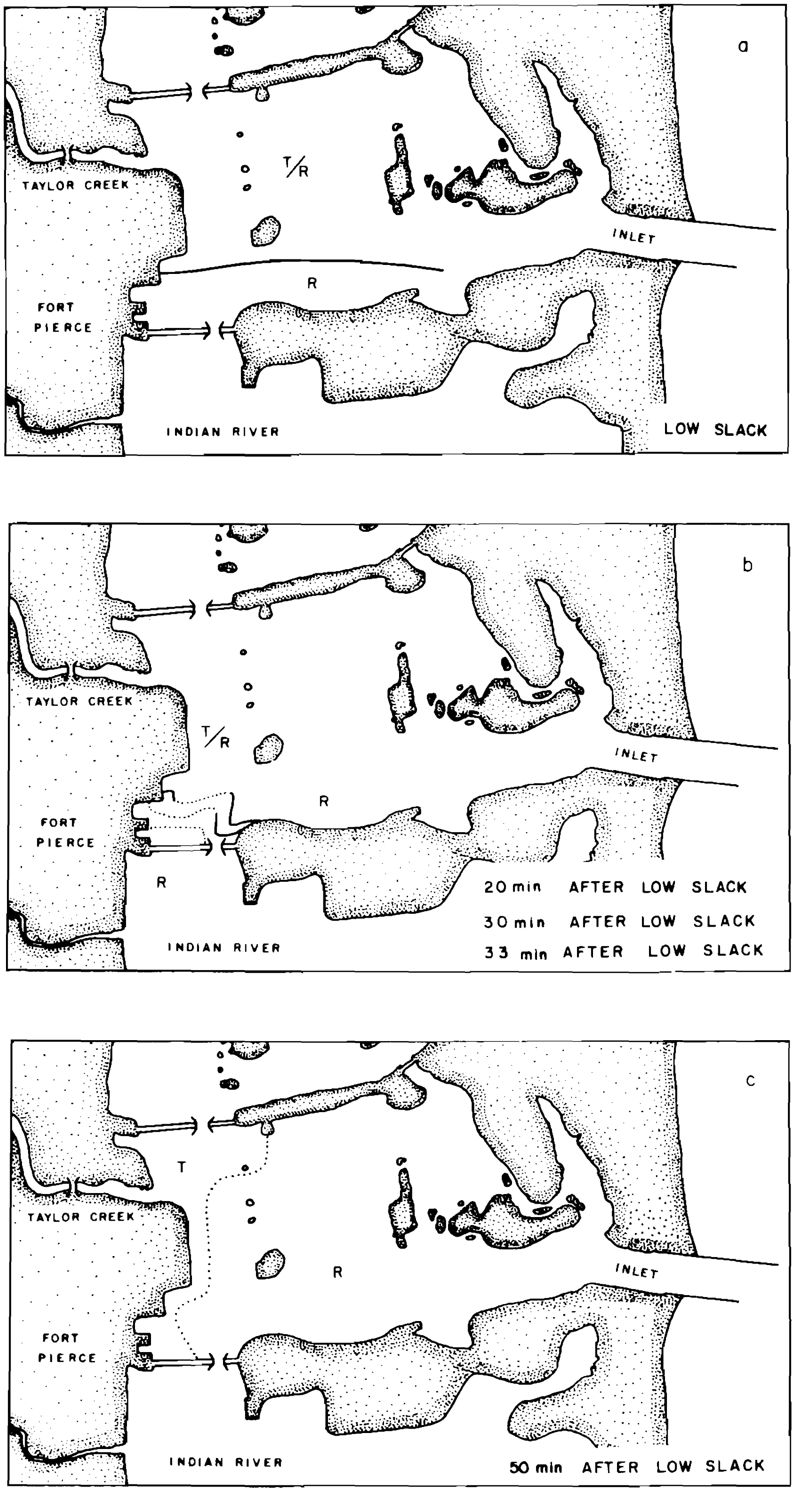
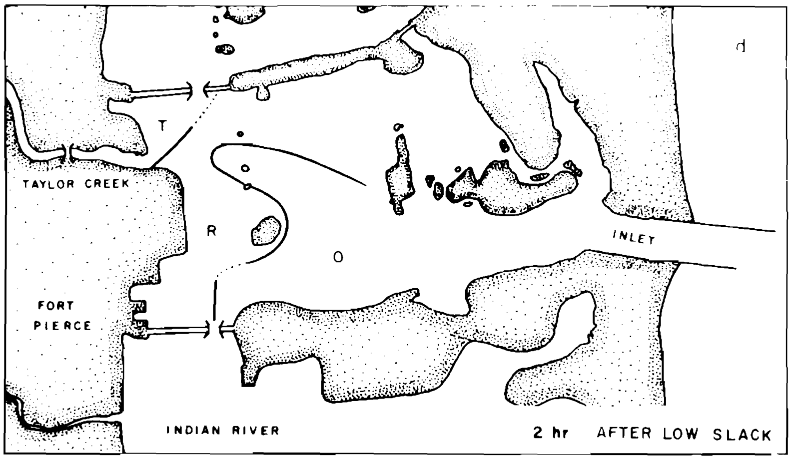
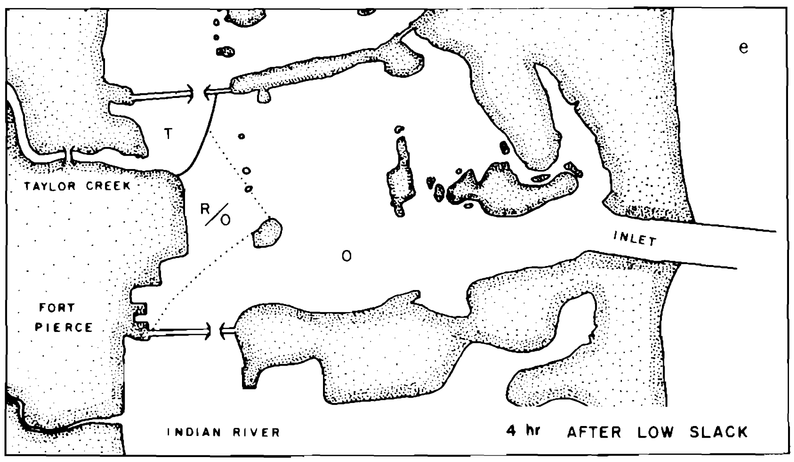


FIG. 12 a–c, WATER MASS DISTRIBUTION IN THE FORT PIERCE INLET AREA DURING FLOOD TIDE; T- TAYLOR CREEK WATER, R- RIVER WATER, O-OCEAN WATER, T/R- MIXTURE OF TAYLOR CREEK AND RIVER WATER, R/O - MIXTURE OF RIVER AND OCEAN WATER, ——— SHARP INTERFACE, ······ DIFFUSED INTERFACE.





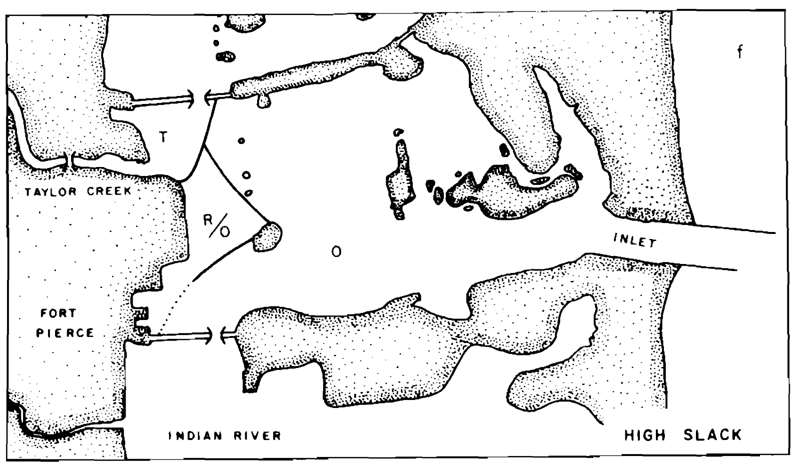


FIG. 12 d-f, WATER MASS DISTRIBUTION IN THE FORT PIERCE INLET AREA DURING FLOOD TIDE; T- TAYLOR CREEK WATER, R- RIVER WATER, O-OCEAN WATER, T/R- MIXTURE OF TAYLOR CREEK AND RIVER WATER, R/O - MIXTURE OF RIVER AND OCEAN WATER, ——— SHARP INTERFACE, ······· DIFFUSED INTERFACE.

In the beginning stages of the ebb tide, the ocean water flows out the Inlet and is replaced by the river-ocean water and by Taylor Creek influenced water. Sharp interfaces, as shown in figure 11b, between the various water masses can be discerned. Shortly after maximum ebb current, the Taylor Creek water and river-ocean water mixture have merged, forming a wedge between Indian River water to the north and the remaining ocean water to the south (Fig. 11c). Towards the period of low slack, ocean water in the harbor-inlet area is completely replaced by Southern Indian River water, which is demarked from a mixture of Northern Indian River/Taylor Creek water covering a large portion of the harbor area. Lateral mixing of these two waters takes place in the western approaches to the Inlet proper as indicated in Figure 11f.

With a change to flood tide, a mixture of Taylor Creek, northern and southern Indian River waters returns into the harbor area. An interface between the returning water (which mixes in the inlet area with even more Taylor Creek/Northern Indian River water), and water from the southern Indian River is formed as indicated in Figure 12b. As the flood tide continues, a more or less North-South diffused interface between Taylor Creek water and returning river water is established (Figure 12c). Towards the period of maximum flood, ocean water enters the inlet and harbor areas as well as the southern branch of the Indian River. At the same time the interfaces between Taylor Creek and remaining river-ocean mixture are being re-established similar to those found at period of slack high water (Figures 12e - f).

A combined analysis of the salinity, temperature and current measurements of the waters encountered within the harbor and inlet areas is consistent with the analysis of the water mass distribution by means of water color and clarity.

Results

Taylor Creek water has been shown to exert a major influence on the waters within the Fort Pierce harbor and inlet area. During ebb tide this water covers large areas of the inlet, mixing with water from the southern branch of the Indian River. During flood tide some of that mixture is forced into the southern branch of the river. Water in the river in the vicinity of the North bridge is strongly modified by Taylor Creek water, expecially during flood tide.

Based on water current observations, the outflow of the Fort Pierce sewage outfall, located near the Causeway Island and south of South bridge, is forced towards the eastern shore of the Indian River during flood tide. During ebb tide the outflow is swept into the ocean.

2. Hydrography of Continental Shelf Water

The investigation of the shelf water was undertaken as a long term program and is planned to continue after questions arising within the estuary are resolved. This study was unfortunately hindered by malfunction of newly purchased equipment (an all too often occurrence). Partial duplication of measuring capabilities and continuing repair of the instrument by the manufacturer have largely overcome these problems.

The data obtained to date consist largely of temperature transects some of which are presented here. Figure 1 shows the location of the transects, while figure 2-4 show typical temperature profiles. Spatial

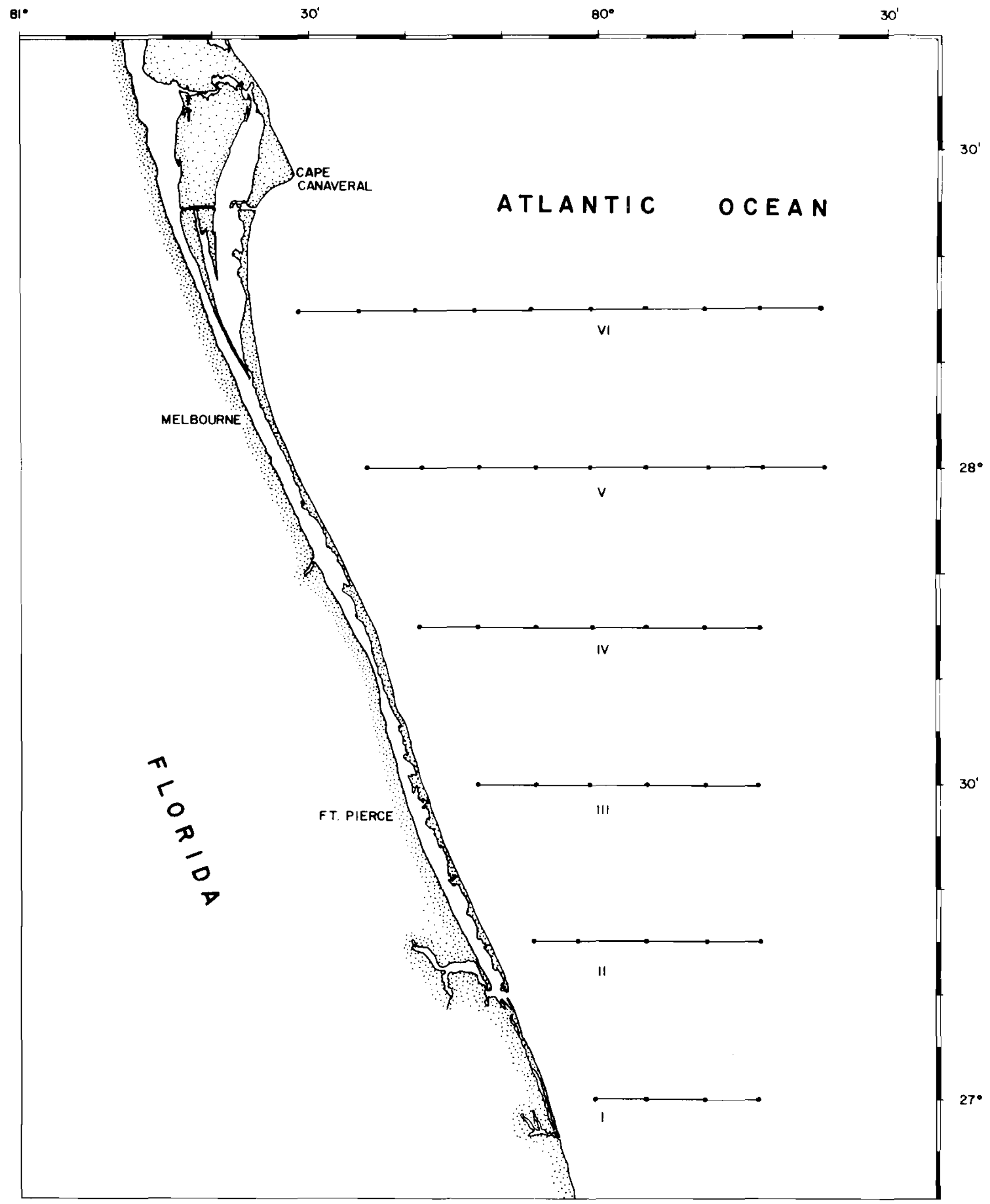


FIGURE I R/V GOSNOLD CRUISE TRANSECTS

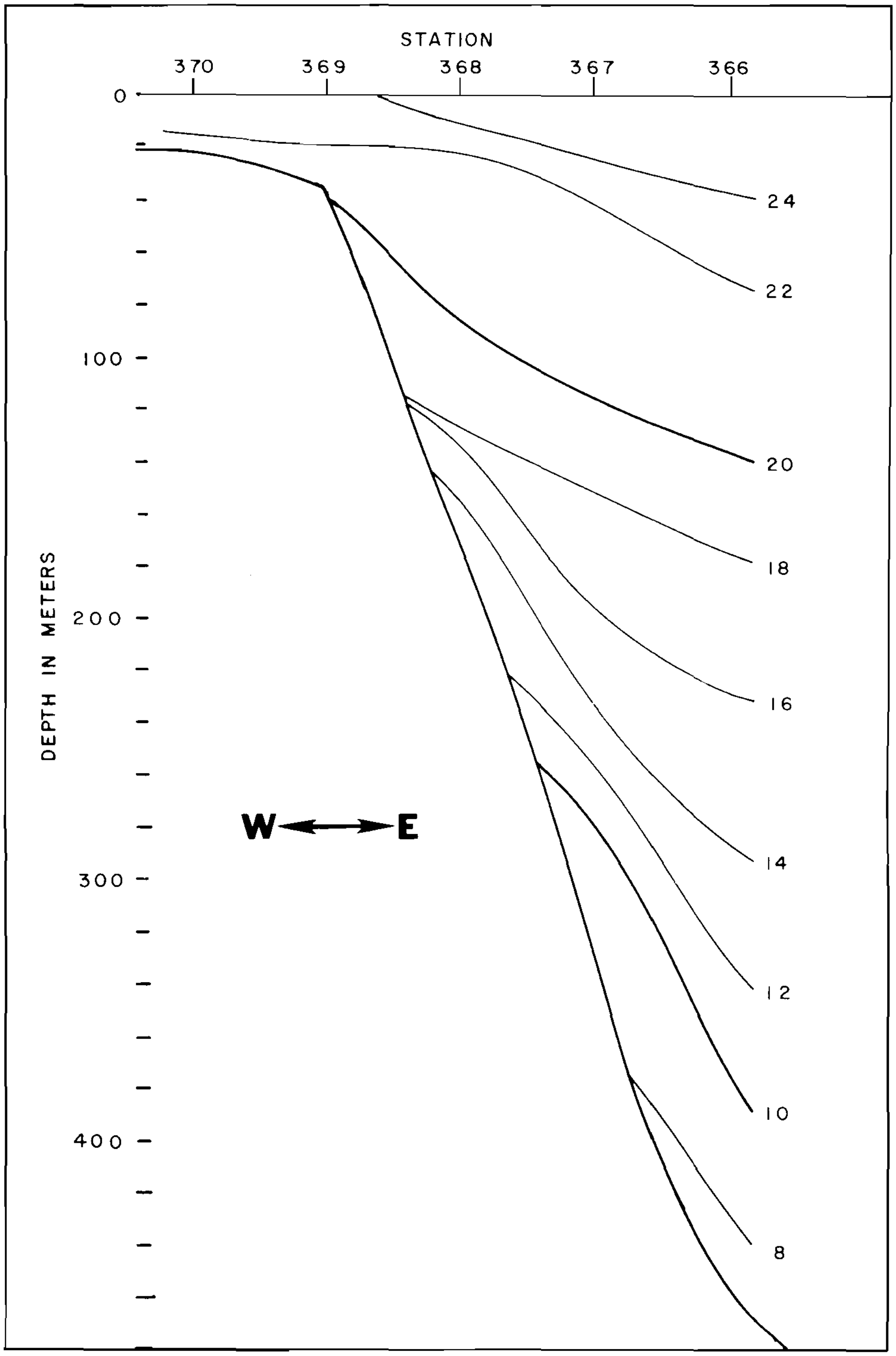


FIGURE 2

R/V GOSNOLD CRUISE 227 TRANSECT II

TEMPERATURE PROFILES (°C) 26 MARCH 1974

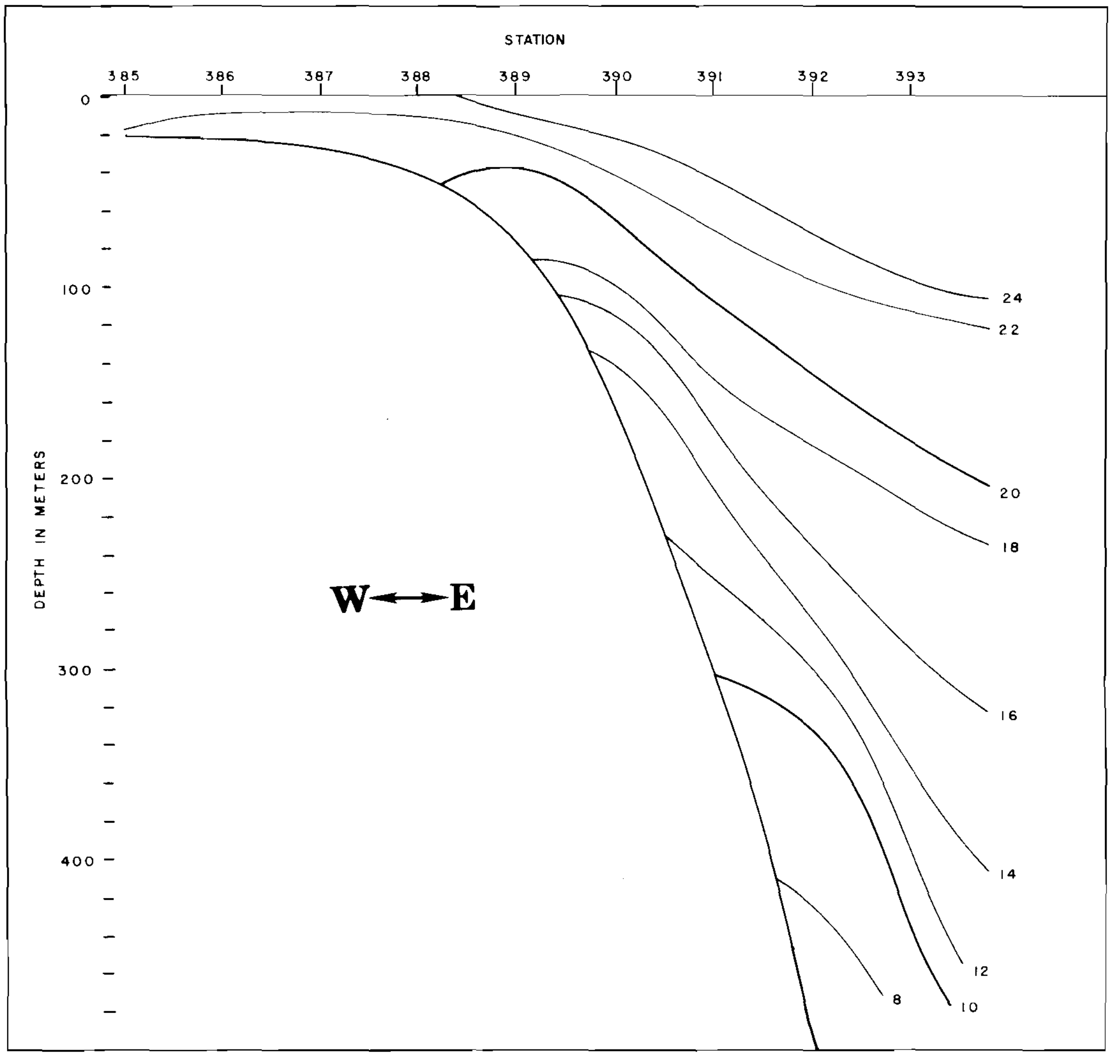


FIGURE 3
R/V GOSNOLD CRUISE 227 TRANSECT V
TEMPERATURE PROFILES (°C) 27 MARCH 1974

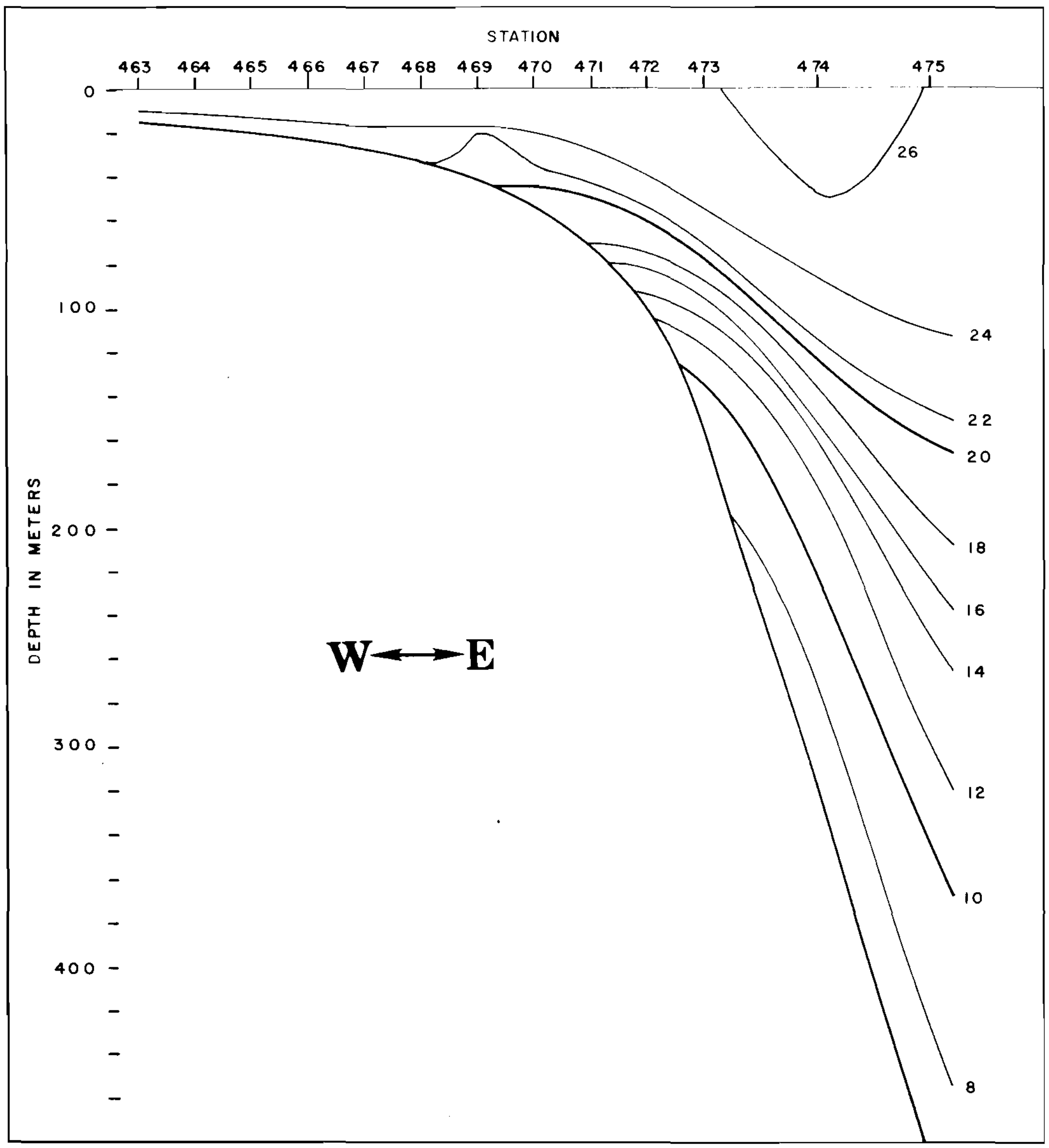


FIGURE 4

R/V GOSNOLD CRUISE 231 TRANSECT V

TEMPERATURE PROFILES (°C) 25 APRIL 1974

differences in the thermal structure can be seen between figures 2 and 3 while a comparison between figures 3 and 4 shows seasonal variation in the thermal structures, by a steepening of the isotherms and a general warming of the water between spring and summer. Seasonal change in surface temperatures from spring to summer is shown in figures 5 through 8. A surface salinity distribution is shown in figure 9.

Future Work

Since the research emphasis of the Indian River Study has now been focused on the lagoon proper, no work is presently being carried out or planned for the hydrographic investigation of the continental shelf waters or the current speed measurements.

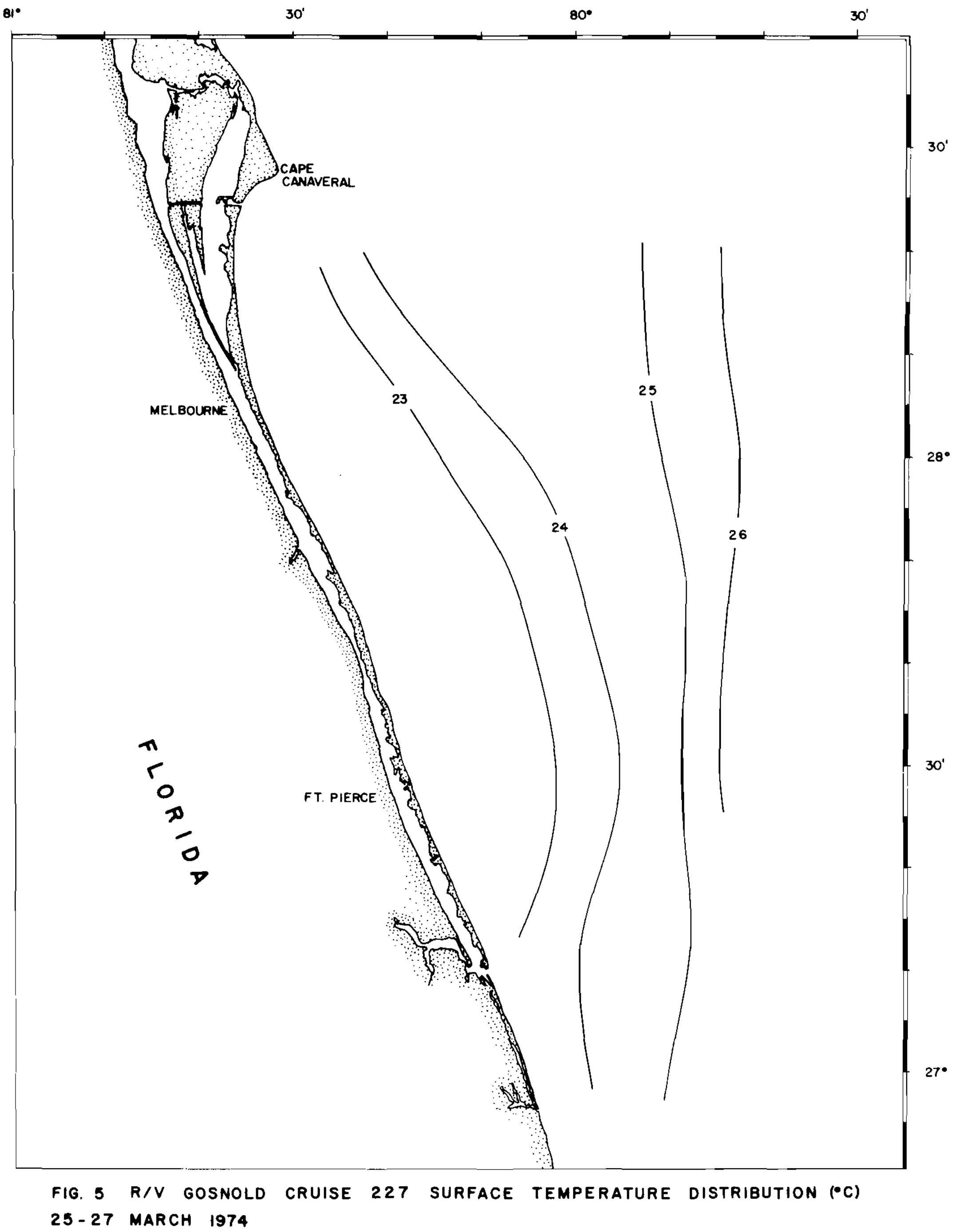


FIG. 5 R/V GOSNOLD CRUISE 227 SURFACE TEMPERATURE DISTRIBUTION (°C)
25-27 MARCH 1974

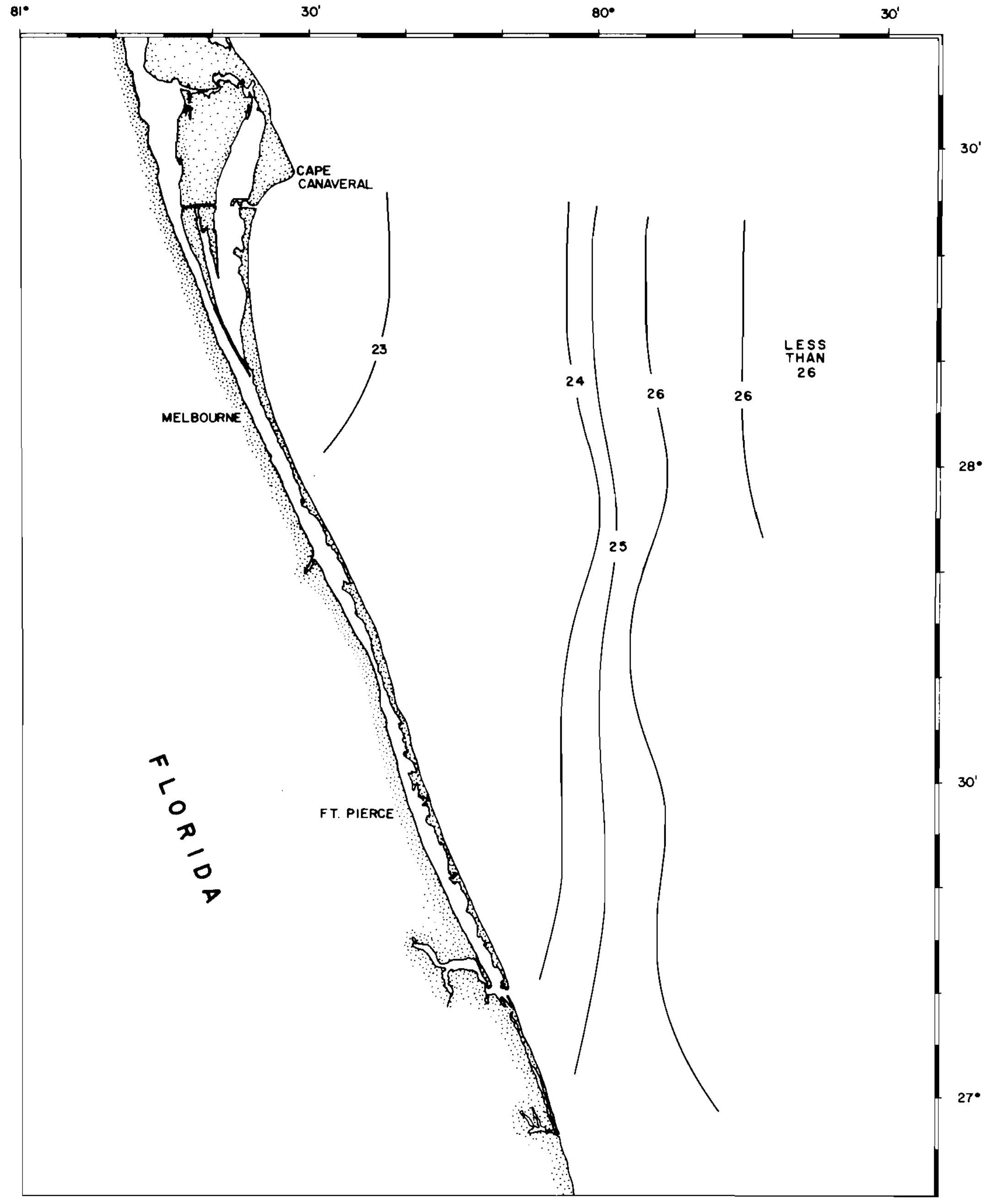


FIG. 6 R/V GOSNOLD CRUISE 231 SURFACE TEMPERATURE DISTRIBUTION (°C)
23 - 26 APRIL 1974

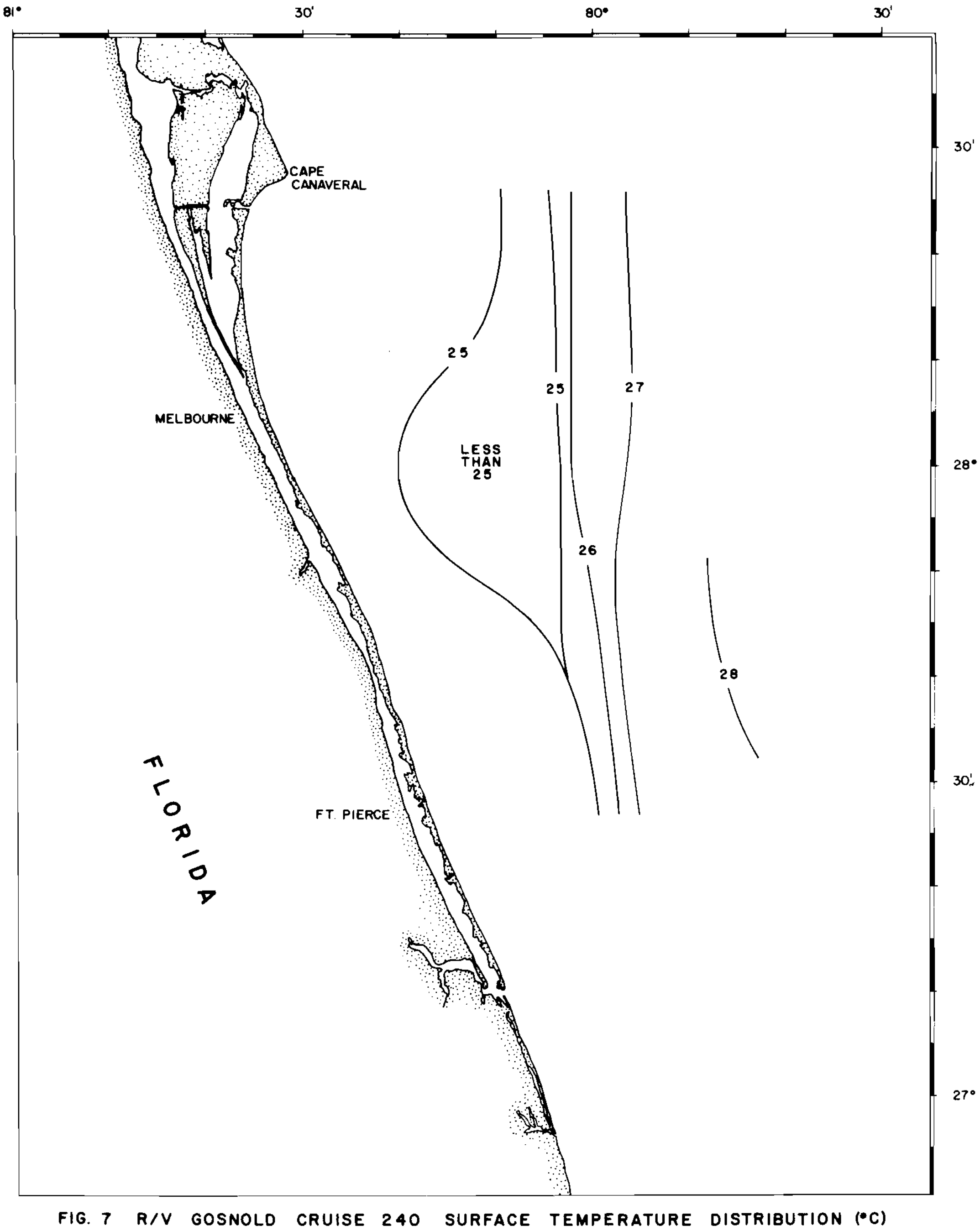


FIG. 7 R/V GOSNOLD CRUISE 240 SURFACE TEMPERATURE DISTRIBUTION (°C)
26-27 JUNE 1974

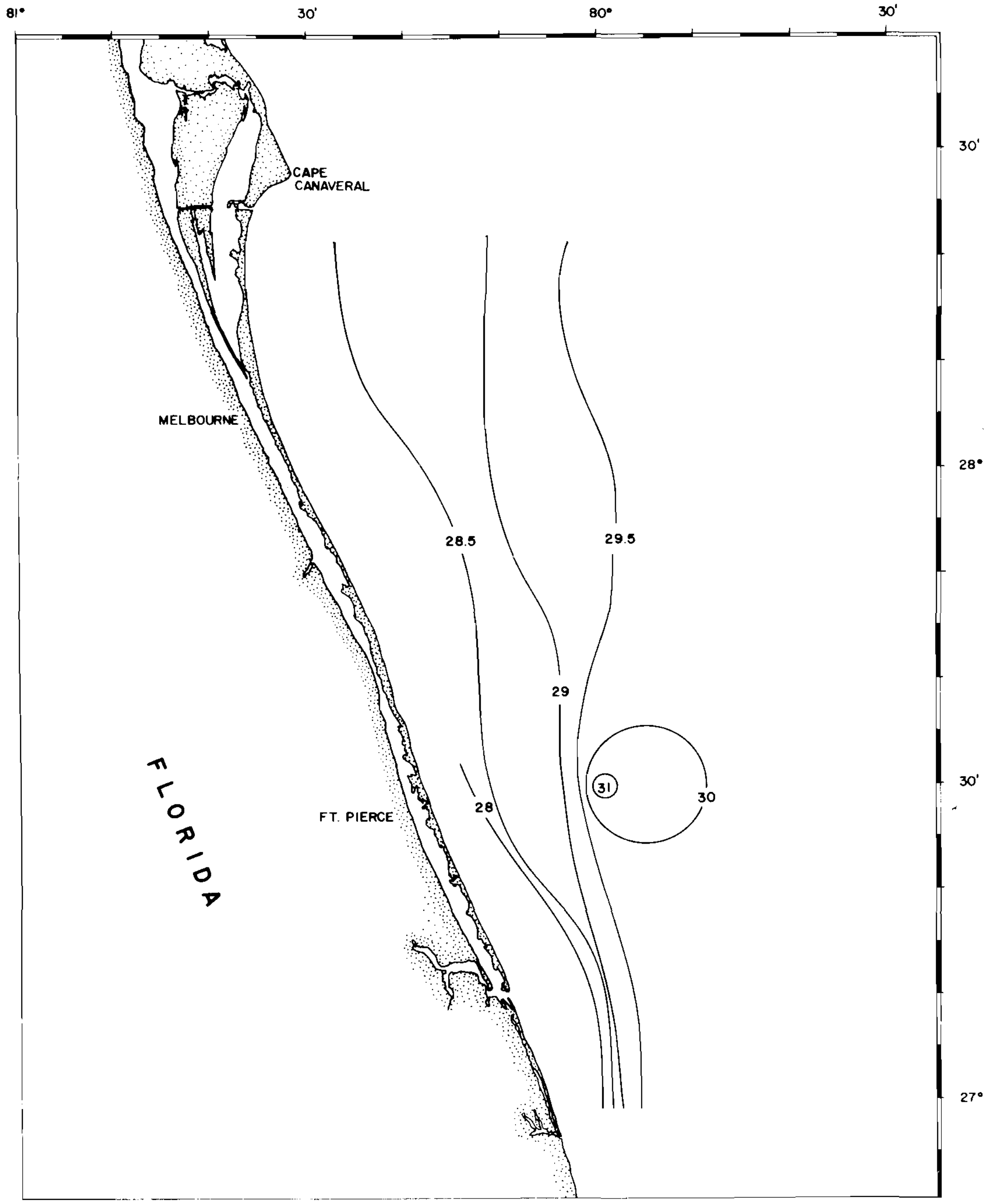


FIG. 8 R/V GOSNOLD CRUISE 244 SURFACE TEMPERATURE DISTRIBUTION (°C)
19-22 AUGUST 1974

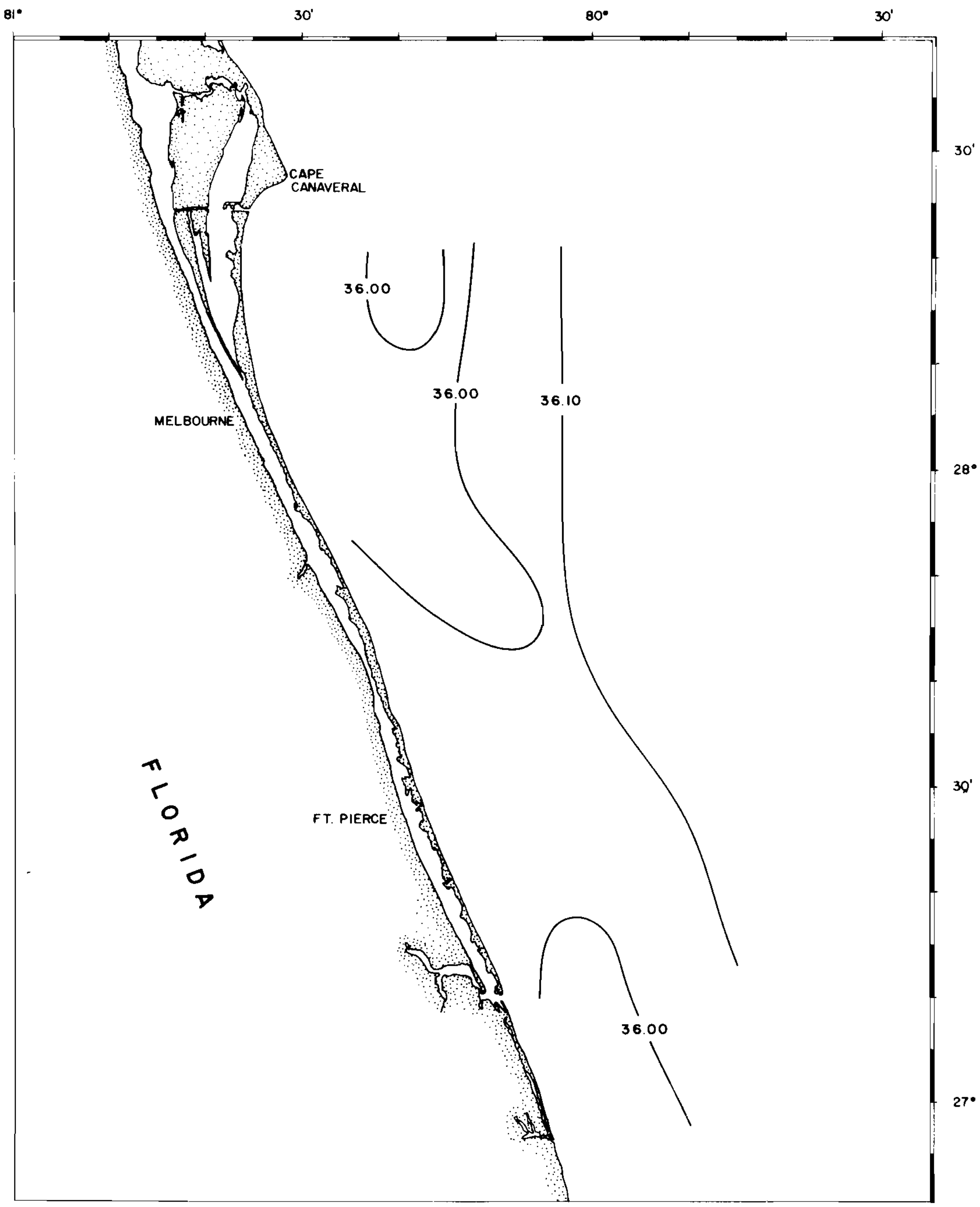


FIG. 9 R/V GOSNOLD CRUISE 240 SURFACE SALINITY DISTRIBUTION (PPT)
24 - 27 JUNE 1974

INDIAN RIVER CIRCULATION STUDY

Proposed Work

The Indian River between Ft. Pierce Inlet and Link Port is a wide, shallow body of water with numerous islands, coves and dead-end side branches. The deepest part of the so-called river is formed by the Intracoastal Waterway which runs lengthwise down the Indian River.

The water encountered within this area is estuarine to lagoonal in nature, consisting of ocean water mixed with fresh water from land run-off and creeks emptying into the river. The salinity of the water ranges from zero near the creeks to 40 ppt in shallow regions of the river, the average salinity is estimated to be between 20 - 30 ppt. The circulation of these waters is, to varying degrees, tidal and wind driven.

The proposed investigation plans on a descriptive basis, to determine the circulation of the Indian River water between the North bridge at Fort Pierce and Link Port. Although the value of numerical modeling of the circulation is recognized none will be attempted in this investigation unless additional personnel experienced in modeling studies become available.

An understanding of the processes occurring in this part of the river and the water circulation requires not only that the contributions of the wind and tidally driven currents be investigated but that they be separated from each other. In order to determine the contribution of the wind to the circulation, long term observations of the water motion in relation to the seasonally varying wind field (as well as evaporation and precipitation) need to be obtained. On the other hand, the tidally driven contributions require that synoptic, or at least quasi-synoptic, observations of salinity, temperature and the current field be obtained over the whole area under investigation, especially in relation to the tidal phase.

Sampling Plan

The main physical parameters to be examined in this investigation are: Tidal height and currents, current patterns, mass transport and water mass distribution. A variety of instruments and observational methods will be used to this end.

It is planned to employ records from moored recording current meters and tide gauges, as well as drogue and dye motion observations and current measurements from boats. Chemical indicators found within the water will be used to help identify water masses and to trace their motion. Local speed and direction measurements are also required.

Preliminary descriptions of the various planned tasks are outlined in the following paragraphs. It must be pointed out at this time that it may be necessary to alter, delete or add to these tasks as results warrant it.

1) Tidal height and current measurements

Recording tide gauges are to be placed throughout the area under investigation. In addition, one gauge will be placed in the ocean near the Ft. Pierce Inlet. This gauge will serve as a reference gauge to the other instruments.

At least four tide recording instruments are required. Three of these are to be placed as follows: 1) in the ocean, 2) North bridge and 3) in the vicinity of Link Port on a long term basis. The fourth instrument is flexible and can be emplaced as may be required. Recording current meters should be emplaced with the tide gauges.

The purpose of installing these instruments is to be able to relate other information collected at other times and locations to the tidal stage as it occurs. Errors would be introduced into the observational program if tidal data were to be taken only from the Tide Tables as published by NOS, since the phase lags in tidal are introduced by the shallow and partially constricted topographical configuration of the Indian River.

2) Mass transport

Values of volume transport are to be calculated from measurements of vertical velocity profiles from two transects across the Indian River. One of these transects will be located at the southern boundary of the area under study near North bridge and Jim bridge. The other transects will be near Link Port. The vertical current velocity profiles are obtained by lowering an on-deck readout current meter from a boat on a two-point mooring.

Unfortunately, the process of setting two anchors at each profile station along the transects is very time consuming. The time required to perform one transect will therefore probably be a significant portion of the semidiurnal tidal period. As a consequence, large errors will be incorporated with the volume transport values.

In order to determine the next flux of water into the area under consideration, it will also be necessary to obtain simultaneous velocity profiles over both transects. Since this requires a duplication of instrumentation, boats and personnel, volume transport values under varying tidal and wind conditions will represent a major effort in addition to requiring considerable personnel and time.

3) Dye and drogue observations

Qualitative (and somewhat quantitative) information on the water motion will be obtained by release and tracking of dyes and drogues in the water. Although some of the tracking of the released material can be done by boats, aerial photography of the released dyes and drogues on a time series basis will yield more rapid information and thus should be undertaken under varying wind and tidal conditions. An aerial photographic survey of the whole area under consideration, as well as an initial effort in determining the main features of the circulation, should be conducted in the beginning phases of this investigation.

4) Wind information

Measurements of wind speed and direction will be related to observed circulation patterns and current speed measurements. The collection of wind data from sensors located near the water and within the river area is mandatory. It will probably prove necessary to establish a wind recording station at a secure location on the river.

5) Watermass distribution

Salinity and temperature measurements need to be obtained on a synoptic basis throughout the water column over the whole area. To accomplish this a multi-boat sampling scheme based on an established sampling station grid needs to be established.

As previously stated, any natural chemical tracers found in the water will be utilized for the purpose of this study. In addition to fluorometry, it is felt that the chemical aspects of this study fall within the province and capability of the chemical group at HBFL.

The complexity of this study merely reflects the fact that hydrographic observations are difficult to obtain and require careful analyses if they are to be properly related to the ambient conditions at the time of the experiment. Since hydrographic conditions are constantly changing, measurements of these data often must be made in duplicate, so that the dynamics are, in effect, made static in time. The topographical and hydrographical attributes that comprise the shallow, lagoonal system known as the Indian River impose further constrictions on the obtaining of data for the analyses of the system.

CHAPTER 4

WATER QUALITY STUDIES OF THE INDIAN RIVER

L. I. Briel

I. CHEMICAL MONITORING

J. M. Fyler
M. Y. Laffey
J. T. Paxton

II. PHYTOPLANKTON STUDIES

F. C. Stephens

With Figures by M. Y. Laffey

INTRODUCTION

The water quality studies of the Indian River region were designed to survey environmental problems in a rapidly-developing area along the coast of east-central Florida, from Titusville southward to Stuart, a distance of approximately 190 kilometers. The principal physiographic feature in this region is a bar-built estuary known locally as the "Indian River', a long, narrow body of brackish water impounded from the Atlantic Ocean by a continuous chain of offshore barrier sand islands. The three inlets (St. Lucie, Fort Pierce, and Sebastian) connecting the lagoon with the Atlantic lie in the southern half of the estuary, and they are relatively small compared to the total length of the Indian River; thus, the overall tidal action in the basin is considerably reduced and the mass transfer of water in the system is complex. Except for the channel of the Intra-coastal Waterway, the basin of the Indian River is very shallow with an average depth of 1.5 meters, and the winds provide an important mechanism for mixing the fresh water runoff with the more saline (marine) components of the estuary. The relative importance of tidal stage, surface runoff, wind mixing, and evapo-transpiration is subject to considerable variation, both areally and temporally.

There are a number of distinct differences between the "blind" northern end of the Indian River and its more "open" southern end. The major centers of urbanization are presently located in the northern end of the estuary, a backwater which stretches sixty-nine miles to the inlet at Sebastian. The sewage outfalls from the cities of Titusville, Cocoa, and Melbourne are discharging millions of gallons of partially treated sewage into this part of the lagoon where there is little chance that the waste products will ever be carried out to sea. Though Haulover Canal does connect this part of the Indian River to the Mosquito Lagoon, the flushing period for this part of the system appears to be very, very long. Under these conditions, the concentration of toxic substances and pathogenic organisms could rise to levels intolerable to the indigenous biota, resulting in eutrophic stagnation. And even if man were not introducing municipal wastes into this part of the River, the very long flushing periods may allow salinities to reach above 40 parts per thousand when the rate of evaporation exceeds the rate of freshwater input and water temperatures in this shallow basin to range from 11 to 32°C. Thus, only the most euryhaline, eurythermal species might be expected to tolerate these natural environmental stresses.

In the central portion of the Indian River between the Sebastian and St. Lucie Inlets, the effects of tidal flushing are considerably more pronounced than they are in the northern end of the system, though the mass transfer of water through this part of the estuary has yet to be determined quantitatively. The tidal periods are diurnal and the water currents are very pronounced in the area of the inlets. Yet at Vero Beach, which is midway between two inlets, the effluent from the municipal sewage plant may never actually reach the ocean because of the restricting, congested nature of the basin in this area. As this city grows larger, the quality of the water in the Indian River at this site will almost certainly decrease, though there may be sufficient interaction with adjacent water masses in the River to prevent complete stagnation. Salinities in this part of the estuary range from 28 to 35 parts per thousand, and the water temperature ranges from 16 to 31°C.

In the "open" southern portion of the estuary the period of tidal flushing is semi-diurnal, and it appears likely that a significant part of the treated sewage from Fort Pierce, Jensen Beach and Stuart is swept out to sea on the outgoing tides. However, it is equally probable that sewage is impounded in the River by the incoming tides, and the effects of pollution at these sites need to be examined carefully in long-term studies designed to investigate the effects of cumulative exposure to sewage wastes. In this region the introduction of large, though highly variable, amounts of fresh water runoff from the St. Lucie River and from the numerous flood-control and irrigation canals causes the salinity to range from less than 1 part per thousand to about 35 parts per thousand near the inlets; thus the organisms living in this part of the Indian River would be expected to show an exceptionally high tolerance to variable salinities. The water temperature varies from 14 to 31°C.

In considering a water mass balance for the Indian River system, there is an additional source of water which is often overlooked. The Floridan Aquifer is under artesian pressure in the study area, and untold amounts of groundwater are being added to the estuary from irrigation wells in the citrus groves. Many of the minor canals in the area discharge water into the River which is not surface runoff but represents water collected from artesian wells. A sophisticated new geochemical technique is now available by which the groundwater component of the estuary may be distinguished from the surface runoff and marine components. The technique employs isotopic fractionation in naturally-occurring uranium isotopes to tag the various components and to calculate their abundances. This method will ultimately permit the calculation of water mass balances in the River by data which are independent of physical-hydraulic considerations.

I. Chemical Monitoring

The monitoring of key chemical parameters in the Indian River estuary seeks to establish base-line information on the quality of water at selected sites, as well as to provide data on the interaction of specific chemical substances in the environment with the biological systems. Initially, the chemical study will attempt to survey the entire estuary on a regular schedule, in order to obtain a broad view of areal and seasonal variations of water quality parameters. Key physical parameters will be included in the chemical survey to gauge the effects of tides, water currents, winds and rainfall on the chemical measurements. During this time, particular emphasis will be focused upon sites of pollution, or potential pollution, within the different parts of the Indian River. Subsequent goals of the chemical study will include the analysis of important chemical parameters in selected habitat types, such as the grassflat areas of the River. Throughout the progress of the study, emphasis will always be placed upon the inter-relationships of chemical and biological data in order to obtain a unified concept of the ecosystem as a whole.

Methods

A significant part of the initial year of the project has been involved with the design and construction of laboratory facilities and instrumentation systems. Four distinct areas are required for the chemical study: (1) the mobile sampling laboratory aboard the R/V Casa Aqua was specifically designed to house the auto-sampler-filtration system, the auto-analyzer instrumentation system, the physical parameter monitoring system, and the meteorological data observation system. Twenty-three physico-chemical measurements are made continuously aboard the boat as the cruise progresses from station to station, and water samples from specific depths in the water column are collected and filtered automatically for more extensive water quality analyses back at Link Port. (2) The analytical instrumentation laboratory aboard the barge at Link Port was designed to house the atomic absorption spectrophotometer for dissolved metal analyses, the ultraviolet--visible light spectrophotometer for plant pigment determinations, the radiological monitoring system for radiological background data, the gas chromatograph for organopesticide analyses, and another auto-analyzer system for more involved nutrient analyses. Sixty-five additional chemical measurements are being made, or are projected, on the water samples that are collected on the R/V Casa Aqua cruises. Table I summarizes the chemical work of the Indian River Study. (3) The wet-sample preparation laboratory was extensively renovated to provide the facilities necessary for wet-chemical processing of the samples prior to the instrumental determinations; and (4) the glass-blowing shop and chemical supplies storage area provide the space necessary for analytical maintenance. These latter areas are also aboard the laboratory barge at Link Port.

With the completion of facilities aboard the R/V Casa Aqua, brief preliminary cruises were begun in April in the area from Vero Beach to the Fort Pierce Inlet. The primary purpose of these cruises was calibration and "debugging" of the various analytical instrumentation systems aboard the houseboat. During this period, some 200 water samples were collected from the Indian River and analyzed aboard ship for the concentrations of essential micro-nutrients in the water column. As the methods became routine, fewer difficulties were encountered with the instrumentation, although it readily became apparent that some of the

TABLE I.

SUMMARY OF CHEMICAL PARAMETERS FOR THE INDIAN RIVER STUDY

Instrumental Method Used:	Parameter Category:	Justification for Measurement:	Parameter Measured:	Status of Analysis: * Current A	Current B	Current C	Projected A	Projected B	Projected C
I. Auto-analyzer	Essential Micro-Nutrients	Nitrogen, phosphorus, silicon, and sulfur compounds are necessary for the metabolism of plants	Ammonia	X					
			Nitrate	X					
			Nitrite		X				
			Total Kjeldahl Nitrogen					X	
			ortho-Phosphate	X					
			Total Phosphate	X					
			Total Inorganic Phosphate					X	
			Silicate	X					
			Sulfate				X		
			Sulfide					X	
II. Atomic Absorption	Dissolved Metals	Class I: Alkali Metals---always present in seawater; usually present in fresh water	Sodium	X					
			Potassium	X					
			Lithium	X					
			Calcium	X					
			Magnesium	X					
			Strontium	X					
		Class II: Essential Heavy Metals---minimum amounts are necessary for healthy growth of both plants and animals; excessive concentrations of these ions are toxic	Iron	X					
			Zinc	X					
			Copper	X					
			Cobalt		X				
			Chromium		X				
			Manganese		X				
			Molybdenum		X				
			Nickel		X				

Table I. (cont.)

Instrumental Methods Used:	Parameter Category:	Justification for Measurement:	Parameter Measured:	Status of Analysis: * Current A	Current B	Current C	Projected A	Projected B	Projected C
Atomic Absorption (continued)	Dissolved Metals	Class III: Pollutant Heavy Metals--- highly toxic substances in very low concentrations	Antimony					X	
			Arsenic		X				
			Bismuth					X	
			Cadmium		X				
			Lead	X					
			Mercury			X			
			Thallium					X	
			Tin					X	
		Class IV: Trace Metals--- seldom found in appreciable concentrations in estuarine waters; however, they merit occasional screening	Barium						X
			Beryllium						X
			Gold						X
			Platinum						X
			Rubidium					X	
			Silver			X			
			Tungsten						X
			Vanadium						X
III. Specific Electrodes and Sensors	Physico-Chemical Parameters	Classical water chemistry measurements that are performed in all oceanographic surveys	Water Temperature	X					
			Salinity	X					
			Chlorinity	X					
			Acidity	X					
			Dissolved Oxygen	X					
			Redox Potential	X					
			Sampling Depth	X					
			Sampling Time	X					
			Station Location	X					
			Air Temperature				X		
			Air Pressure				X		
			Wind Speed				X		
			Wind Direction				X		
			Rainfall				X		
			Tidal Stage				X		

Table I. (cont.)

Instrumental Methods Used:	Parameter Category:	Justification for Measurement:	Parameter Measured:	Status of Analysis: * Current A	B	C	Projected A	B	C
VIII. "Wet" Methods	Instrumental Standardization Procedures	Most of the instrumental procedures must be checked and calibrated by means of manual procedures	Dissolved Oxygen		X				
			Ammonia		X				
			Nitrate		X				
			Nitrite			X			
			ortho-Phosphate		X				
			Total Phosphate		X				
			Silicate		X				
			Chlorinity			X			
			Redox Potential			X			

* Status of Analysis Code:

A = Routine sample analysis for every station monitored

B = Regular sample screening for selected key stations

C = Occasional sample determination for selected stations automated chemistries of the Technicon auto-analyzer system would require operating conditions which could not be optimized on the moving boat. The availability of the second Technicon system at Link Port proved an invaluable asset to the program, both for checking shipboard results and for running the more involved methods which required digestion procedures. Since the purpose of these early cruises was debugging the auto-analyzer system, reliable analytical data on micro-nutrients in the water is at best fragmentary.

During this period, other methodologies were being explored and modified for instrumentation aboard the laboratory barge. Approximately 100 water samples were brought back from the cruises and analyzed for their dominant phytoplankton populations and major plant pigments (see Section II); and about half of these water samples were also scanned for their concentrations of various dissolved metals (Table 1). Key samples of the estuary were also analyzed for their uranium isotopes parameters. Most of these early results indicated that further modifications would be needed in the analytical procedures to determine these data to an acceptable degree of precision, and an ongoing program of method development was started at that time.

The physical parameter monitoring system was delivered in June and installed aboard the R/V Casa Aqua. This instrumentation employs a bank of specific sensor probes to measure the classical parameters of most oceanographic surveys: temperature, salinity, chlorinity, acidity, dissolved oxygen, redox potential, and sampling depth. All of these measurements are made simultaneously and continuously throughout the cruise. Unfortunately, however, in the extremely shallow water of the Indian River, the configuration of the sensor assembly does not facilitate trolling it behind the houseboat, since to do so would subject the delicate sensors to severe damage were the assembly to strike a submerged object. To circumvent this difficulty, Mr. John Holt of the Harbor Branch Foundation Engineering Laboratory designed and constructed a special flow-cell for the sensor assembly. Instead of dragging the sensors through the water, we chose to pump water from the River past the sensors at a rate equal to the cruising speed of the boat, thus protecting the probes from unexpected impact and at the same time pumping onboard a sample for the auto-analyzer. The depth of the sampling intake is variable, so that we can take a vertical profile of the water column with the apparatus.

An integral part of this auto-sampler-filtration system involves an innovative new filtering circuit that automatically delivers filtered aliquots of the water sample to the intake of the auto-analyzer system. The filter system utilizes an ingenious new type of filter material which is available at comparatively low cost, and the system provides the option of one or two stages of filtration for the aliquot samples. The specific details of this device will be published as a separate report in one of the professional journals.

The meteorological data observation system has just recently been installed aboard the R/V Casa Aqua. With it, the chemical survey will be able to monitor air temperature, air pressure, wind speed and wind direction; and these parameters should provide useful information on atmospheric effects. A portable tide gauge station has also been utilized recently to determine the stage of the tide for the 24-hour tidal cycle studies made in conjunction with the September cruise. The gauge was placed in shallow water near the boat anchorage so that the relative tidal stage could be monitored as the water samples were collected and

and analyzed. The emplacement of several permanent tide gauge stations has been planned for key locations in the estuary so that overall long-term effects of tidal lag on mass transfer of water may be determined quantitatively. This work is being done in cooperation with the physical oceanographic survey of the Indian River system by other scientists on the project.

Results

Since the middle of June, four major chemistry sampling cruises of the north-south axis of the Indian River estuary have been completed. Data have been acquired for some fifty-two different physico-chemical parameters, and a total of 12,000 individual pieces of data has been processed and stored in the Smithsonian computer. To maximize the immediate availability of this data, programs have been written for the Hewlett-Packard 9820A calculator and this machine is being used to reduce raw data and to plot preliminary figures.

To provide comprehensive coverage of the whole study area, seventy-five permanent chemical data stations were selected at fixed markers along the channel of the Intra-coastal Waterway in the Indian River, ten stations in the Banana River, and eighteen stations in the St. Lucie River (Figure 1). A number of additional sites of special interest were included in the regular sampling network. These sites include the mouths of the major freshwater streams and canals which drain into the estuary; the effluents of the municipal sewage plants which discharge into the River; and sites which represent selected habitat types, such as the grassflat areas in the River. Additional data sites of special interest will be included in the chemical survey as the need arises.

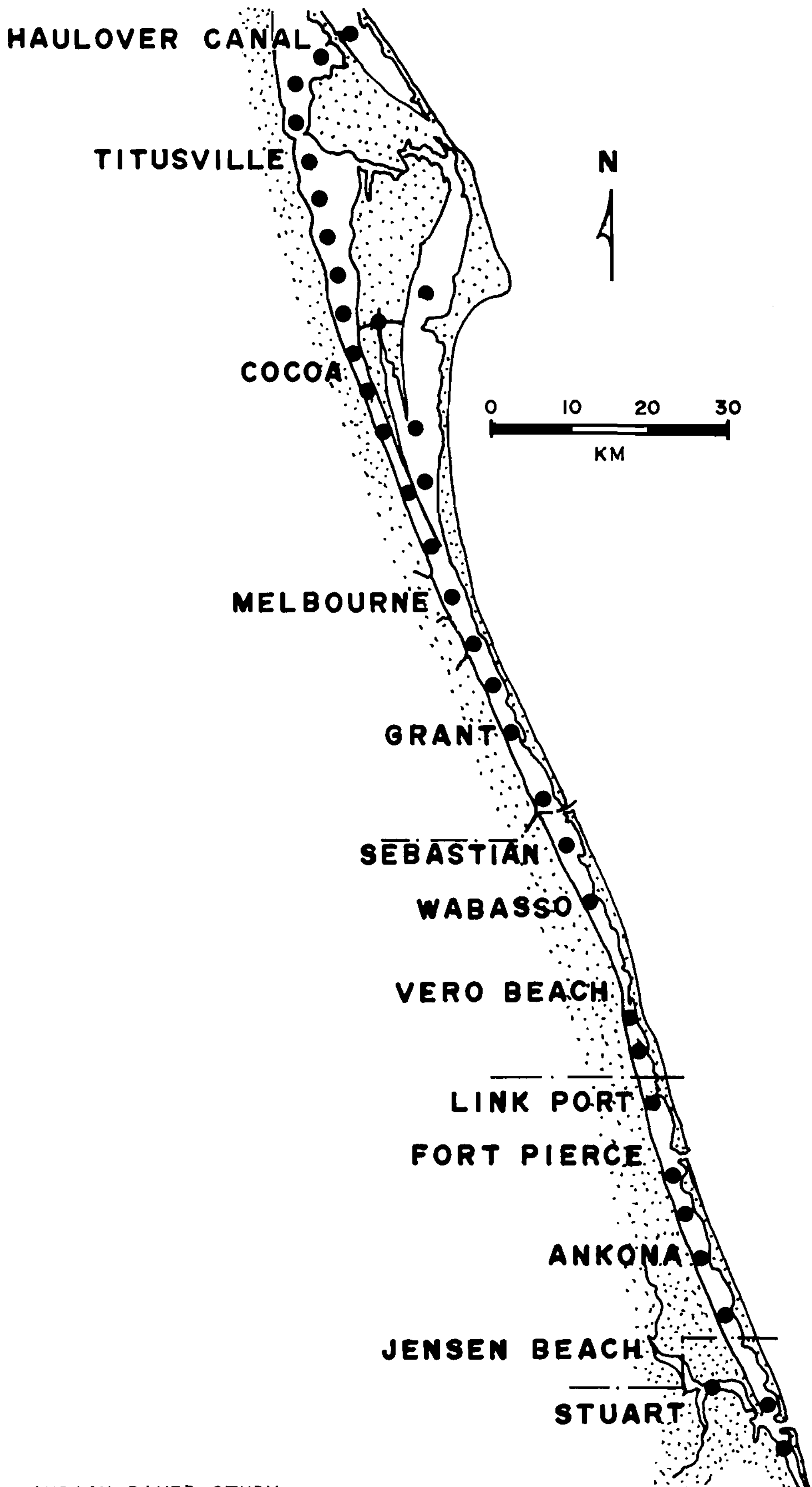


Figure 1: INDIAN RIVER STUDY

KEY MONITORING STATIONS
FOR THE CHEMICAL SURVEY

As an aid inthe interpretation of the chemical data, the Indian River study area was subdivided into seven segments. The location of these regions is shown in Figure 2, and the location of the permanent monitoring stations in each region is shown in Figures 3 -- 9. It is important to note that the choice of these regions was entirely arbitrary, and that there is an intentional degree of overlap between each region and those which adjoin it. The overlap minimizes the possibility of ignoring trends which may occur at the boundaries of a region and ensures a continuity in the data from one region to the next.

Table II lists by region the maximum and minimum values of selected chemical parameters for each of the four chemistry samplings that have been completed since June. Most of the data from the September cruise is still in the process of being reduced, due to a temporary breakdown in the Hewlett-Packard calculator system. Some of the measurements are available, however, so they have been included in Table II.The extended length of time required for sampling the northern end of the Indian River estuary places certain constraints on the cruises. Because of these limitations, Regions VI and VII are sampled on alternate cruises and a footnote to this effect is provided in Table II.

A new feature that was incorporated into the sampling schedule of the September cruise was a 24-hour survey of the tidal-cycle variations in key parameters at the grassflat site just north of the St. Lucie Inlet (see Figure 5). Figure 10 is a record from a portable tide gauge at this 24-hour study site. Future cruises will include similar surveys on four grassflat areas north of this one (see Figures 5 - 7). The primary purpose of these focused studies will be to determine the ecological inter-relationships which exist within the grassflat habitat, and the effects of local pollution upon this habitat type.

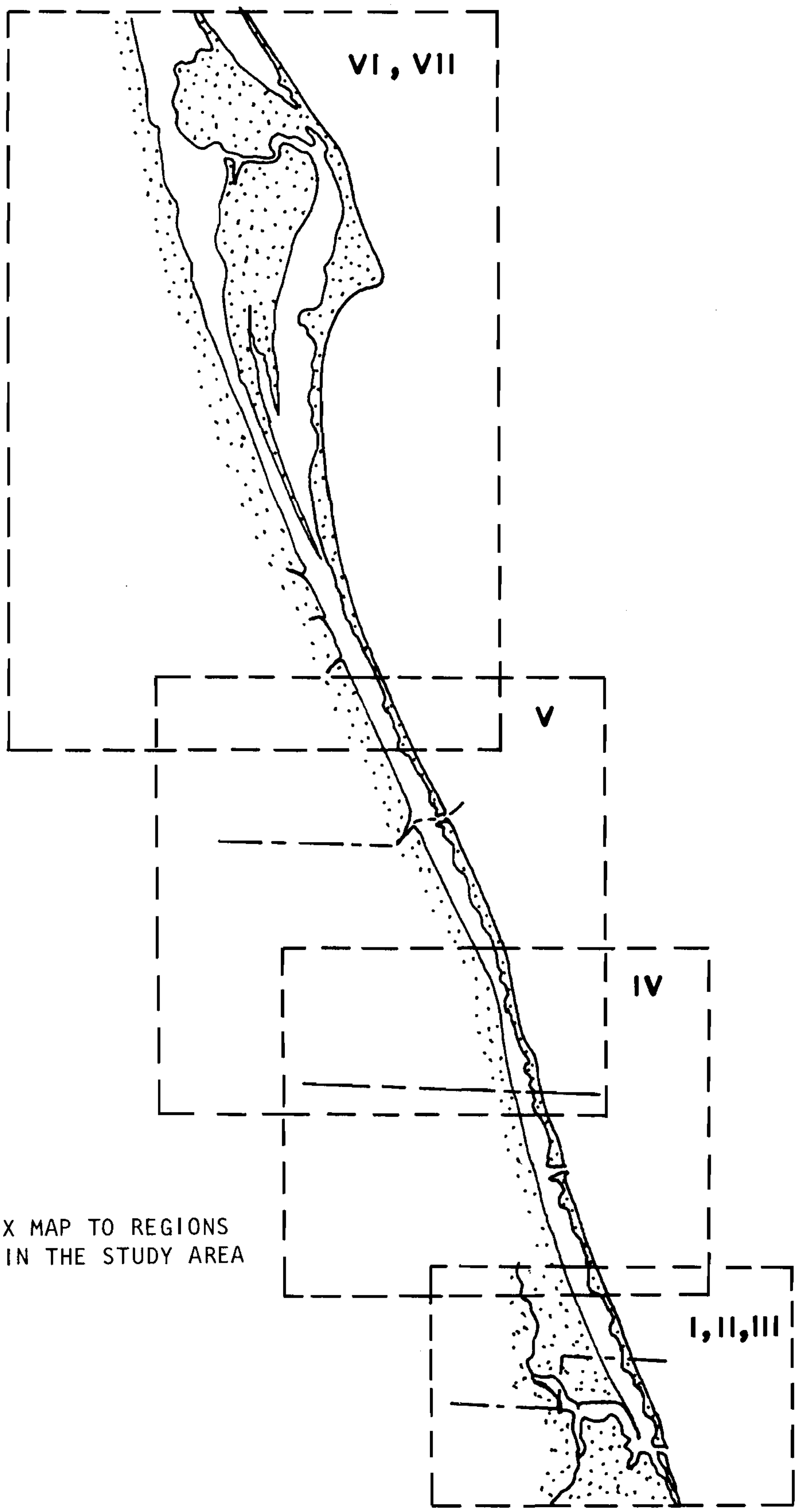


Figure 2: INDEX MAP TO REGIONS WITHIN THE STUDY AREA

Table II. Maximum and minimum values for water quality parameters in the Indian River

Region I: South Fork, St. Lucie River

Parameter	June 1974	July 1974	August 1974	September 1974
Essential Micro-Nutrients:				
Ammonia, µm/l	++	34.8 - 15.8		**
Soluble Nitrate, µm/l		10.8 - 3.5	0.63	**
Soluble o-Phosphate, µm/l		9.5 - 6.6	5.3 - 4.0	**
Soluble Silicate, µm/l		353 - 280	199 - 75	**
Dissolved Metals:				
Calcium, ppm		112 - 14	130 - 70	**
Magnesium, ppm		1200 - 77	371 - 93	**
Sodium, ppm			3400 - 1000	**
Potassium, ppm		192 - 2	197 - 62	**
Strontium, ppm		1.0 - .03	1.3 - .43	**
Lithium, ppm		.23 - .00	.11 - .03	**
Iron, ppb		6204 - 1427	1613 - 966	**
Zinc, ppb		36 - 4	11 - 5	**
Copper, ppb		6.4 - .80	2.6 - 1.4	**
Specific Electrode Parameters:				
Water Temperature, °C		29.5 - 29.0	31.0 - 29.5	26.5 - 26.0
Conductivity, Kmhos/cm^2		12.0 - 0.33	25.0 - 4.60	26.0 - 9.2
Acidity, pH units		7.70 - 7.20	8.20 - 7.90	8.10 - 7.60
Dissolved Oxygen, ppt		5.50 - 3.30	7.70 - 5.20	7.50 - 5.40
Oxidation - Reduction Potential, mv		220 - 160	240 - 230	160 - 140

** Data currently being reduced
++ Stations not sampled on this cruise

Table II (cont'd.)

Region I: (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Major Plant Pigments:				
Chlorophyll a, mg/M^3		12.2 - 3.7	5.9 - 2.6	**
Chlorophyll c, mg/M^3		1.6 - 0.0	3.2 - 2.2	**
Carotenoids, mg/M^3		2.6 - 1.2	1.6 - 0.8	**
Phaeophytins, mg/M^3		12.6 - 4.6	9.2 - 4.9	**
Region II: North Fork, St. Lucie River				
Essential Micro-Nutrients:				
Ammonia, µm/l	++	29.4 - 10.8		**
Soluble Nitrate, µm/l		11.0 - 8.5	0.63	**
Soluble o-Phosphate, µm/l		7.9 - 6.2	6.8 - 4.5	**
Soluble Silicate, µm/l		349 - 260	244 - 75	**
Dissolved Metals:				
Calcium, ppm		112 - 23	130 - 74	**
Magnesium, ppm		923 - 169	371 - 57	**
Sodium, ppm			3400 - 500	**
Potassium, ppm		40 - 4	197 - 26	**
Strontium, ppm		1.0 - .23	1.3 - 0.7	**
Lithium, ppm		.23 - .00	.11 - .03	**
Iron, ppb		4380 - 331	1959 - 966	**
Zinc, ppb		33 - 4	17 - 4	**
Copper, ppb		319 - 0.8	2.4 - 2.2	**

** Data currently being reduced
++ Stations not sampled on this cruise

Table II (cont'd.)

Region II: (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Specific Electrode Parameters:				
Water Temperature, °C	++	30.0 - 29.0	31.0 - 29.5	26.5 - 26.0
Conductivity, Kmhos/cm^2		15.0 - 0.75	25.0 - 3.9	32.0 - 9.0
Acidity, pH units		7.80 - 7.10	8.20 - 7.90	8.20 - 7.50
Dissolved Oxygen, ppt		5.80 - 4.40	7.90 - 5.50	7.80 - 6.30
Oxidation - Reduction Potential, mv		230 - 155	240 - 175	160 - 130
Major Plant Pigments:				
Chlorophyll ^{a}, mg/M^3		18.2 - 5.2	8.9 - 2.6	**
Chlorophyll ^{c}, mg/M^3		1.2 - 0.4	4.0 - 2.2	**
Carotenoids, mg/M^3		3.6 - 1.2	3.6 - .84	**
Phaeophytins, mg/M^3		11.7 - 4.6	13.6 - 5.1	**
Region III: The St. Lucie Inlet				
Essential Micro-Nutrients:				
Ammonia, µm/l	4.1 - 3.3	15.8 - 3.8		
Soluble Nitrate, µm/l		11.0 - 2.0	2.8 - 0.6	**
Soluble o-Phosphate, µm/l	1.7 - 1.5	10.6 - 5.9	4.8 - 1.9	**
Soluble Silicate, µm/l	1.2 - 0.1	260 - 40	123 - 16	**

** Data currently being reduced
++ Stations not sampled on this cruise

Table II (cont'd.)

Region III: (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Dissolved Metals:				
Calcium, ppm	324 - 290	102 - 60	255 - 130	**
Magnesium, ppm	1615 - 1154	785 - 477	986 - 372	**
Sodium, ppm			6800 - 3400	**
Potassium, ppm		353 - 237	432 - 197	**
Strontium, ppm	4.9 - 4.3	1.1 - 0.6	2.8 - 1.3	**
Lithium, ppm		.19 - .11	.27 - .11	**
Iron, ppb	349 - 129	1492 - 732	966 - 505	**
Zinc, ppb	10.1 - 8.4	24 - 13	8.8 - 6.7	**
Copper, ppb		3.2 - 1.3	2.4 - 0.8	**
Specified Electrode Parameters:				
Water Temperature, °C		29.0 - 28.0	30.5 - 29.0	26.5 - 25.5
Conductivity, Kmhos/cm		31.0 - 15.0	48.0 - 25.0	50.0 - 32.0
Acidity, pH units		8.20 - 7.80	8.20 - 7.40	8.20 - 7.50
Dissolved Oxygen, ppt		6.80 - 5.40	7.70 - 6.40	9.00 - 5.50
Oxidation-Reduction Potential, mv		205 - 150	240 - 210	180 - 130
Major Plant Pigments:				
Chlorophyll ^{a}, mg/M^3	9.1 - 1.5	12.7 - 6.1	4.8 - 1.0	**
Chlorophyll ^{c}, mg/M^3		.50 - .00	4.7 - 2.1	**
Carotenoids, mg/M^3		2.3 - 1.5	2.0 - 0.8	**
Phaeophytins, mg/M^3	5.2 - 0.4	6.9 - 6.7	10.5 - 4.3	**

** Data currently being reduced

Table II (cont'd.)

Region IV: Jensen Beach to Vero Beach

Parameter	June 1974	July 1974	August 1974	September 1974
Essential Micro-Nutrients:				
Ammonia, µm/l	25.3 - 2.9	9.8 - 0.3		**
Soluble Nitrate, µm/l		19.3 - 0.8	13.3 - 0.3	**
Soluble o-Phosphate, µm/l	1.9 - 1.4	7.8 - 3.1	20.7 - 2.0	**
Soluble Silicate, µm/l	61.3 - 0.1	288 - 24	234 - 26	**
Dissolved Metals:				
Calcium, ppm	359 - 204	126 - 23	255 - 147	**
Magnesium, ppm	1784 - 846	1062 - 92	986 - 509	**
Sodium, ppm			6800 - 4200	**
Potassium, ppm		43 - 6	432 - 273	**
Strontium, ppm	5.0 - 4.0	1.2 - 0.4	2.8 - 1.5	**
Lithium, ppm		.26 - .17	.27 - .14	**
Iron, ppb	287 - 130	5786 - 455	1498 - 71	**
Zinc, ppb	11.7 - .82	30.0 - 10.9	25.2 - 4.6	**
Copper, ppb		191 - .64	4.2 - .90	**
Specific Electrode Parameters:				
Water Temperature, °C	27.5 - 27.0	30.0 - 28.0	31.0 - 27.5	30.5 - 25.0
Conductivity, Kmhos/cm^2	48.0 - 40.0	40.0 - 19.0	45.0 - 11.0	49.0 - 34.0
Acidity, pH units	8.20 - 8.10	8.30 - 7.00	8.50 - 7.10	8.60 - 7.50
Dissolved Oxygen, ppt	7.70 - 6.50	7.00 - 4.80	8.50 - 5.00	8.40 - 5.50
Oxidation-Reduction Potential, mv	245 - 225	220 - 190	210 - 150	170 - 140

**Data currently being reduced

Table II (cont'd.)

Region IV (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Major Plant Pigments:				
Chlorophyll , mg/M	11.5 - 1.1	16.6 - 2.5	27.1 - 3.0	**
Chlorophyll , mg/M		8.8 - 0.6	10.0 - 1.5	**
Carotenoids, mg/M		4.4 - 0.6	9.2 - .99	**
Phaeophytins, mg/M	10.2 - 0.2	14.9 - 1.4	26.5 - 7.2	**
Region V: Link Port to Stuart				
Essential Micro-Nutrients:				
Ammonia, µm/l	0.9 - 0.2	3.3 - 0.2		**
Soluble Nitrate, µm/l	1.1 - .05	19.3 - 1.0	0.4 - 0.2	**
Soluble o-Phosphate, µm/l	3.1 - 1.6	6.4 - 5.8	5.0 - 3.8	**
Soluble Silicate, µm/l	24 - 9.1	242 - 66	155 - 70	**
Dissolved Metals:				
Calcium, ppm	340 - 280	112 - 79	220 - 147	**
Magnesium, ppm	1180 - 952	969 - 646	848 - 509	**
Sodium, ppm	11400 - 8620		5800 - 4200	**
Potassium,ppm	584 - 488	406 - 316	344 - 230	**
Strontium, ppm	9.9 - 9.3	1.2 - .77	2.7 - 1.7	**
Lithium, ppm	.34 - .26	.24 - .17	.23 - .16	**
Iron, ppb	605 - 238	5785 - 566	197 - 34	**
Zinc, ppb	17 - .88	40 - 9.1	47 - 6.9	**
Copper, ppb		191 - .62	2.9 - .37	**

**Data currently being reduced

Table II (cont'd.)

Region V (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Specific Electrode Parameters:				
Water Temperature, °C	27.5 - 26.0	30.0 - 28.0	31.5 - 29.8	30.5 - 29.0
Conductivity, Kmhos/cm^2	50.0 - 39.0	28.0 - 19.0	30.0 - 11.0	41.0 - 34.0
Acidity, pH units	8.20 - 8.00	8.20 - 7.80	8.50 - 8.10	8.30 - 7.50
Dissolved Oxygen, ppt	7.70 - 5.60	7.70 - 4.80	9.40 - 5.50	10.40 - 5.50
Oxidation-Reduction Potential, mv	250 - 230	220 - 200	230 - 150	
Major Plant Pigments:				
Chlorophyll ^{a}, mg/M^3	10.8 - 9.1	17.6 - 7.2	27.1 - 4.2	**
Chlorophyll ^{c}, mg/M^3		9.1 - 3.9	15.2 - 3.2	**
Carotenoids, mg/M^3		4.7 - 1.2	9.4 - 2.5	**
Phaeophytins, mg/M^3	8.7 - 7.5	14.9 - 6.2	21.9 - 8.4	**
Region VI: Grant to Haulover Canal				
Essential Micro-Nutrients:				
Ammonia, µm/l	1.7 - 0.2	0.4 - 0.3		**
Soluble Nitrate, µm/l	0.9 - .04	6.4 - 1.0	0.8 - 0.4	**
Soluble o-Phosphate, µm/l	5.2 - 0.8	7.4 - 5.1	2.5 - 1.3	**
Soluble Silicate, µm/l	19.6 - 8.5	131 - 74	52 - 17	**

** Data currently being reduced

Table II (cont'd.)

Region VI (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Dissolved Metals:				
Calcium, ppm	346 - 280	121 - 93	226 - 197	**
Magnesium, ppm	1150 - 910	892 - 708	801 - 671	**
Sodium, ppm	1010 - 819		5500 - 4800	**
Potassium, ppm	629 - 491	383 - 331	334 - 291	**
Strontium, ppm	10.8 - 1.0	3.1 - .95	2.7 - 2.4	**
Lithium, ppm	.40 - .27	.23 - .18	.22 - .18	**
Iron, ppb	659 - 88	4000 - 169	297 - 102	**
Copper, ppb		170 - 0.4	2.8 - 1.82	**
Specific Electrode Parameters:				
Water Temperature, °C	27.6 - 25.5	32.0 - 27.5	31.5 - 30.0	30.0 - 27.0
Conductivity, Kmhos/cm^2	44.0 - 39.0	38.0 - 21.0	37.0 - 31.0	32.0 - 24.0
Acidity, pH units	8.50 - 7.90	8.60 - 8.10	8.60 - 8.40	8.70 - 8.00
Dissolved Oxygen, ppt	7.90 - 5.80	10.10 - 5.90	7.70 - 5.70	10.40 - 6.90
Oxidation-Reduction Potential, mv	210 - 190	280 - 220	240 - 200	170 - 160
Major Plant Pigments:				
Chlorophyll ^{a}, mg/M^3	5.6 - 0.6	12.2 - 1.5	15.9 - 2.9	**
Chlorophyll ^{c}, mg/M^3		10.2 - 2.4	11.1 = .91	**
Carotenoids, mg/M^3		4.6 - 0.7	6.1 - 1.4	**
Phaeophytins, mg/M^3	10.6 - 1.9	13.1 - 2.1	19.5 - 4.12	**

**Data currently being reduced

Table II (cont'd.)

Region VII: Banana River Stations

Parameter	June 1974	July 1974	August 1974	September 1974
Essential Micro-Nutrients:				
Ammonia, μm/l	1.7 - 0.3	0.4 - 0.3	++	**
Soluble Nitrate, μm/l	0.9 - .04	22.4 - 1.0		**
Soluble o-Phosphate, μm/l	5.2 - 1.6	7.0 - 2.9		**
Soluble Silicate, μm/l	196 - 107	132 - 73		**
Dissolved Metals:				
Calcium, ppm	317 - 287	107 - 65		**
Magnesium, ppm	1150 - 968	815 - 692		**
Sodium, ppm	1010 - 841			**
Potassium, ppm	61 - 50	36 - 32		**
Strontium, ppm	1.1 - 0.8	3.1 - 1.1		**
Lithium, ppm	.38 - .31	.21 - .18		**
Iron, ppb	3030 - 1830	4000 - 253		**
Zinc, ppb	21 - 7	48 - 15		**
Copper, ppb		64 - .37		**
Specific Electrode Parameters:				
Water Temperature, °C	28.0 - 25.6	30.5 - 28.5		30.0 - 26.5
Conductivity, Kmhos/cm^2	48.5 - 39.0	36.0 - 21.0		34.0 - 25.0
Acidity, pH units	8.10 - 8.00	8.60 - 8.00		8.40 - 8.00
Dissolved Oxygen, ppt	7.20 - 5.30	9.30 - 6.10		10.4 - 5.90
Oxidation-Reduction Potential, mv	250 - 180	270 - 220		180 - 160

** Data currently being reduced
++ Stations not sampled on this cruise

Table II (cont'd.)

Region VII (cont'd.)

Parameter	June 1974	July 1974	August 1974	September 1974
Major Plant Pigments:				
Chlorophyll a, mg/M^3	9.2 - 5.2	15.4 - 2.1	++	**
Chlorophyll, c, mg/M^3		10.2 - 1.8		**
Carotenoids, mg/M^3		5.1 - 0.9		**
Phaeophytins, mg/M^3	16.3 - 7.2	14.4 - 2.9		**

** Data currently being reduced
++ Stations not sampled on this cruise

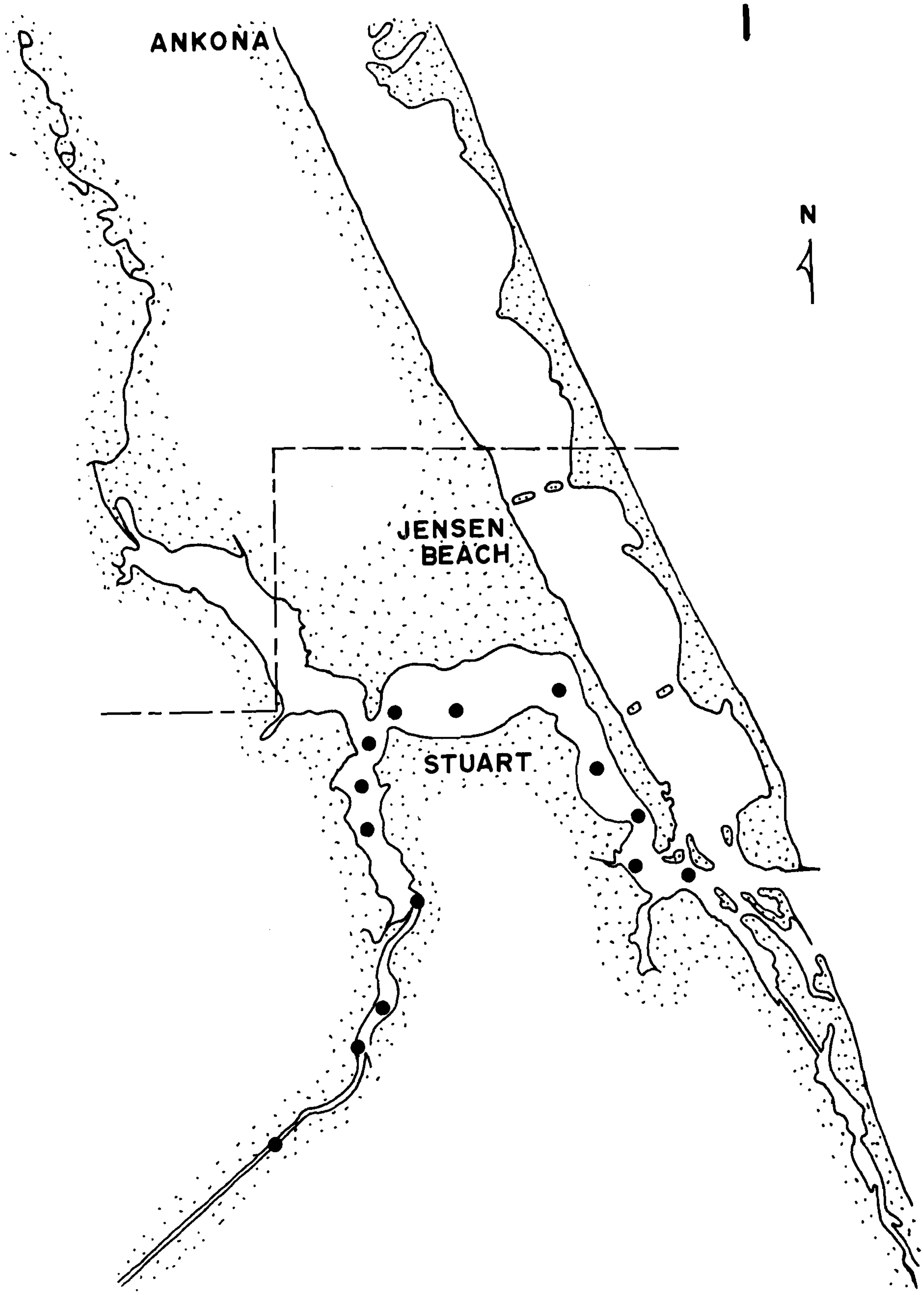


Figure 3: REGION I:
South Fork, St. Lucie River

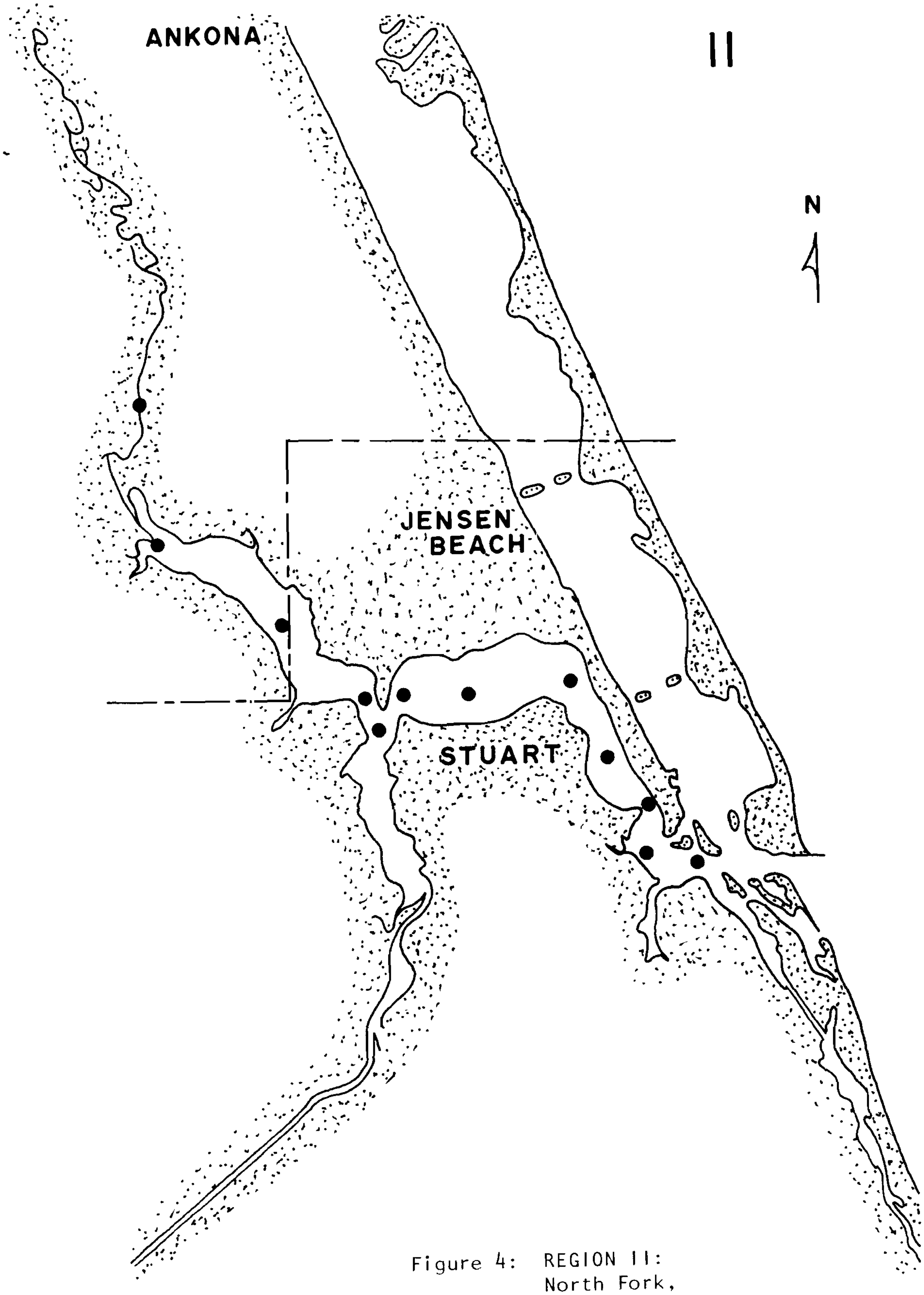


Figure 4: REGION II:
North Fork,
St. Lucie River

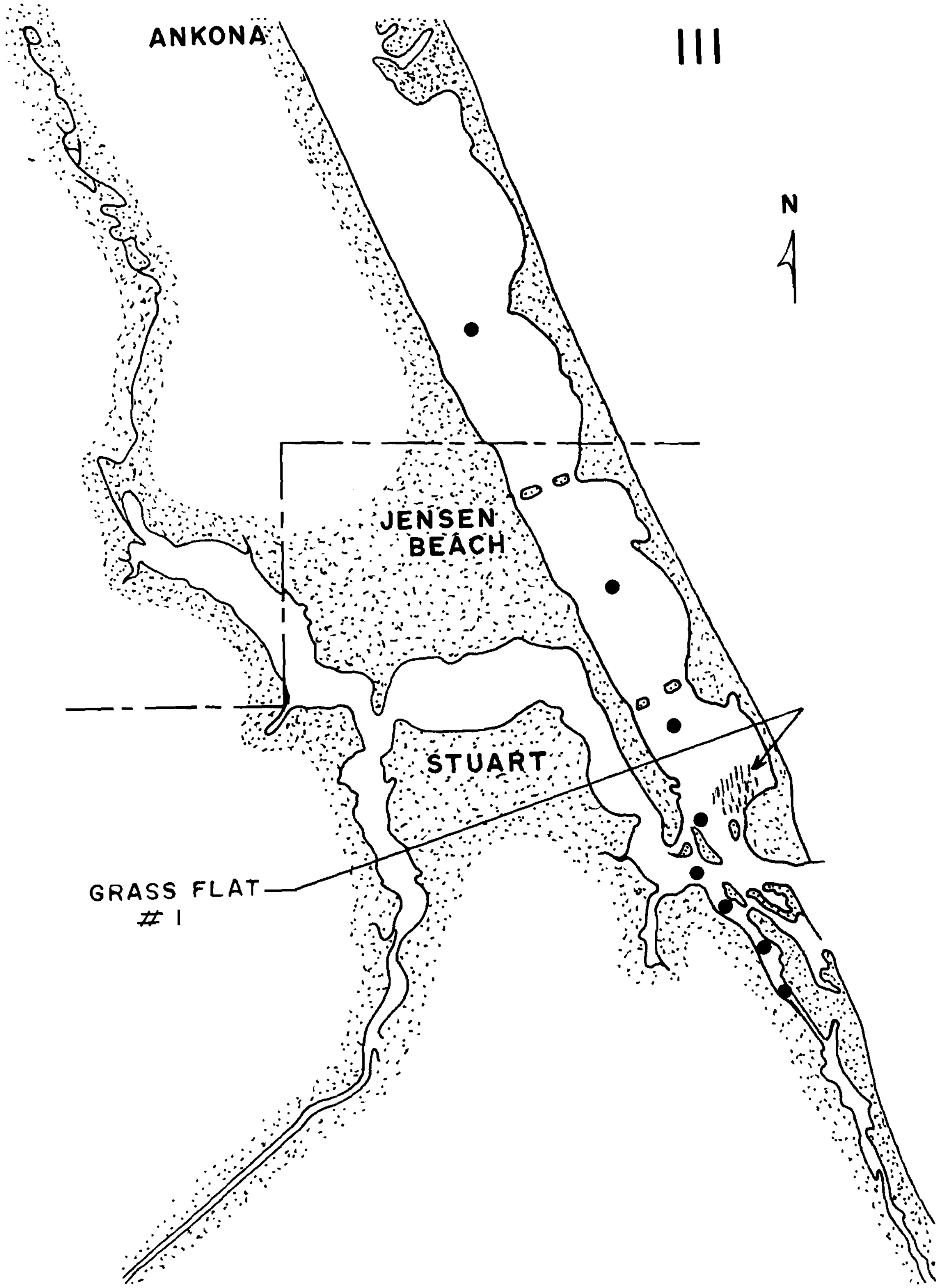


Figure 5: REGION III:
The St. Lucie Inlet

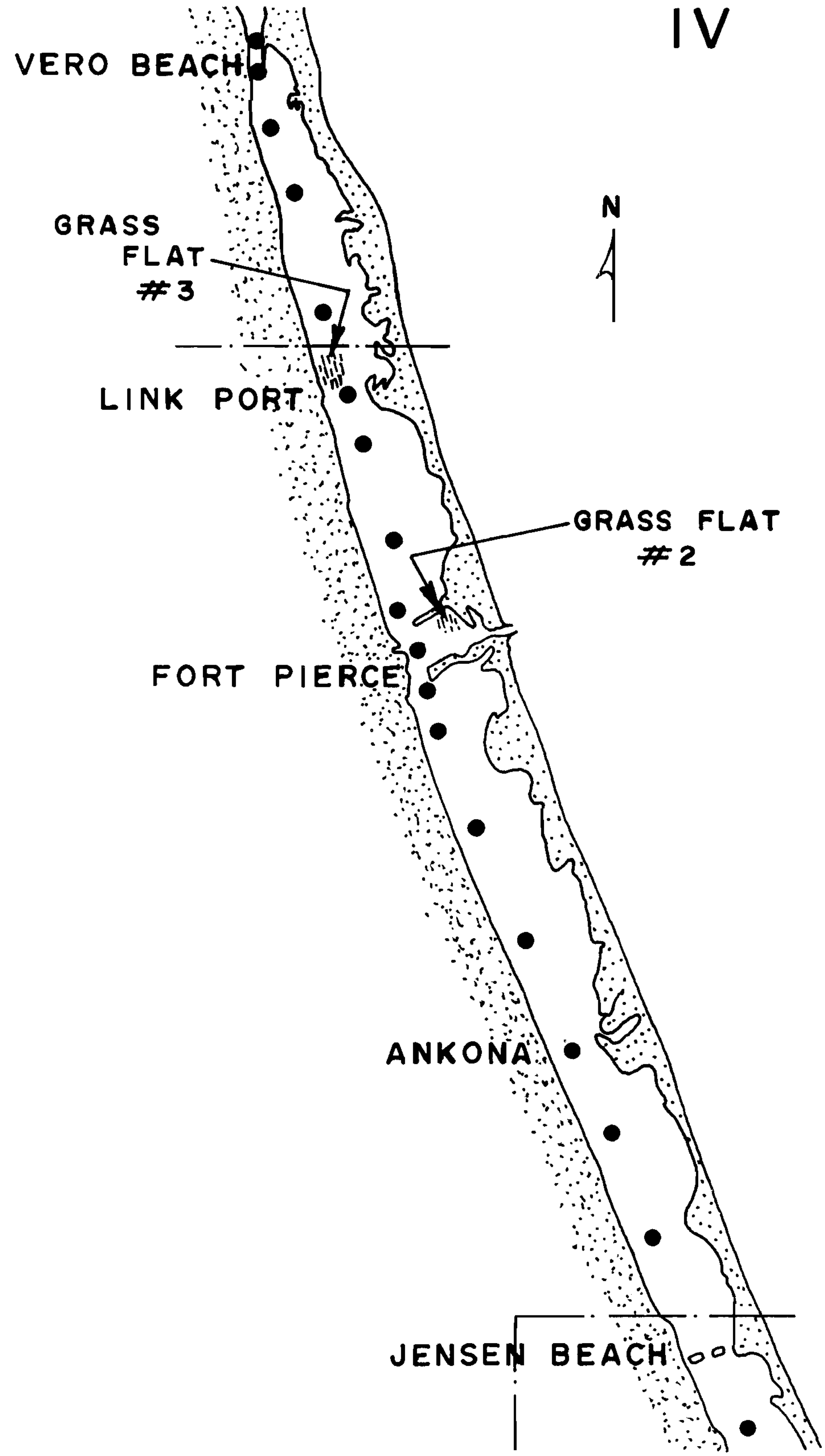


Figure 6: REGION IV:
Jensen Beach to
Vero Beach

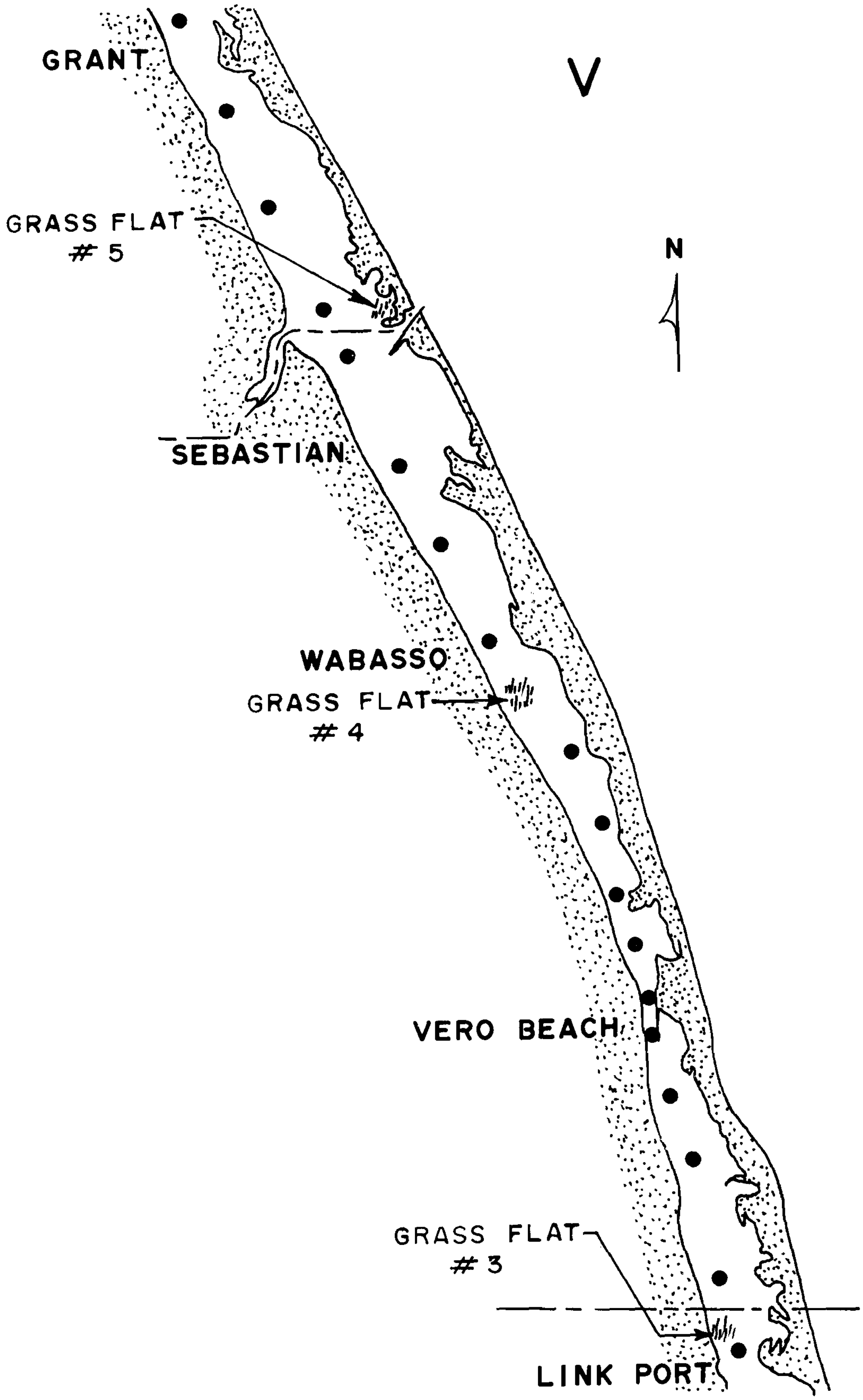


Figure 7: REGION V:
Link Port to grant

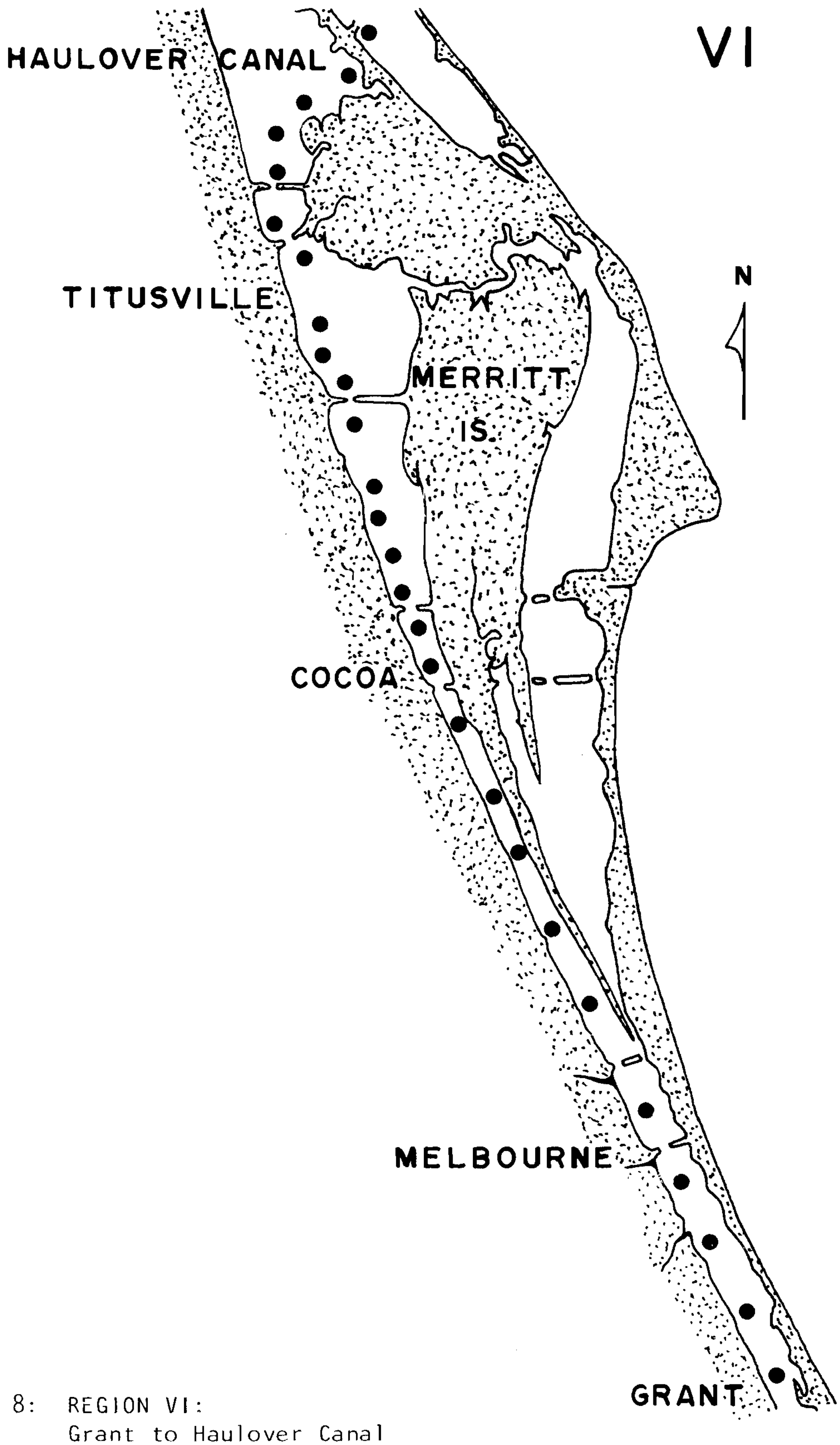


Figure 8: REGION VI:
Grant to Haulover Canal

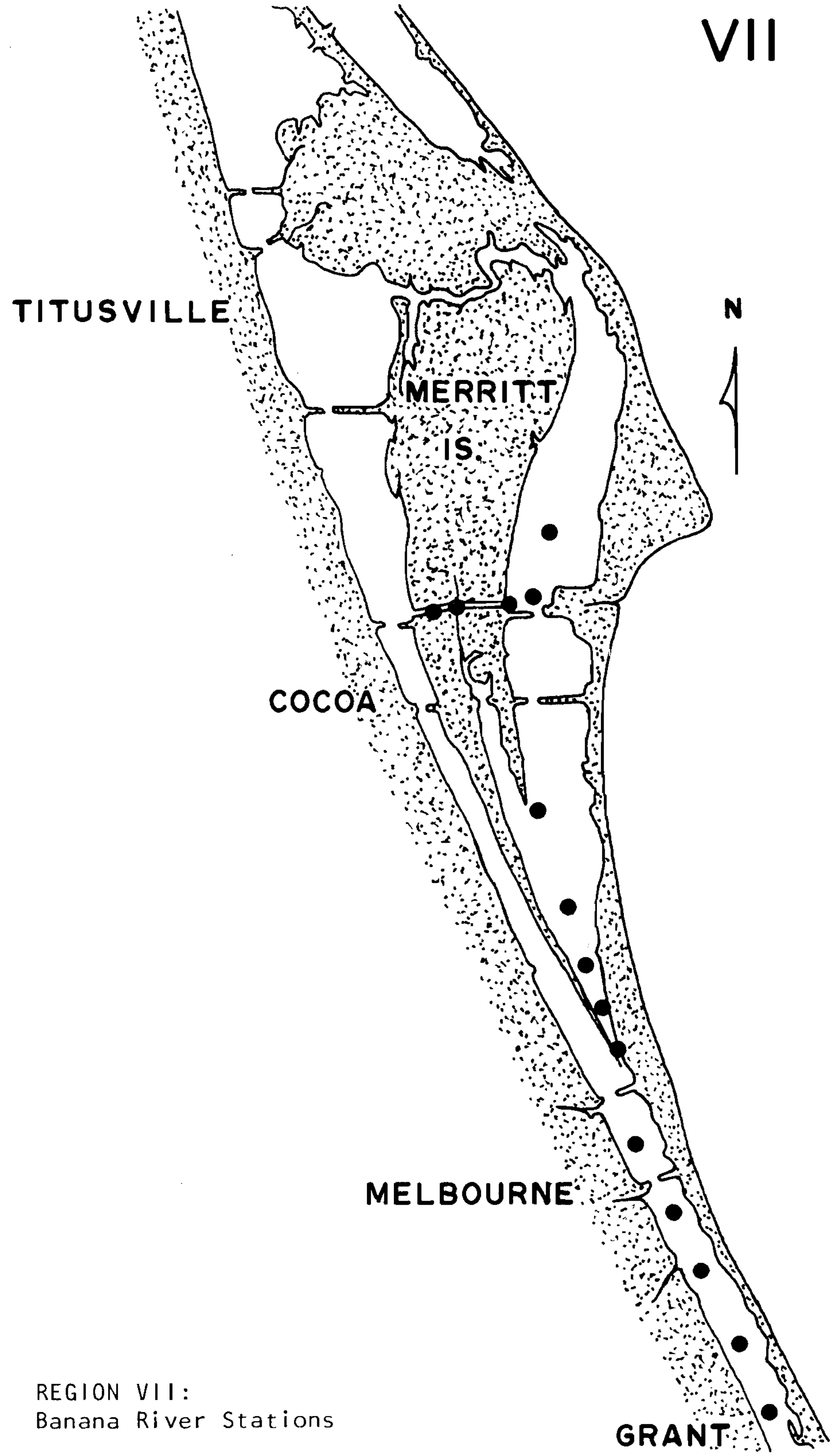


Figure 9: REGION VII:
Banana River Stations

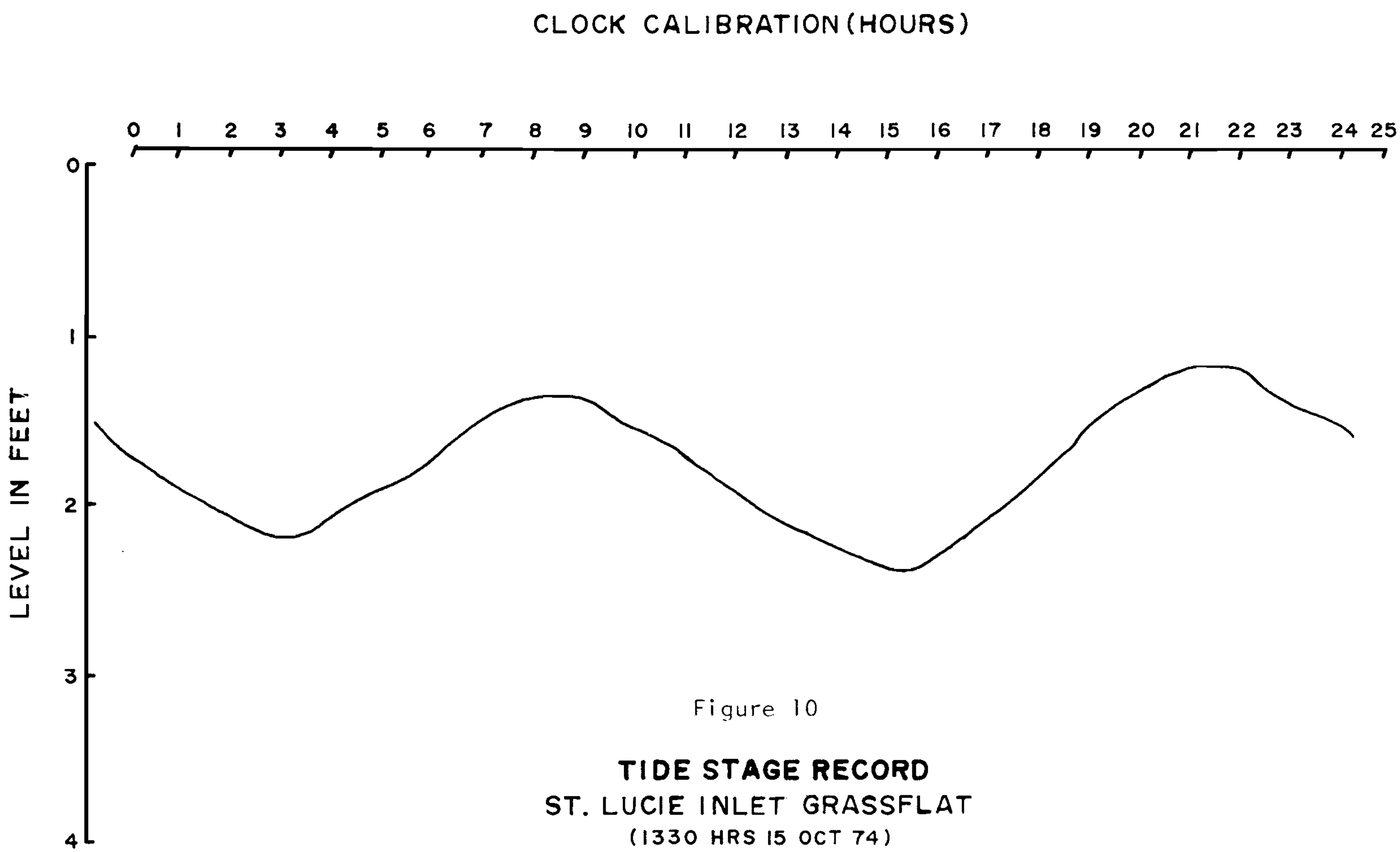


Figure 10

TIDE STAGE RECORD
ST. LUCIE INLET GRASSFLAT
(1330 HRS 15 OCT 74)

Appendix I presents the variation of selected chemical parameters in Region IV for the July cruise. Visual correlation between parameters is facilitated by the graphical mode of presentation. More involved statistical analysis is currently underway to determine the more complex inter-relationships involved in seasonal and areal trends. At this point it would be premature to speculate on long-range variations in water quality except to state that the Indian River may indeed be one of the last relatively unpolluted coastal lagoons in Florida.

II. Phytoplankton studies

Knowledge of the dominant species of phytoplankton, their relative abundance, their occurrence, and their physiological state is essential to the overall evaluation of water quality. Because of their small size, their rapid reproductive rates, and hence, their rapid response to environmental changes, phytoplankters are among the first organisms to be affected by environmental pollution. As primary producers in aquatic food chains, changes in species composition and numbers of phytoplankters are felt throughout the ecosystem.

To date, only a few isolated studies have been made of the phytoplankton in the Indian River region, and the important aspects of temporal and areal changes of the dominant phytoplankters have not been collated. Therefore, a study of phytoplankton became an important part of the water quality studies of the Indian River Study.

Methods

Chlorophyll measurements were initiated on the houseboat cruise of April 11, 1974, and since that time, approximately 400 surface water samples have been collected and analyzed for chlorophyll content. These samples have also been analyzed for dissolved oxygen, temperature, salinity, chlorinity, and acidity by methods given in Section I. Phytoplankton identifications and enumerations were carried out on 53 of these samples. The amount of chlorophyll, abundance of phytoplankters, and species composition of the phytoplankton populations have been examined from the viewpoint of seasonality of occurrence and regional distribution within the estuary.

The initial measurements of chlorophyll were made without correction for phaeopigments (i.e., degredation products of chlorophyll from dead, or dying, plants), which are predominately phaeophytin and phaeophorbide. However, after observing a great many empty diatom frustules of the benthic type, especially during periods of turbulence due to winds and rainfall, it was realized that a significant percentage of the chlorophyll measured was not living or active. Thus, the estimates of the amount of primary production in the estuary were probably erroneously high. Therefore, in the latter part of May the procedure for the determination of chlorophyll "a" was modified to correct for phaeopigments (4).

Water samples are presently being filtered through a 0.45μ Millipore filter membrane at the time of collection, and a suspension of magnesium carbonate is added to the last few milliliters of sample to pass through the filter. Magnesium carbonate serves as a buffer and prevents breakdown of the chlorophyll. The filter membranes are placed in centrifuge tubes, frozen, and returned to Link Port for analysis. Samples are warmed in the dark to room temperature and then 10 milliliters of 90% reagent acetone are added to each. The samples are agitated and the extraction of the pigments is allowed to proceed for 24 hours in the refrigerator; after which the samples are centrifuged for 15 to 20 minutes at 3000 revolutions per minute. The clear supernatant is decanted into a 5 centimeter spectrophotometer cell and the extinction is measured against a matched cell containing the supernatant from a blank filter membrane which has been treated in the same manner as the sample filters. The samples are measured at 750, 665, 645, 510 and 480 nanometers; then, they are acidified with two drops of 6-n HCl and allowed to react for 5 minutes to remove the magnesium from the porphyrin ring of the chlorophyll molecule, and the extinction is measured again at 665 nanometers.

For the phytoplankton population studies, samples were initially collected on 0.45μ Millipore filter membranes, dried and cleared with immersion oil, and then examined microscopically. Unfortunately, this procedure was found to give erroneous results because only the less fragile diatom cells remained intact. The more delicate cells, expecially the green flagellates which had been noted from wet mounts at the time of sampling, appeared as unrecognizable masses on the dried filter membranes. The sampling procedure was changed to the "settling tube technique" of Dodson and Thomas (2), and modified according to the suggestions of Mr. Robert Gibson and Dr. Thomas Hopkins of the University of South Florida. This technique has been found to work well for collecting and concentrating the organisms in the samples, and the data obtained by this method are more comprehensive than those obtained by the earlier technique. The samples are preserved aboard ship with mercuric chloride and kept under refrigeration until the time of examination. An inverted microscope is used at 1000 power magnification for qualitative examination and at 400 power magnification for quantitative enumeration.

Mr. Gibson also suggested the addition of dissolved humic color to the list of parameters being monitored by the Indian River Study. He believes that humic color, as a naturally occurring tracer of freshwater influx, will yield a better understanding of mixing patterns in the estuary than can be obtained through the examination of silicate and salinity data alone (3). The humic color parameter may also serve as an independent check on the mixing volumes obtained by the uranium isotopes technique.

Results

Phytoplankton organisms in the Indian River estuary are not homogeneously distributed, as revealed by differences both in the concentration of chlorophyll "a" (Figure 11) and in the plankton counts (Figure 12). Blooms, i.e., concentrations of organisms greater than 10^5 cells per cubic meter, are patchy in occurrence and the dominant species change from one area to another. As might be expected in an estuarine basin, both freshwater and oceanic phytoplankton species have been identified in the Indian River (Table III). A seasonal succession of species has also been observed at certain stations. For example, in Taylor Creek the dominant species noted in April was *Skeletonema costatum*, a cylindrical chain-forming diatom; this species was replaced in May and June by several species of benthic and pelagic diatoms, which in turn were replaced in September by naked green flagellates. Likewise, at a station in the River near Linkport, *Skeletonema costatum* was the dominant species in April, followed by benthic and pelagic pinnate diatoms in May and June, with *Skeletonema costatum* regaining dominance in early September. Such changes in phytoplankton populations appear to be related, in part, to wind-generated turbulence which brings benthic diatoms to the surface.

Numbers of organisms also varied during the period studied, as shown in Table IV. Phytoplankton populations were found to be high in regions with a correspondingly high content of dissolved oxygen. Overall production

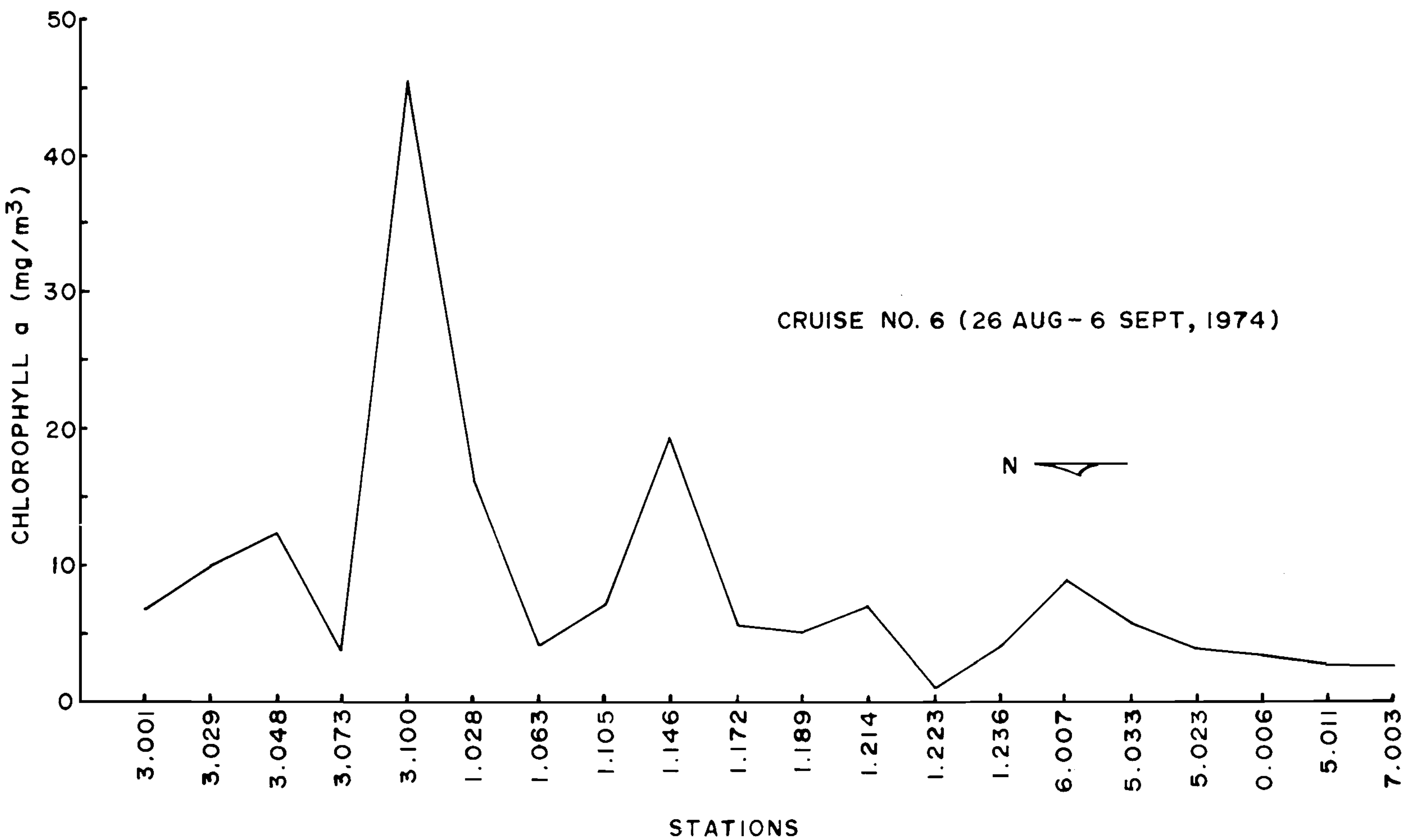

CRUISE NO. 6 (26 AUG - 6 SEPT, 1974)
N
CHLOROPHYLL a (mg/m³)
0
10
20
30
40
50
3.001
3.029
3.048
3.073
3.100
1.028
1.063
1.105
1.146
1.172
1.189
1.214
1.223
1.236
6.007
5.033
5.023
0.006
5.011
7.003
STATIONS

FIG. 11

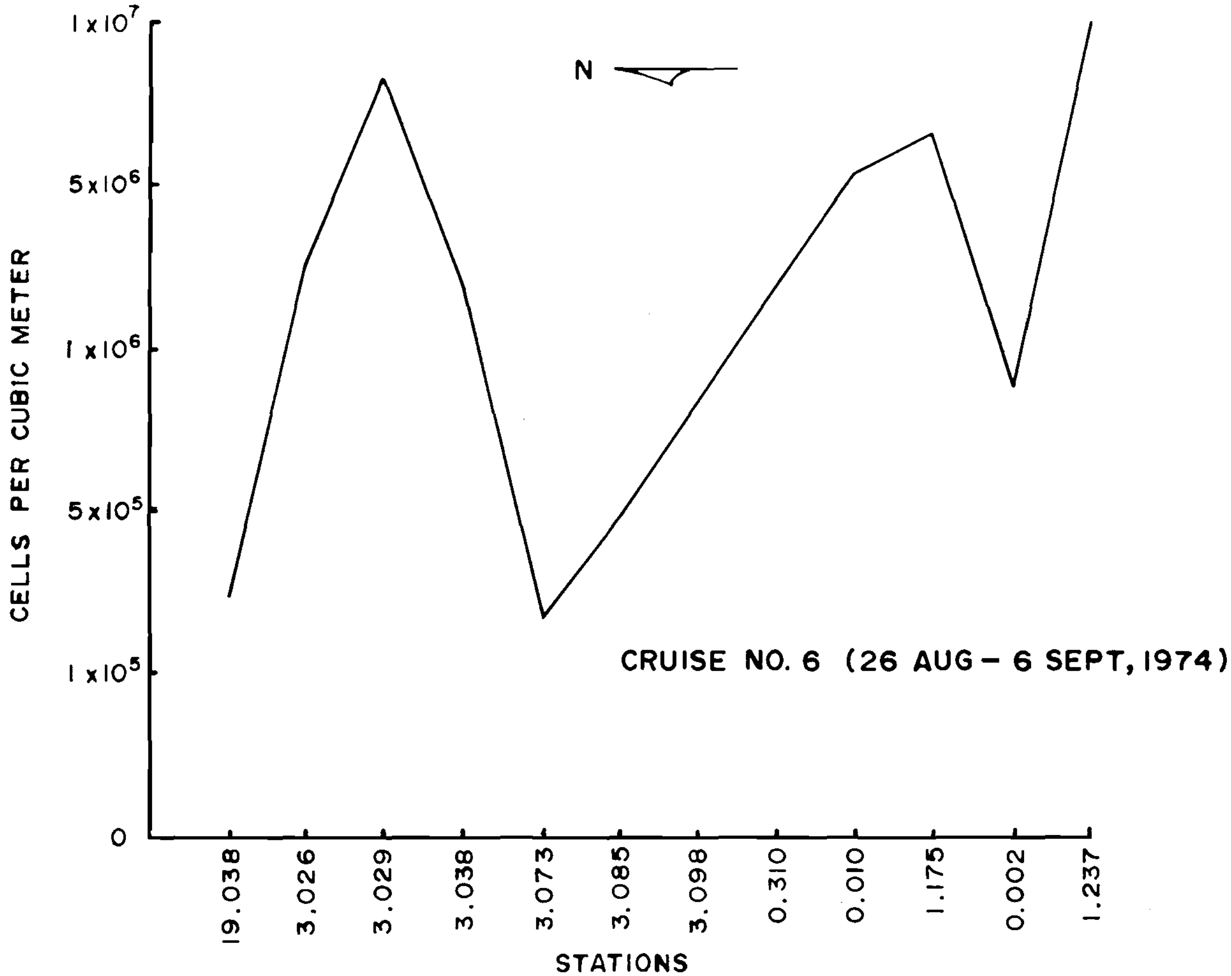

1 x 10^7
5 x 10^6
1 x 10^6
5 x 10^5
1 x 10^5
0
CELLS PER CUBIC METER
N
CRUISE NO. 6 (26 AUG – 6 SEPT, 1974)
19.038
3.026
3.029
3.038
3.073
3.085
3.098
0.310
0.010
1.175
0.002
1.237
STATIONS

FIG. 12

Table III. Dominant Phytoplankton Species in the Indian River Estuary April - September 1974.

Bacillariophyceae (Diatoms)

Amphora sp. a, b
Asterionella japonica
Biddulphia aurita
Ceratulina pelagica
Chaetoceros affinis
Chaetoceros didymum ?
Coccinodiscus sp.
Coscinosira sp.
Cyclotella sp.
Eupodiscus radiatus
Grammatophora marina ?
Gyrosigma sp.
Melosira sp.
Navicula several species
Nitzchia closterium
Nitzchia longissima
Nitzchia pugens
Pleurosigma sp.
Rhizosolenia setigera
Skeletonema costatum
Thalassionema nitzchioides ?
Thalassiosira sp. a,b
Unidentified "Pennate" forms

Chlorophyceae (grass-green algae)

**Scenedesmus* sp.
**Schroederia* sp.
*Volvocales
*Unidentified species of family Chlorococcaceae - 8 to 10 species

Chrysophyceae (golden-brown flagellates)

**Ochromonas* sp.

Cyanophyceae (Blue-green algae)

**Anabaena* sp.
**Nodularia* sp.
**Oscillatoria* sp.
**Trichodesmium* sp.

Dinophyceae (Dinoflagellates)

Ceratium sp.
Dictyochia sp.
Dinophysis sp.
Distephanus sp.
Gonyaulax sp.
Gymnodinium sp.
Peridinium sp.
Prorocentrum micans ?

Eugleninaea (Euglenoid Flagellates)

**Euglena* sp.
**Phacus* sp.

Green Flagellates (Motile single cells)

Unidentified forms

*Primarily freshwater organism.

Table IV. Seasonal Variations in Numbers of Diatoms**

April - May	129 - 255 cells/100 fields
June - July	$2.0 \times 10^5 = 2.6 \times 10^6$ live cells/liter
August - September	$2.55 \times 10^5 - 2.70 \times 10^7$ cells/meter^3

**Different units for population enumeration resulted from the different techniques employed for sample collection.

of phytoplankton in the estuary reached its peak in late August, as indicated by the highest concentrations of chlorophyll "a" measured on the fourth cruise.

Future cruises will include 24-hour surveys of phytoplankton populations at five grassflat areas in the Indian River. These stations will be examined from the viewpoint of variations of phytoplankton populations with water depth, temperature, salinity, dissolved oxygen and other chemical parameters throughout a complete tidal cycle.

It is the aim of this part of the Indian River Study to work in cooperation with other planktology researchers in the State, for example, Thomas Hopkins and Robert Gibson of the University of South Florida, and Karen Steidinger of the St. Petersburg Laboratory of the Department of Natural Resources, so that the data generated by this project will be comparable to that from other areas and than an overall view of the role of phytoplankton as primary producers in Florida waters can be obtained.

SUMMARY

At the close of the first year of the Indian River Study, five months' chemical data is on file for fifty-two different water quality parameters. A total of 110 stations in the Indian River Study area have been sampled to produce 12,000 individual pieces of data. Computer storage, correlation, and retrieval of this data are in progress, and the beginning of seasonal and areal variations in these parameters is being observed. More involved statistical analysis is also underway to determine the more subtle inter-relationships within this suite of data. An attempt at mathematical modeling of this ecosystem would indeed be premature with less than a single year's backlong of chemical data.

However, the following empirical observations on the phytoplankton studies are worth noting:

The concentration of chlorophyll "a" in the study area during the past five months has ranged from 1 - 46 milligrams per cubic meters, reaching its peak in late August and early September. The average concentration of chlorophyll "a" plus phaeopigments during this time was 21 milligrams per cubic meter, which is almost twice the value reported for the Anclote River (13 mg/M^3), and three times the average value reported for the Gulf of Mexico (7 mg/M^3) in 1971 (1). Phytoplankton organisms in the Indian River estuary are not homogeneously distributed, as revealed by differences both in the concentration of chlorophyll "a" and in the plankton counts. Maximum species diversity occurred during periods of greatest water turbulence, due to wind action which brought benthic forms to the surface. Skeletonema costatum was the most ubiquitous species in the study area from May to September, and it may be the dominant form during periods of relative quiescence.

PERSONNEL

Mr. James M. Fyler joined the staff of the Indian River Study in October 1973; he has been employed by the Harbor Branch Foundation as an analytical chemist for several years. Mr. Fyler has a Master of Science degree in analytical chemistry from Purdue University, where he did research in applied vibrational and atomic spectroscopy and completed an evaluation of sources for inverse-Raman spectroscopy. On the Indian River Study Mr. Fyler has served in the capacity of research assistant and laboratory supervisor, and he has been responsible for the implementation of instrumented analytical techniques and for the modification of published methods to suit the highly variable concentration ranges of the environmental parameters being surveyed. He has also been responsible for the reduction of the raw instrumental readings to suitable concentration data using the Hewlett-Packard 9820A calculator system. Mr. Fyler has served as chief scientist on many of the recent chemistry cruises of the R/V Casa Aqua.

Mr. Michael Y. Laffey joined the staff of the Indian River Study in October 1973; previously, he had been employed by the United States Geological Survey as a laboratory technician assigned to water quality studies. Mr. Laffey has an Associate of Arts degree from Central Florida Community College and has completed some additional coursework toward his Bachelor's degree. On the Indian River Study, Mr. Laffey has been responsible for running many of the nutrient analyses on the auto-analyzer instrumentation system aboard the R/V Casa Aqua and he has been a working scientist on many of the houseboat cruises. Mr. Laffey has also performed additional laboratory analyses at Link Port and has had experience in the field collection of water samples from wells, lakes, canals and streams. Mr. Laffey is a talented draftsman and is responsible for many of the drawings and figures which appear in this report.

Mr. Jeffrey T. Paxton joined the staff of the Indian River Study in April 1974; previously, he had been employed by Worthington Biochemical Corporation as a senior laboratory technician assigned to an analytical methods development group. Mr. Paxton has a Bachelor of Arts degree in biology from Southampton College, Southampton, New York. On the Indian River Study, Mr. Paxton has been responsible for running many of the dissolved metal analyses, for processing the uranium isotopes samples, and for assisting with many of the onboard operations of the houseboat cruises. He has also assisted in the modification of many of the auto-analyzer techniques to suit the particular needs of this project. His industrial background in the development of new analytical techniques in the field of gas chromatography prove useful as the chemical survey begins to examine the study area for organic pollutants.

Ms. F. Carol Stephens joined the staff of the Indian River Study in February 1974; previously, she had been employed by the Olin Corporation as a laboratory technician in the analytical section of the quality control department. Ms. Stephens has a Bachelor of Science degree in biology from the Florida State University, where she has also performed marine research in the Department of Oceanography. On the Indian River Study Ms. Stephens has been responsible for all work involving the phytoplankton studies, and she is the author of Section II of this chapter. She has been responsible for consulting with authorities in this field and for the modification and development of improved methods for phytoplankton analysis which are being applied in the Indian River Study. She has participated in most of the cruises of the R/V Casa Aqua and has assisted with the measurement of onboard chemical parameters.

Mr. David R. Yonge served the Indian River Study on an eight-week summer internship which was sponsored by the Link Foundation. He was given the opportunity to perform many different types of chemical analysis and gained experience with instrumented techniques used in the assay of water quality. Mr. Yonge also participated in two of the houseboat cruises and in several of the field sampling trips. Mr. Yonge is a senior undergraduate student at the Florida Institute of Technology, Jensen Beach campus, and has returned to school this fall to complete his Bachelor's degree. His internship on the Indian River Study should prove valuable experience to him in his career in oceanography.

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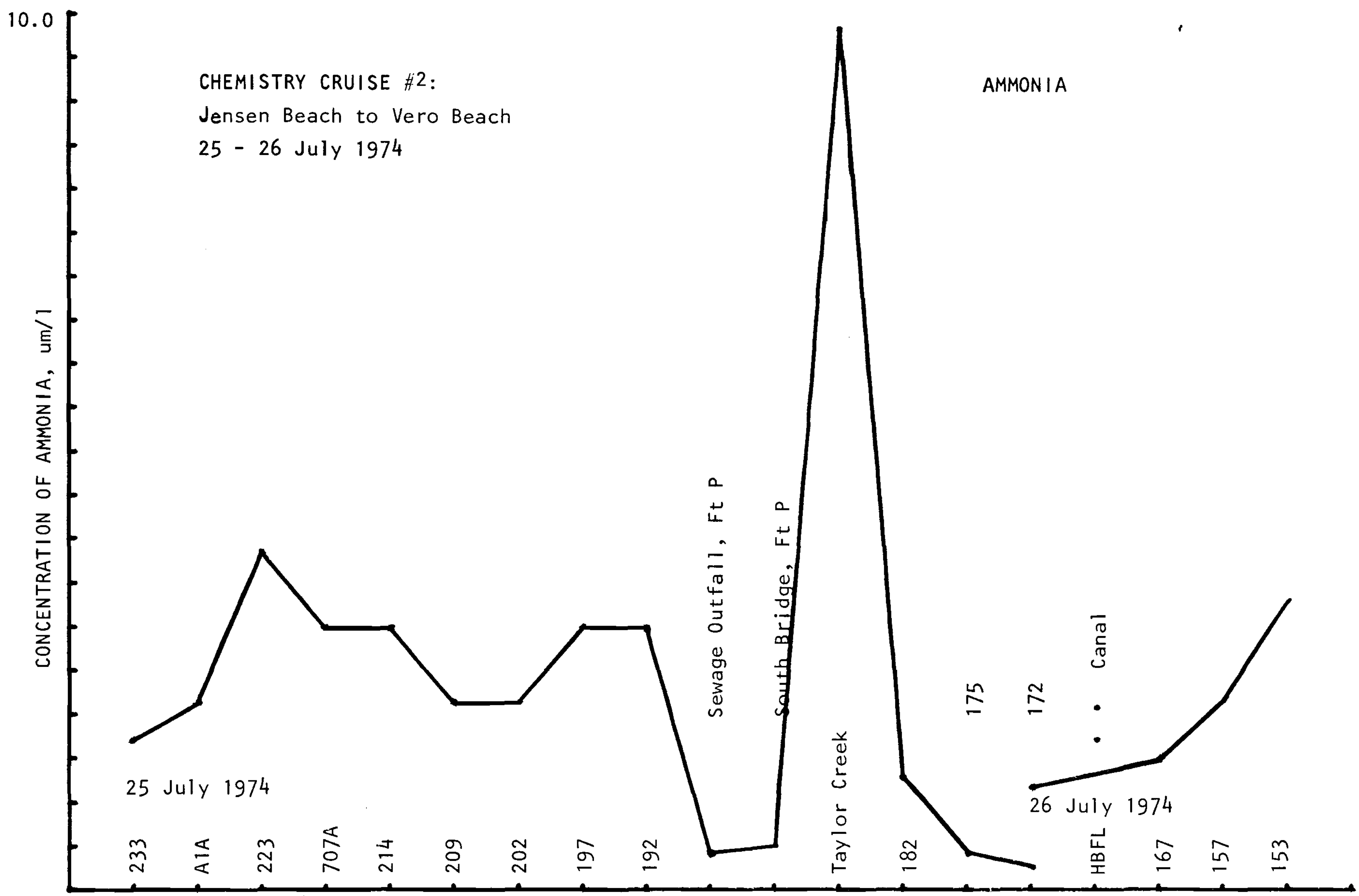
(1) Anclote Environmental Project Report. 1973. prepared for Florida Power Corporation by the Department of Marine Science, University of South Florida, Tampa, Florida.

(2) Dodson, A. N., and W. H. Thomas. 1964. Concentrating Plankton in a Gentle Fashion, Limnol. Oceanogr., 9:455-456.

(3) Hopkins, T. L. 1961. Natural Coloring Matter as an Indicator of Inshore Water Masses. Limnol. Oceanogr., 18:516-524.

(4) Strickland, J. D. H., and T. R. Parsons. 1972. A Practical Handbook of Seawater Analysis, Bulletin 167, Fisheries Research of Canada, Ottawa.

APPENDIX I: Data figures for selected chemical parameters for all stations sampled within Region IV of the Indian River, 25 - 26 July 1974.


10.0
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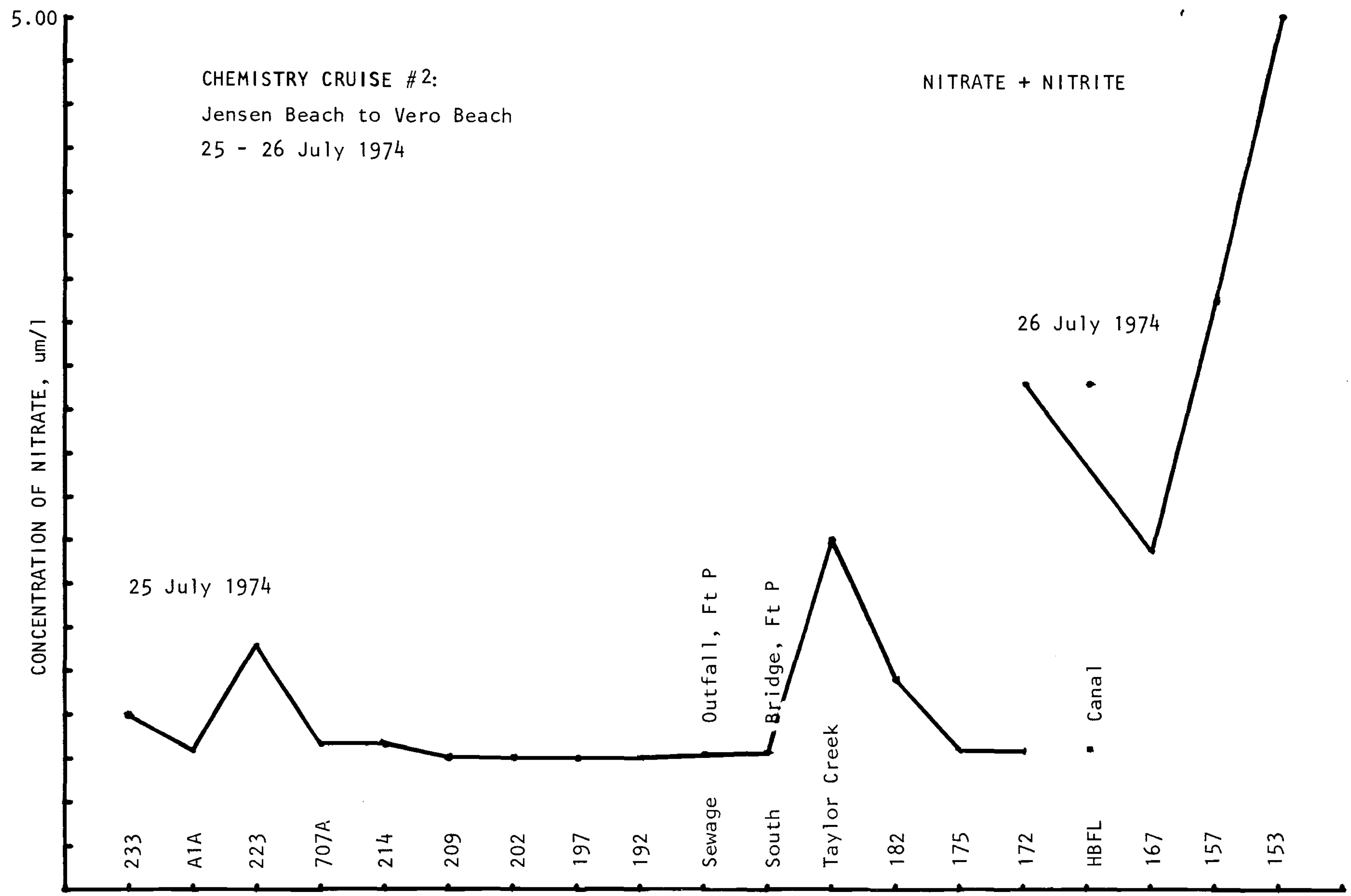
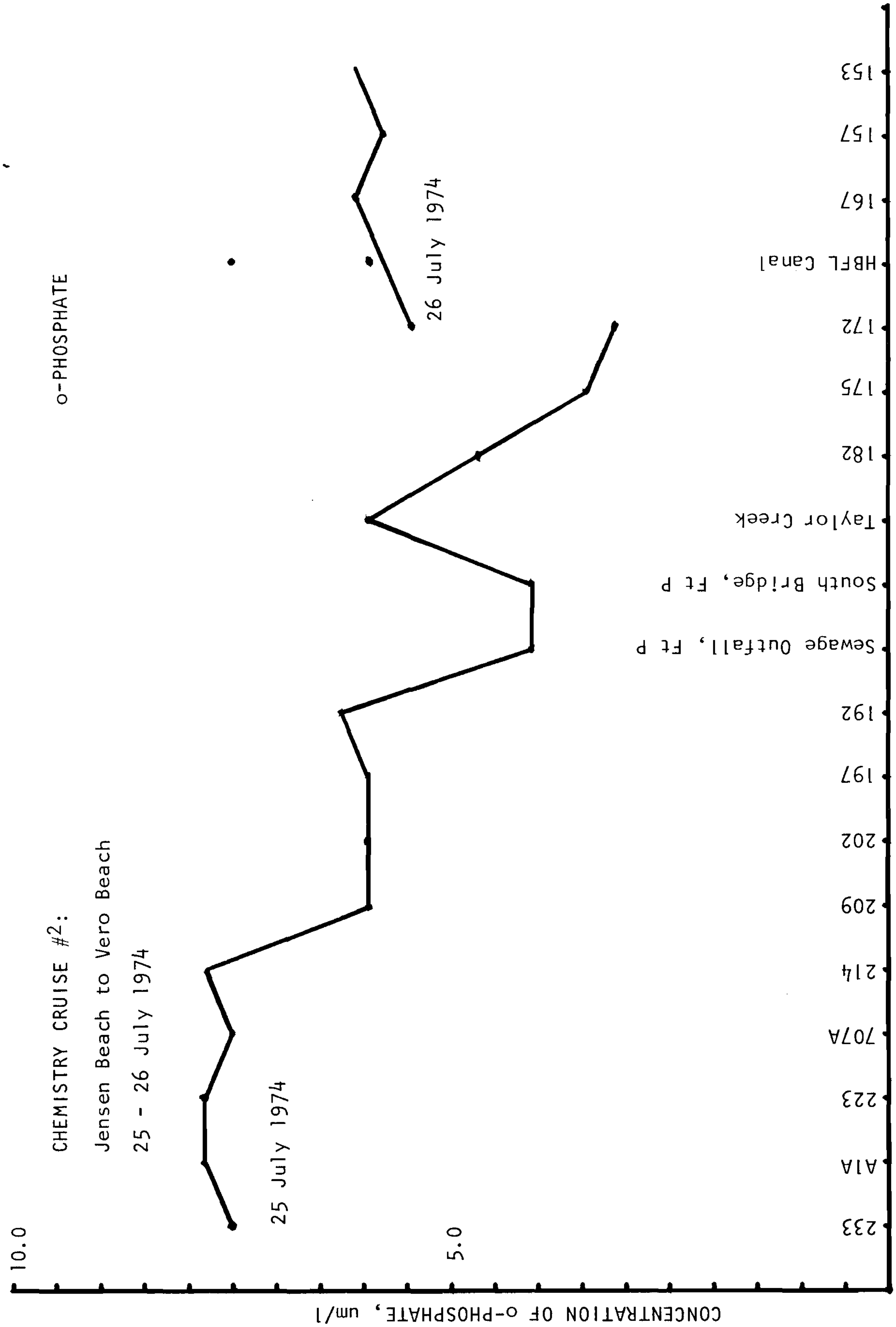
Jensen Beach to Vero Beach
25 - 26 July 1974
AMMONIA
CONCENTRATION OF AMMONIA, um/l
25 July 1974
26 July 1974
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL
Canal
167
157
153


5.00
CONCENTRATION OF NITRATE, um/l
CHEMISTRY CRUISE #2:
Jensen Beach to Vero Beach
25 - 26 July 1974
NITRATE + NITRITE
25 July 1974
26 July 1974
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153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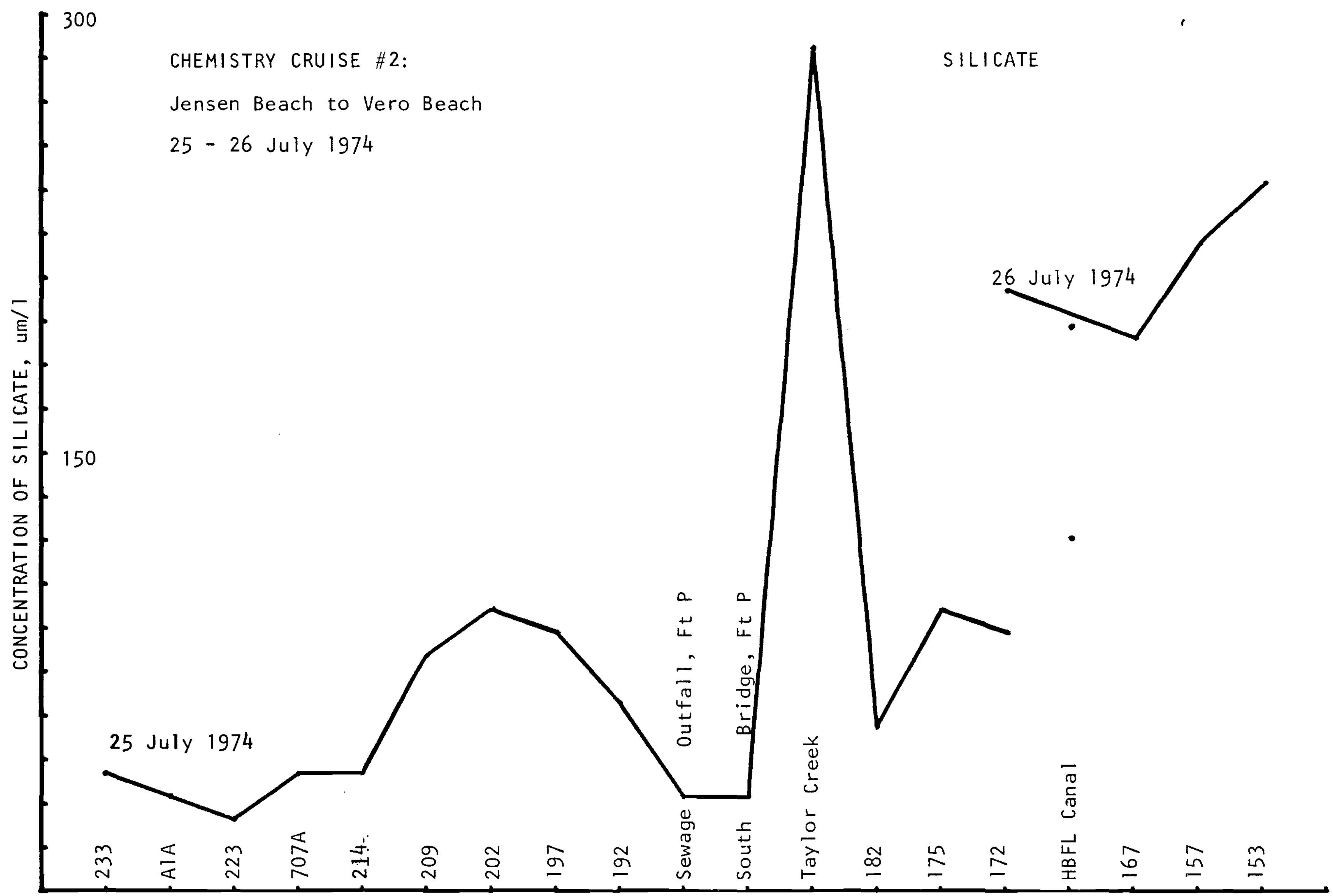
Jensen Beach to Vero Beach
25 - 26 July 1974
o-PHOSPHATE
25 July 1974
26 July 1974
10.0
5.0
CONCENTRATION OF o-PHOSPHATE, um/l
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153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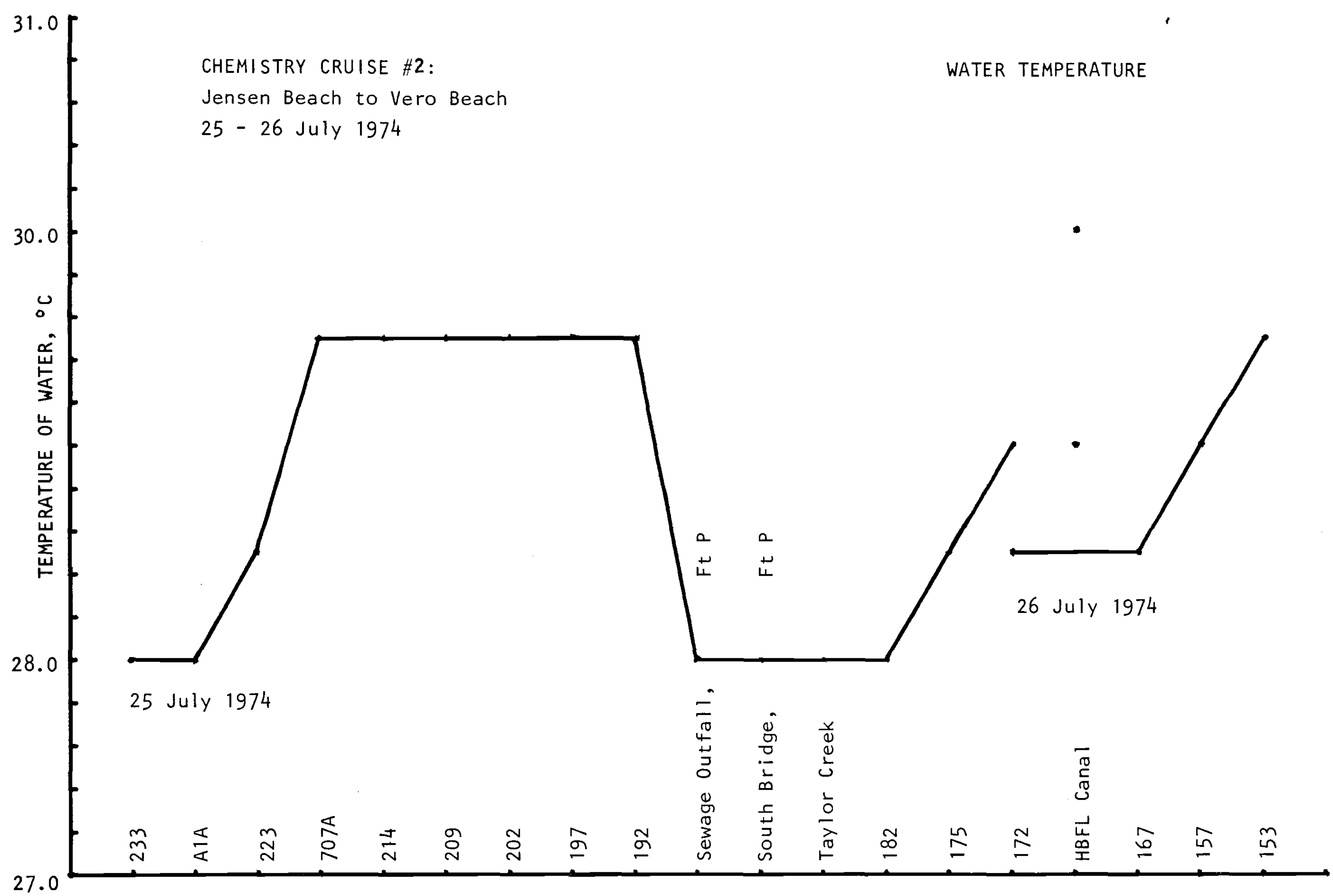
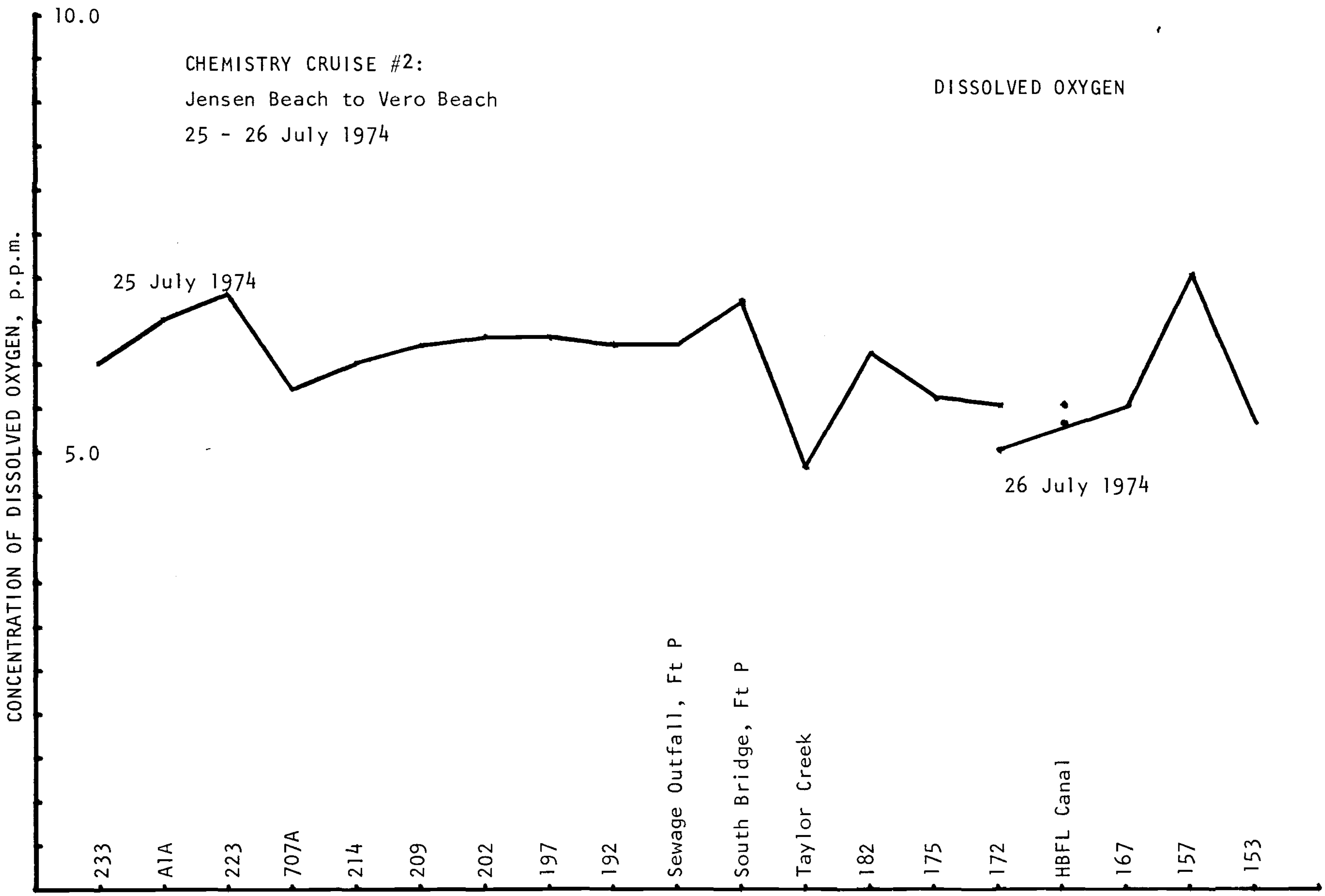
Jensen Beach to Vero Beach
25 - 26 July 1974
SILICATE
CONCENTRATION OF SILICATE, um/l
300
150
25 July 1974
26 July 1974
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153


CHEMISTRY CRUISE #2:
Jensen Beach to Vero Beach
25 - 26 July 1974
WATER TEMPERATURE
TEMPERATURE OF WATER, °C
31.0
30.0
28.0
27.0
25 July 1974
26 July 1974
Ft P
Ft P
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall,
South Bridge,
Taylor Creek
182
175
172
HBFL Canal
167
157
153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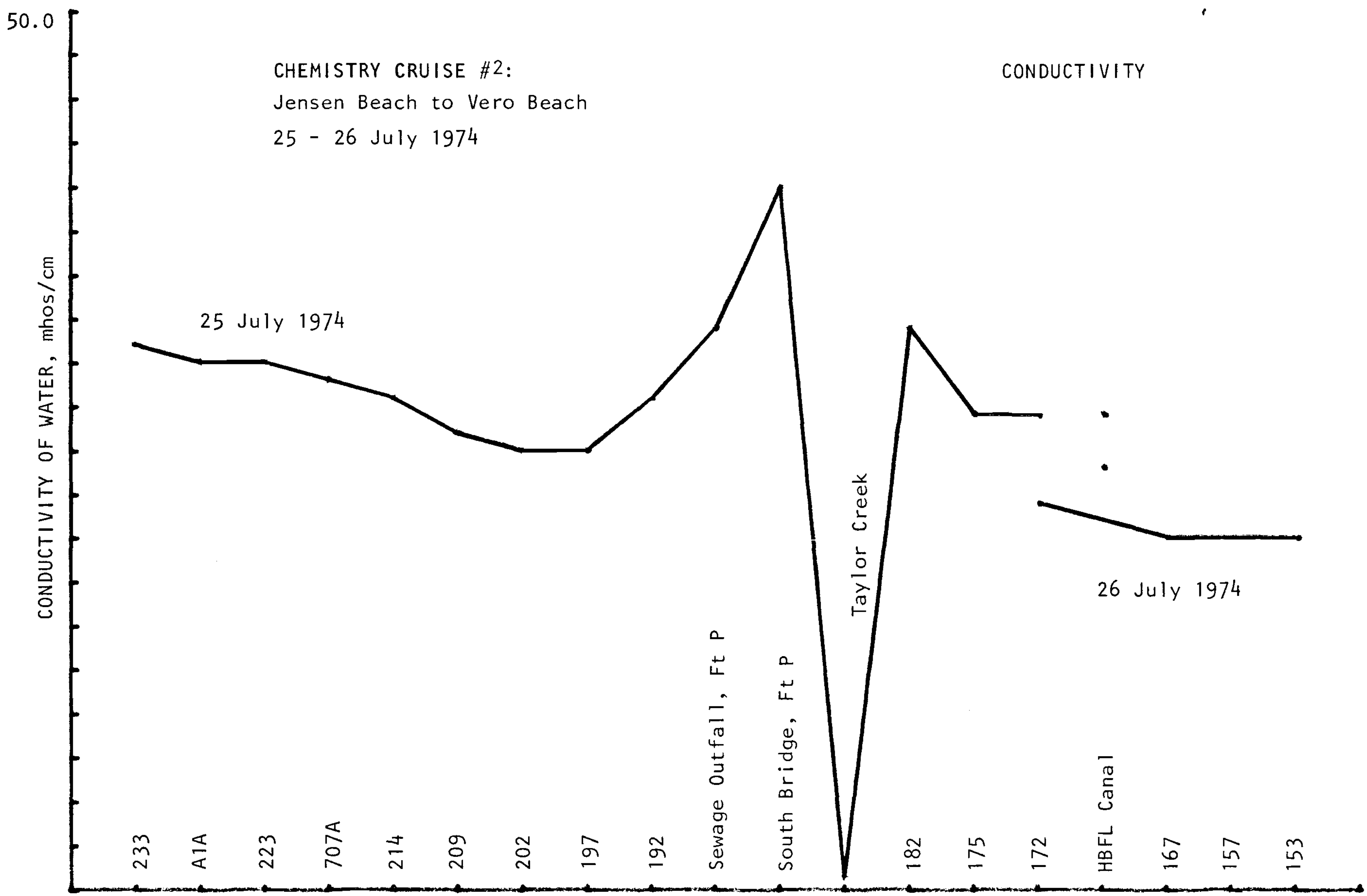
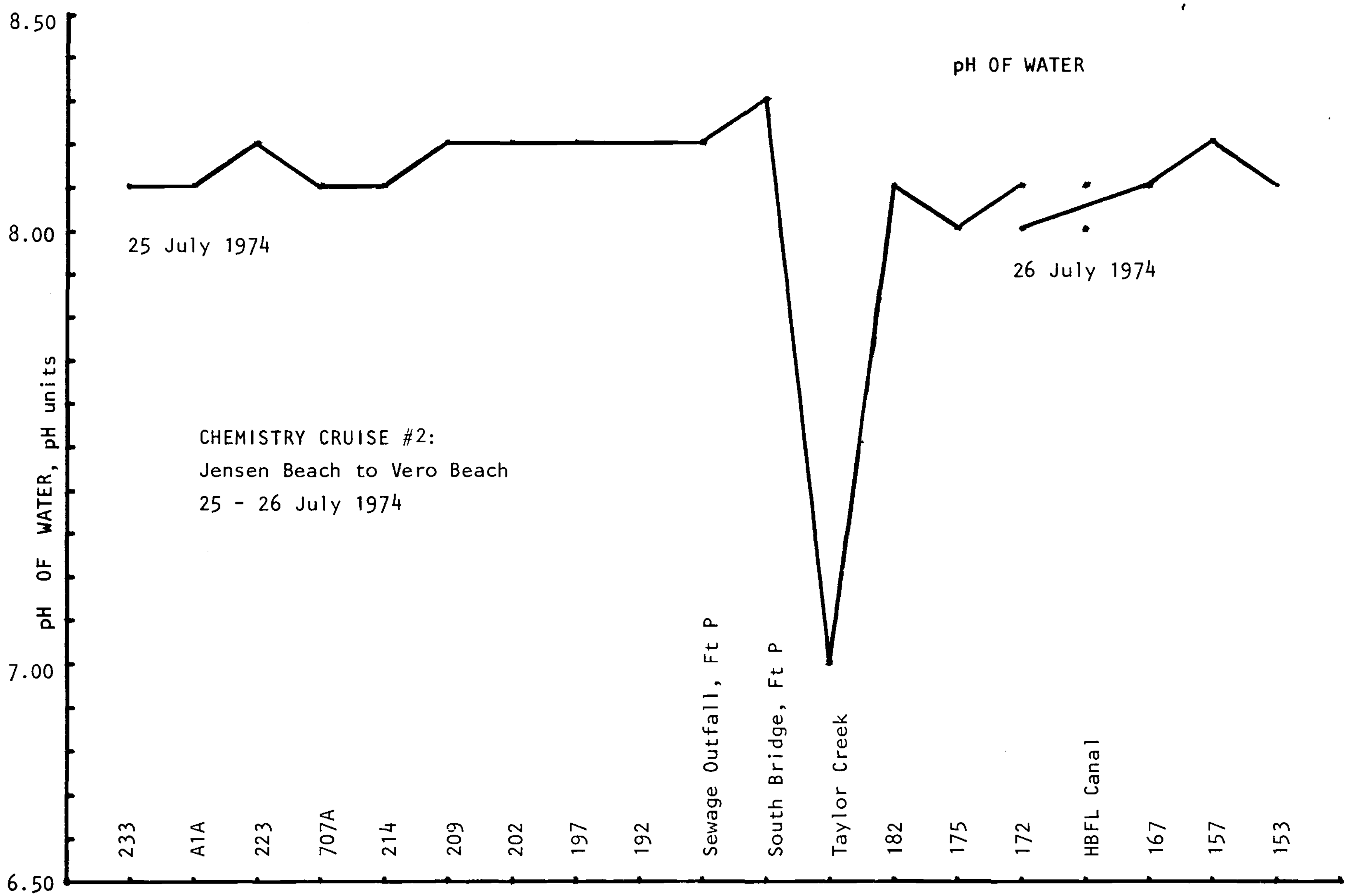
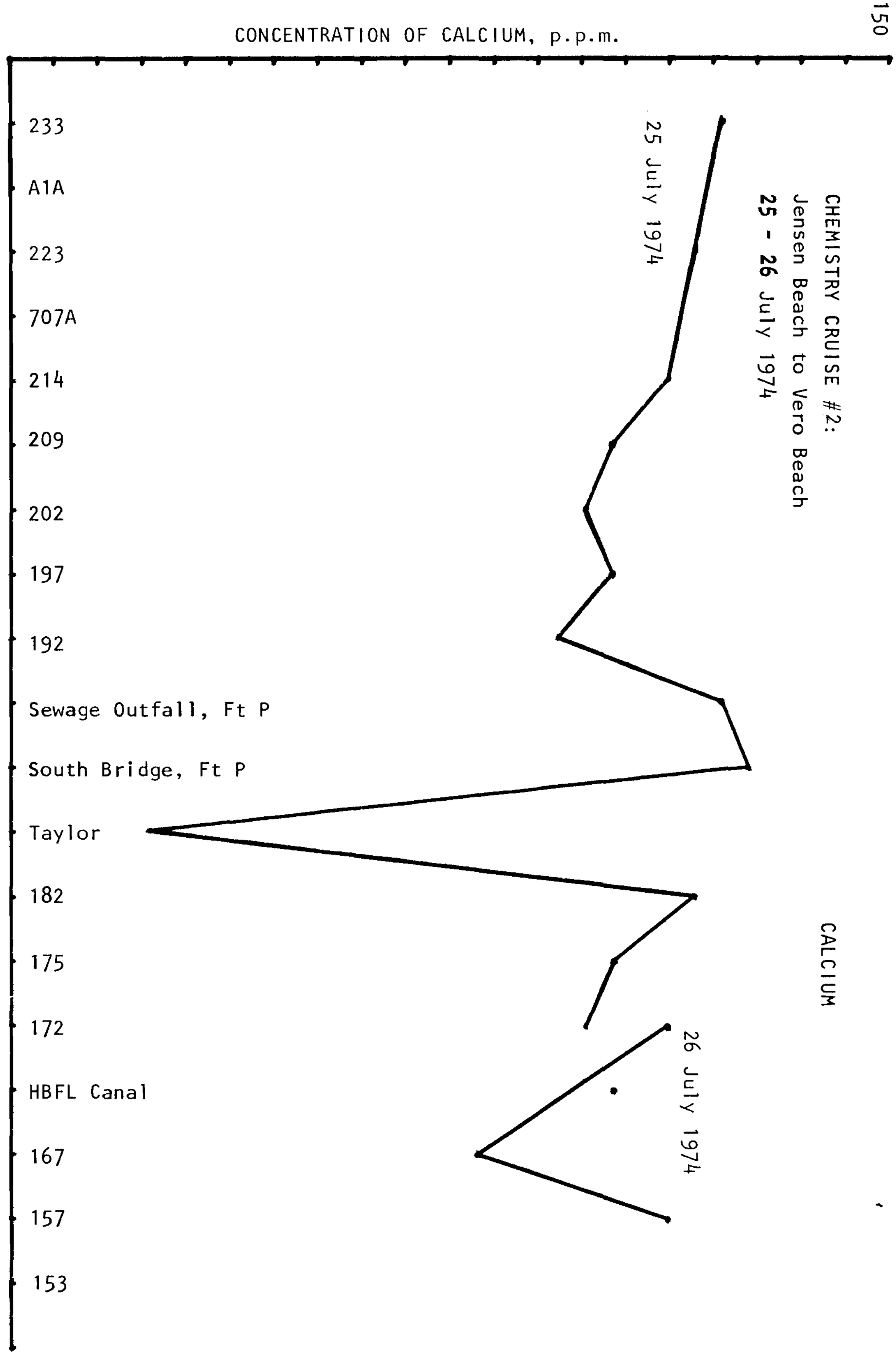
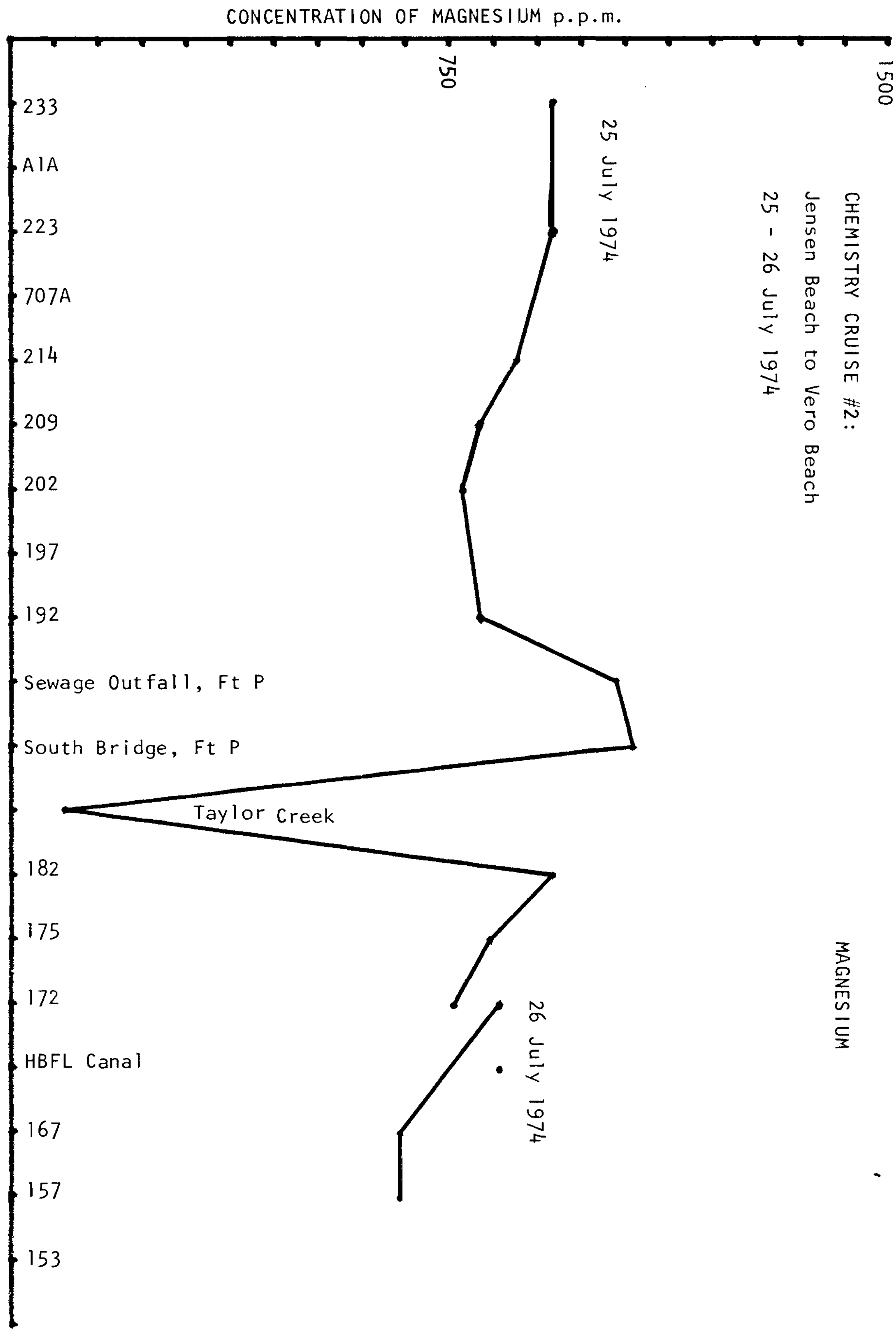
Jensen Beach to Vero Beach
25 - 26 July 1974
DISSOLVED OXYGEN
CONCENTRATION OF DISSOLVED OXYGEN, p.p.m.
10.0
5.0
25 July 1974
26 July 1974
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153

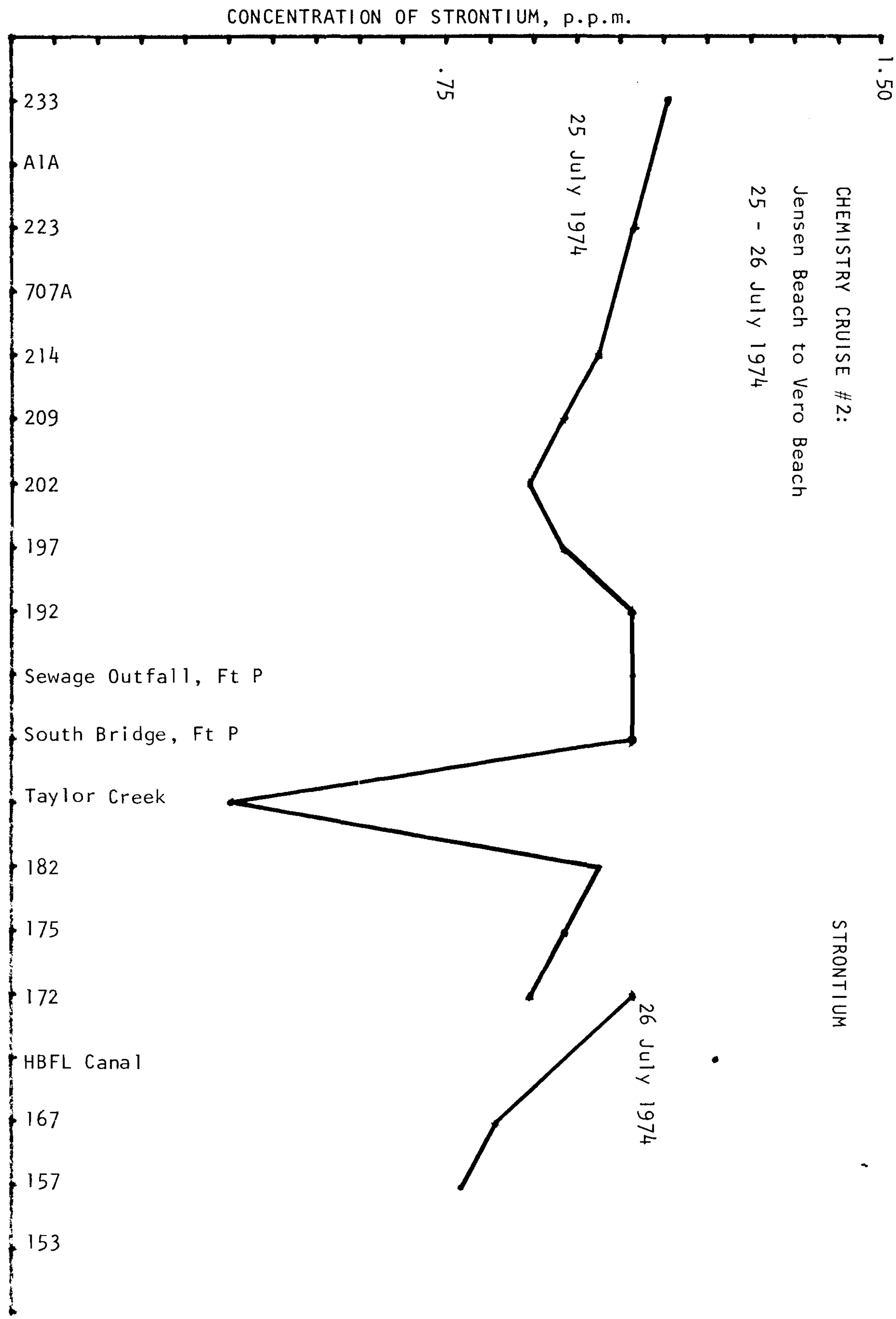

50.0
CHEMISTRY CRUISE #2:
Jensen Beach to Vero Beach
25 - 26 July 1974
CONDUCTIVITY
CONDUCTIVITY OF WATER, mhos/cm
25 July 1974
26 July 1974
Taylor Creek
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
182
175
172
HBFL Canal
167
157
153


pH OF WATER
CHEMISTRY CRUISE #2:
Jensen Beach to Vero Beach
25 - 26 July 1974
25 July 1974
26 July 1974
pH OF WATER, pH units
8.50
8.00
7.00
6.50
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153



CONCENTRATION OF CALCIUM, p.p.m.
150
CHEMISTRY CRUISE #2:
Jensen Beach to Vero Beach
25 - 26 July 1974
CALCIUM
25 July 1974
26 July 1974
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor
182
175
172
HBFL Canal
167
157
153


CONCENTRATION OF MAGNESIUM p.p.m.
750
1500
CHEMISTRY CRUISE #2:
Jensen Beach to Vero Beach
25 - 26 July 1974
MAGNESIUM
25 July 1974
26 July 1974
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153


CONCENTRATION OF STRONTIUM, p.p.m.
.75
1.50
CHEMISTRY CRUISE #2:
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25 - 26 July 1974
25 July 1974
26 July 1974
STRONTIUM
233
A1A
223
707A
214
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202
197
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Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
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HBFL Canal
167
157
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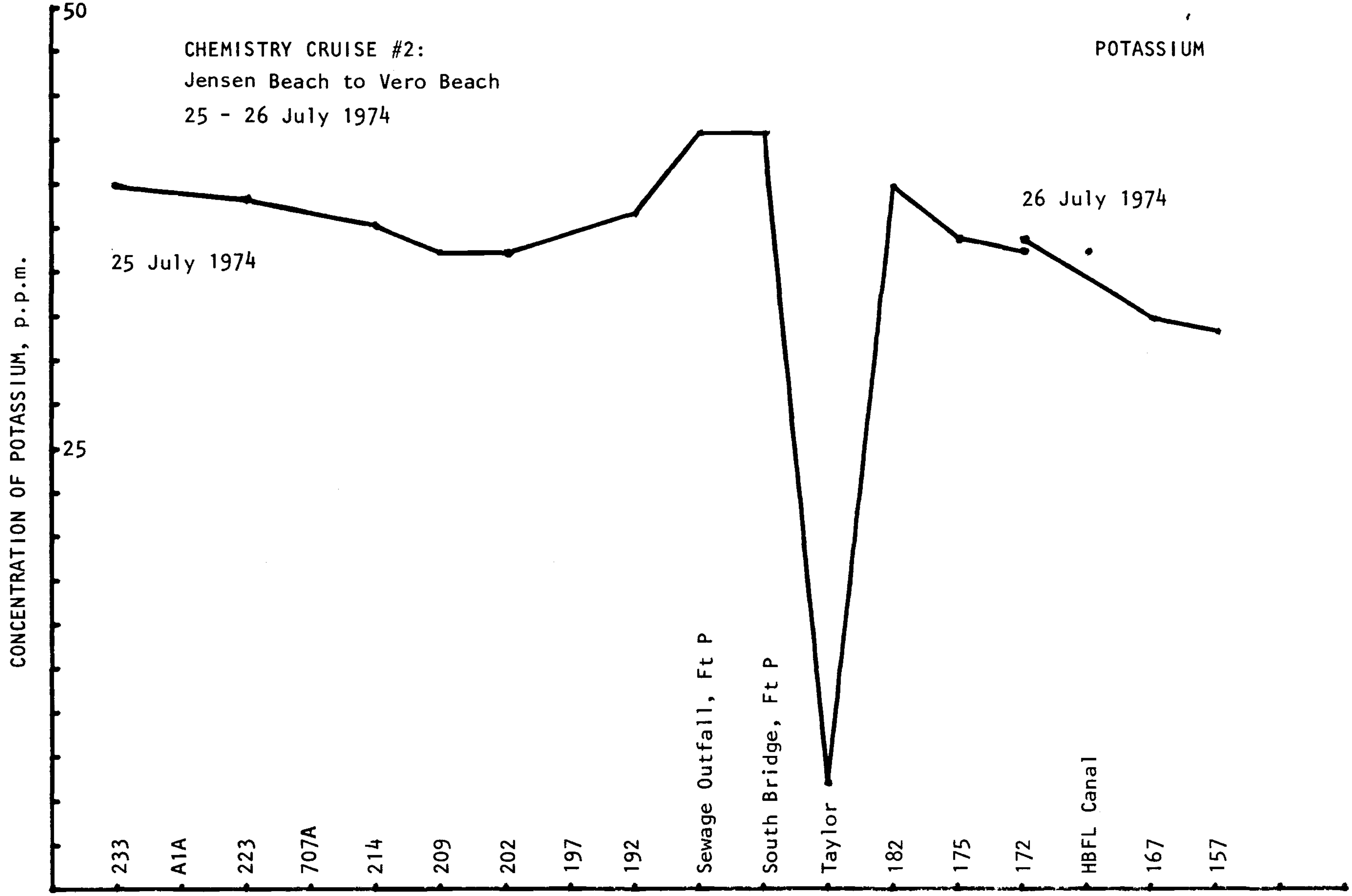

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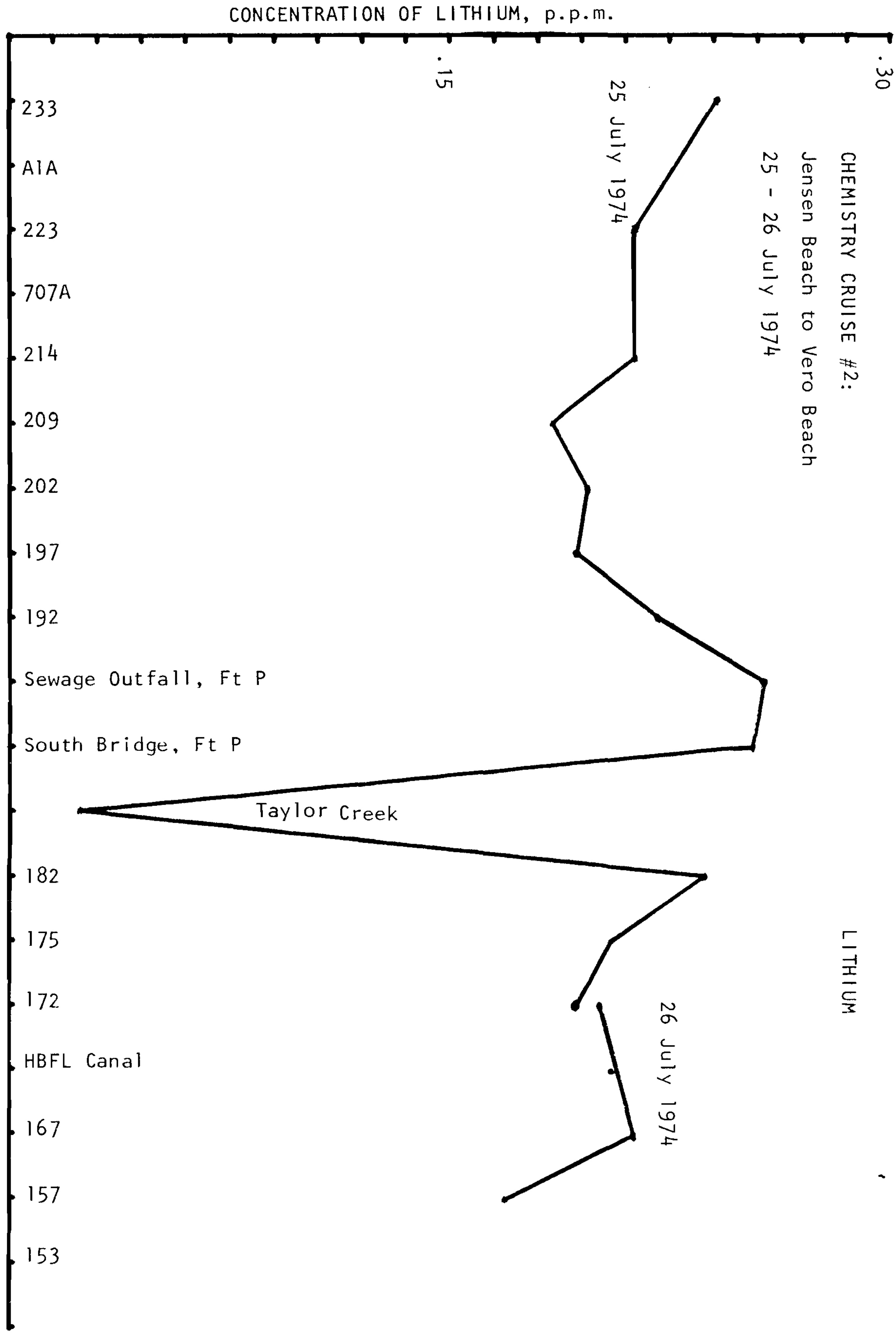
25 - 26 July 1974
POTASSIUM
25 July 1974
26 July 1974
50
25
CONCENTRATION OF POTASSIUM, p.p.m.
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor
182
175
172
HBFL Canal
167
157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.15
.30
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25 - 26 July 1974
25 July 1974
26 July 1974
LITHIUM
233
A1A
223
707A
214
209
202
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192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
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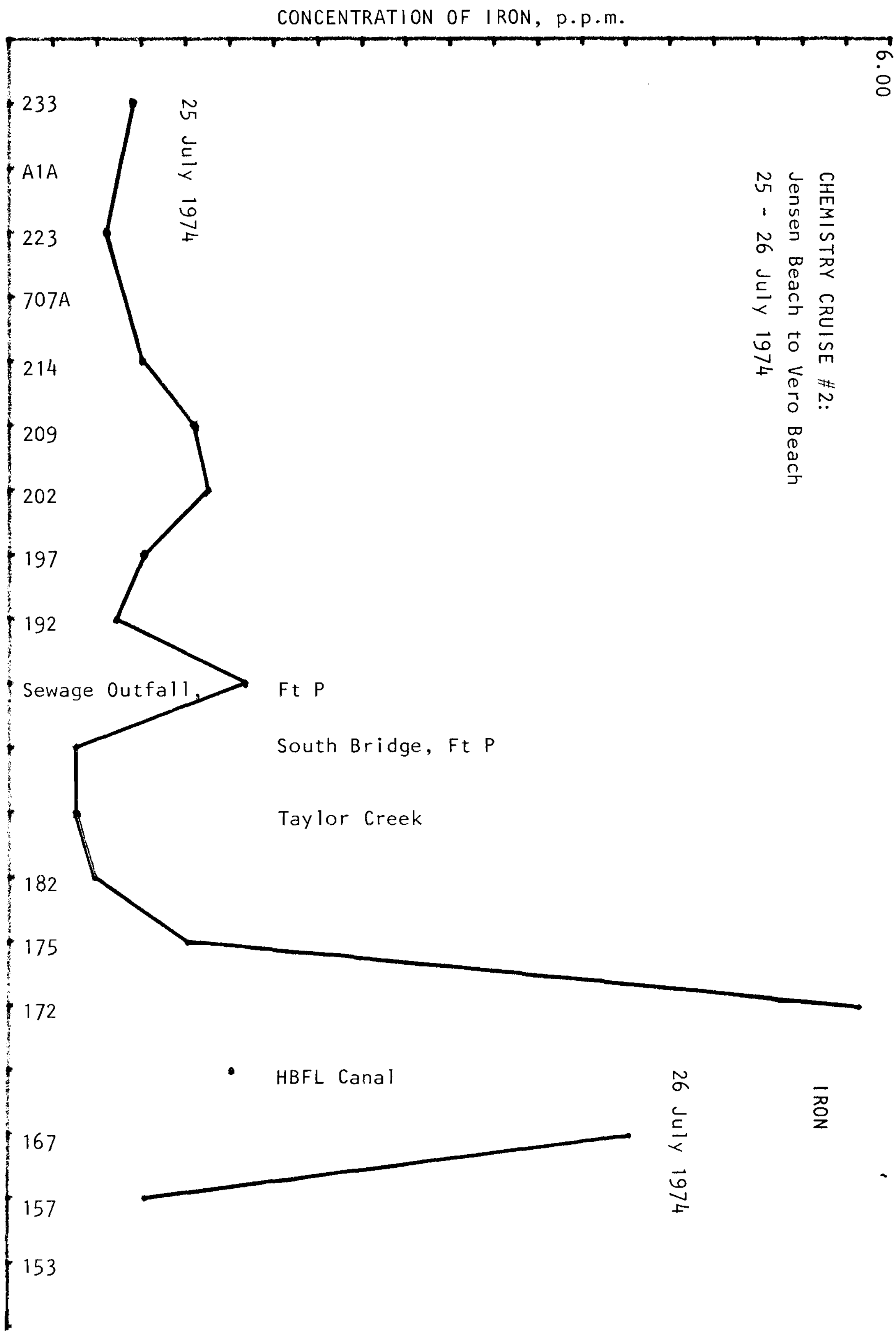
HBFL Canal
167
157
153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25 - 26 July 1974
25 July 1974
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A1A
223
707A
214
209
202
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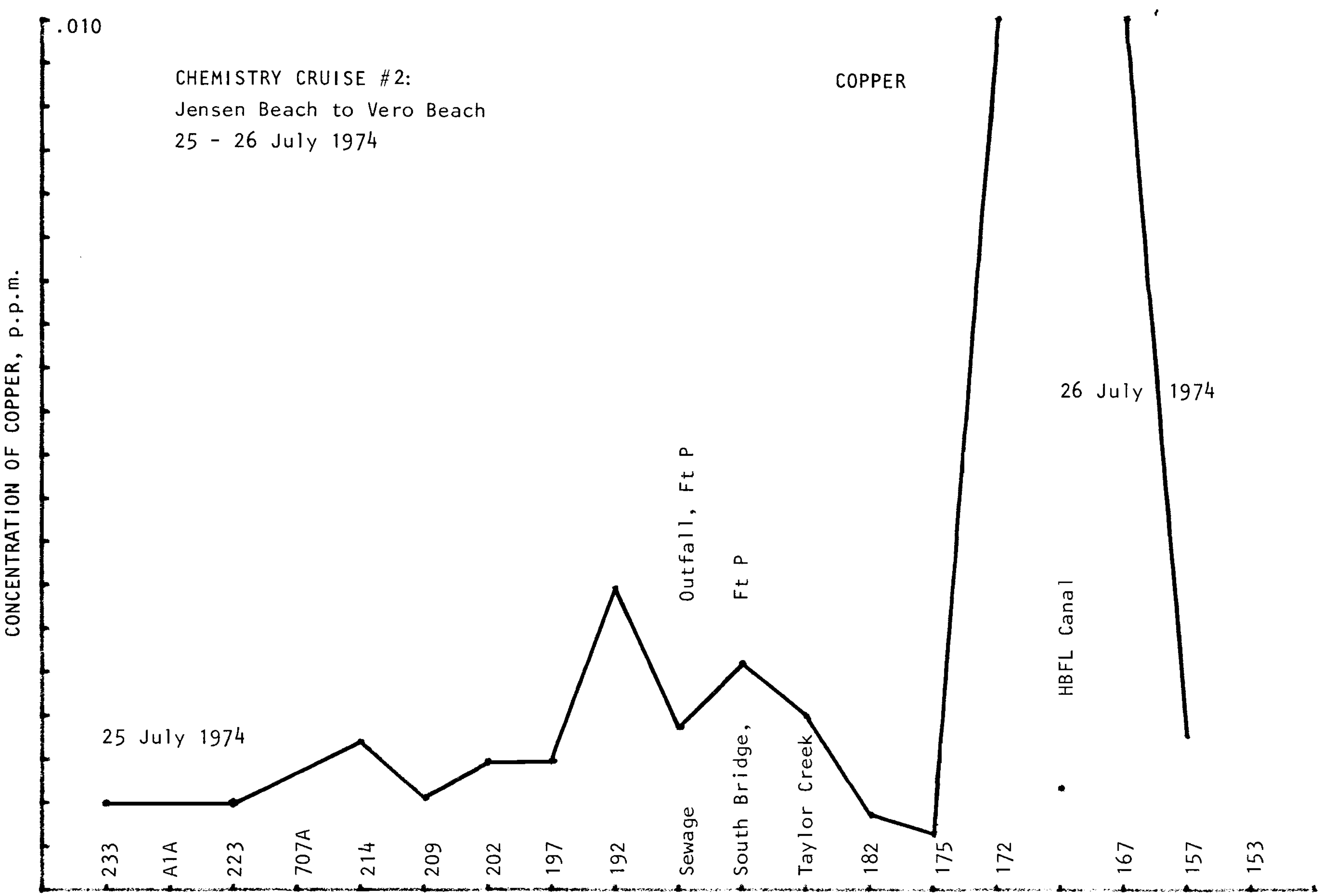
192
Sewage Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153
26 July 1974
IRON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25 - 26 July 1974
COPPER
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25 July 1974
26 July 1974
Outfall, Ft P
Ft P
HBFL Canal
233
A1A
223
707A
214
209
202
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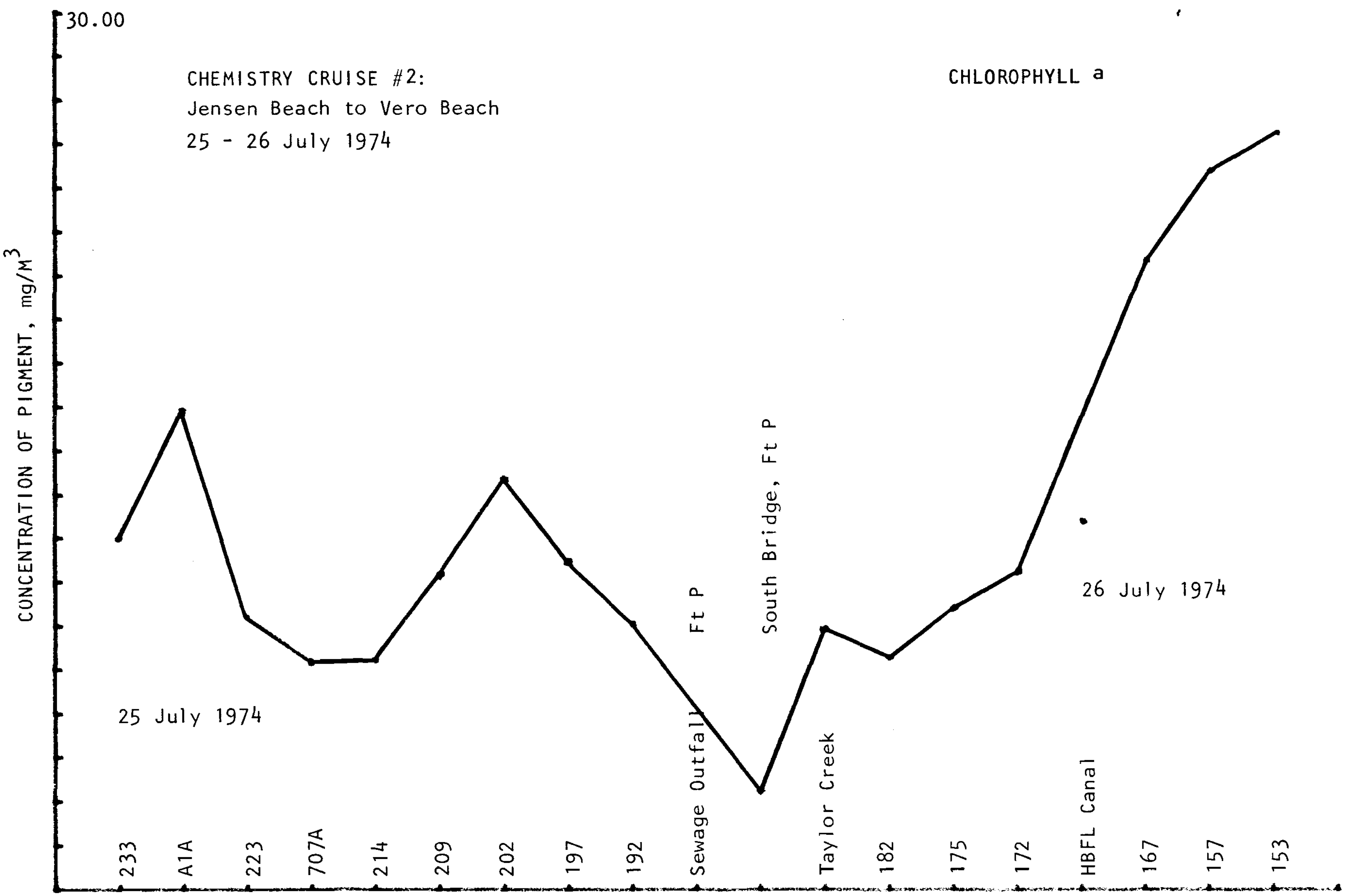
192
Sewage
South Bridge,
Taylor Creek
182
175
172
167
157
153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25 - 26 July 1974
CHLOROPHYLL a
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25 July 1974
26 July 1974
Ft P
South Bridge, Ft P
233
A1A
223
707A
214
209
202
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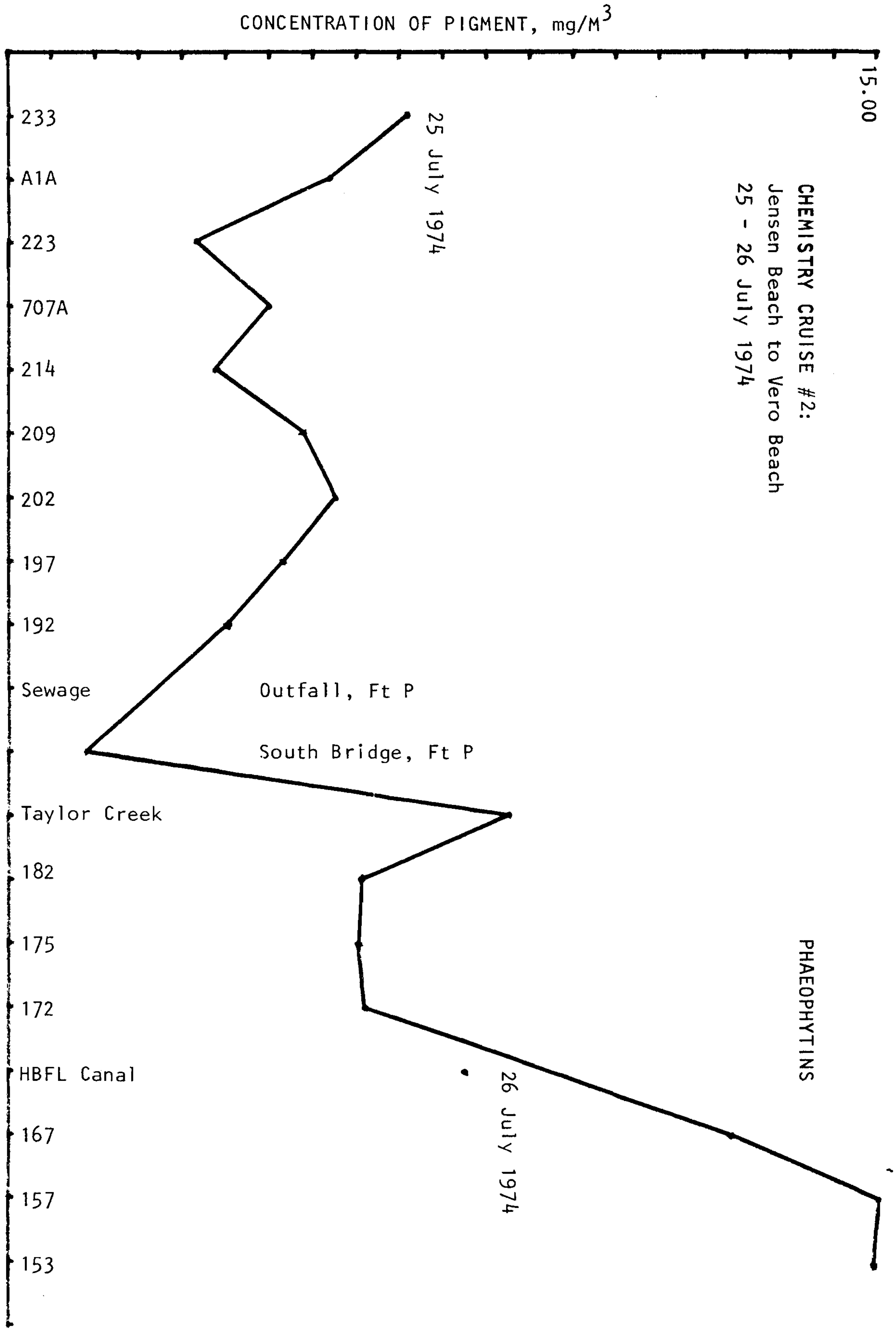
192
Sewage Outfall
Taylor Creek
182
175
172
HBFL Canal
167
157
153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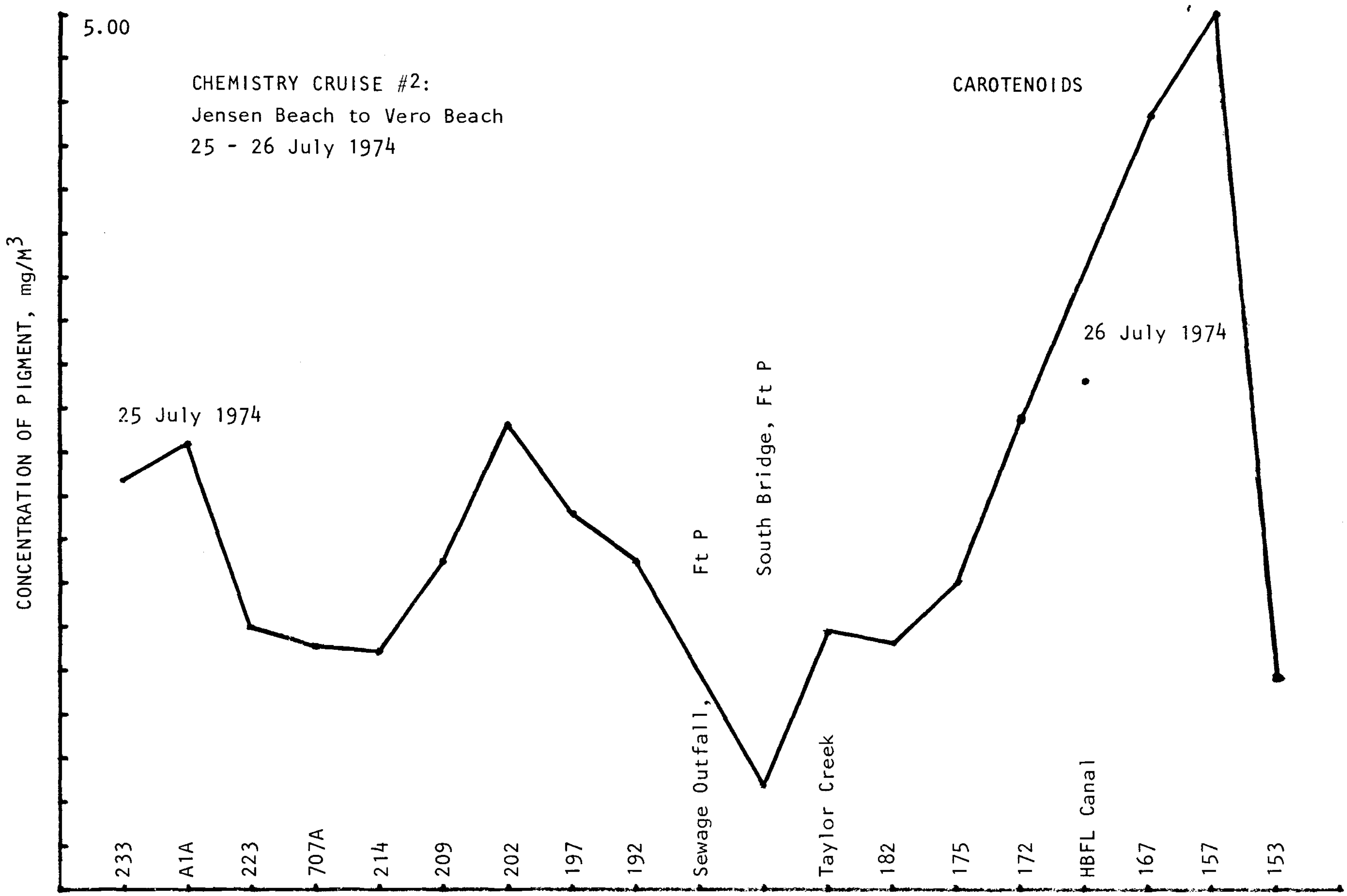
Jensen Beach to Vero Beach
25 - 26 July 1974
25 July 1974
26 July 1974
PHAEOPHYTINS
233
A1A
223
707A
214
209
202
197
192
Sewage
Outfall, Ft P
South Bridge, Ft P
Taylor Creek
182
175
172
HBFL Canal
167
157
153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25 - 26 July 1974
CAROTENOIDS
25 July 1974
26 July 1974
Ft P
South Bridge, Ft P
CONCENTRATION OF PIGMENT, mg/M3
233
A1A
223
707A
214
209
202
197
192
Sewage Outfall,
Taylor Creek
182
175
172
HBFL Canal
167
157
153

CHAPTER 5

STUDIES OF THE FISHES OF THE INDIAN RIVER REGION

Robert S. Jones

R. Grant Gilmore, Jr.

George R. Kulczycki

Wayne C. Magley

Introduction

The basic philosophy of the Indian River Study was spelled out in the original proposal as follows:

> "Much of our understanding of an ecosystem depends on man's ability to define the interactions and cause-effect relationships between the biotic and abiotic components. This is critically important today when pollution is increasingly affecting natural ecosystems."

> "Most commonly, previous baseline information about a specific area to be studies is lacking, so data on seasonal and annual variations are not available. In addition, information on species present in an affected area is incomplete regarding occurrence and distribution of all stages of the life histories."

The community of marine fishes is one of the many parts of this multidisciplinary study to be considered. The basic premise is that perturbations in water quality in the Indian River estuarine ecosystem would result in changes in the fish communities of the river and adjacent continental shelf. During the first phase of the study, reported herein, the pertinent parameters were to be chosen and baseline levels established for comparison with later years as urbanization and pollution problems increased along the Indian River.

The initial goal of any study of this nature is to compile a list of the fishes occurring in the study area. This has been the objective of the first years of operation (1971-1974). One of the authors of this report (Gilmore) initiated the work and has kept the fish program viable and active to date. The results of his study are appended to this chapter. We are confident that the checklist of species is nearly complete for the Indian River lagoon. Although the continental shelf has been sampled by several vessels, including the R/V GOSNOLD and R/V HERNAN CORTEZ, considerable work remains to be done before a checklist is complete regarding fishes of offshore waters. The sampling techniques (most 10 and 20 ft. otter trawls) used to date were designed primarily to investigate the relatively well known fish populations of the open, sand bottom portions of the continental shelf and are inadequate to sample the less well known organic banks and reefs. These structures are one of the unique features of the shelf in this region and probably afford protection for a rich aggregation of species. The "reefs or banks" are extremely productive fishing grounds for both commercial and sport fisherman. Large landings of snapper, grouper and many other reef-related species have been reported. It will be necessary to design more adequate sampling and observation techniques to study these features and associated fish communities. In all probability, the Johnson-Sea-Link will be of great value in investigating this concentrated community of fishes.

We are of the opinion that, in terms of pollution and degredation of water quality, the estuary will be affected sooner and the reduced flushing and dilution characteristics of this enclosed body of water will probably result in more dramatic changes than those on the shelf. We will therefore concentrate our initial efforts more in the estuary and tackle the shelf as time allows, when a vessel is available to replace the R/V GOSNOLD and when the Johnson-Sea-Link is ready for sea.

With the major part of the species list or "inventory" phase of the Indian River Study behind us, more effort will be focused on quantitative sampling in an attempt to establish baseline data for fish communities including such indices as species diversity and total biomass at selected stations. We also need data on distribution of individual species, their individual biomass, basic life histories and rank of relative importance to the Indian River ecosystem. Once the temporal and spatial considerations of the above parameters have been worked out, there will exist a bank of data against which deviations from the present state of the ecosystem can be measured over time, and we can test our basic hypothesis that degredation of water quality will lead to changes in one or more of the above indices.

The biggest problems we face are in developing statistically reliable sampling procedures and in the fact that the system on which we are attempting to establish baseline data is a dynamic one and already in a state of flux with regard to water quality and associated marine organisms. Whether or not we can effectively measure the "extant" ecosystem in order to obtain reliable baseline data is going to be a critical question.

Progress to Date

The sampling program began in the fall of 1971 and continued through March 1974 as a part of a general Indian River faunal survey, under the guidance of Dr. Robert Gore. Gilmore was assigned the fish section of this survey.

The attached manuscript by Gilmore (Appendix) shows the progress made on the fish work thus far. His paper contains a comprehensive physical description of the Indian River study area and considers regional geography, geology, drainage systems and modifications thereto, salinity and temperature regimes, rainfall and other background data.

Gilmore lists the major fish biotopes of the Indian River and adjacent continental shelf and describes each briefly. He recognizes fresh water tributaries and canals, canal and river mouths, mosquito impoundments, open sand bottom, spermatophyte grass flats, lagoon reefs, and inlets as the primary biotopes of the Indian River. On the continental shelf, he lists the surf zone-sand/shell bottom, the surf zone reefs, the offshore reefs (2 to 110m), the benthic open shelf, and neritic biotopes.

The paper includes a qualitative checklist of fishes based on over 100 continental shelf stations collected from the R/V GOSNOLD and the R/V HERNAN CORTEZ and over 1000 collections from the estuary at 79 different stations. The qualitative sampling, along with a literature survey, resulted in a checklist of 533 species. This number includes 75 species not previously recorded from the Indian River region. Much of the resultant reference collection was catalogued in the Florida State Museum at Gainesville because of lack of space at Link Port.

We do not feel that the fish survey section is complete as yet and will continue to make quarterly qualitative samples in the Indian River lagoon and on the continental shelf as the equipment becomes available. We estimate that the checklist to date includes more than 90 percent of the Indian River species and approximately 60-70 percent of the species likely to occur on the continental shelf.

As pointed out in the Introduction, the Indian River faunal survey was expanded in the fall of 1973 to a major ecological study of the area with the effects of pollution as a major goal. Upon completion of his initial fish survey (Appendix), Gilmore designed a quantitative sampling technique tailored to the ecological objectives of the Indian River Study. This technique is reported on in greater detail below.

Future Research

Up until March 1974, all the fish work was conducted on a qualitative basis, using a wide variety of collecting techniques. The fish team has used 20 to 150 foot seines, cast nets, dip nets, gill nets, 10 to 20 foot otter trawls, spears, fish poison, and miscellaneous dredges to collect fishes. These qualitative techniques will continue to be used but we must now begin gearing our program more toward quantitative sampling methods. To this end, Gilmore has designed a seining technique to sample shoreline species. The method involves setting two 50 ft. barricade nets perpendicular to the beach and 100 ft. apart. A 150 ft. seine is stretched out from the outer end of the downstream barricade net and in a lagoonward direction. Once the full length of the seine is out, the lagoonward end is swung toward the lagoonward end of the upstream barricade net. When overlap is established, both ends of the 150 ft. seine are brought shoreward, inside of the barricade nets, and the seine and its contents are beached. Models show that this technique entraps and samples an area of about 1,161 m^2. The enclosed table gives a sample of results and shows a comparison between two of our permanent stations using this technique. Permanent stations include Bessie Cove, Jensen Beach Causeway, Big Mud Creek, Jim Island Flat, Harbor Branch Foundation Laboratory, Wabasso Causeway, and Pelican Island Cove. These stations were chosen to include areas both near and away from the inlets.

The above method has proven effective for shore-bound fishes but is somewhat biased because of the edge effect caused by the shoreline. We need to include sampling stations lagoonward of the shore area as well. We plan to use gill net stations and trawl sampling in the mid-lagoon regions. Both techniques have been used by other researchers in similar surveys but again, both lack good control in quantification. Another more controllable method used by past workers is the drop net. This method employs a suspended net that can be preset and then triggered remotely to drop and entrap an area of a known size. We are presently working with R&D on a preliminary design. Hopefully, we can develop a workable system by early 1975.

The continental shelf region remains a sampling problem. We do not anticipate a program of quantitative sampling in the near future but would like to continue our qualitative work (inventory). As pointed out in the Introduction, we will not be able to continue our trawl survey of the open shelf community until a new sea-going vessel is acquired by Harbor Branch Foundation. The nearshore and surf zone reef communities will be investigated using SCUBA gear and small boats. An underwater tape recorder is presently being fabricated for use in this survey during periods when water clarity and sea state allows us to work in these zones. Collections of fishes will be made over these inshore reefs with spears, hand nets and fish poisons.

As pointed out above, the deep reef system of the shelf and its important fishery will be investigated, hopefully, by observations with the CORD TV system and the Johnson-Sea-Link. These observations will be supplemented by lockout diver collections, if possible, and fish traps.

Although not as part of the Indian River Study, Jones will be contributing an underwater tape recorder/transect study of reef fish communities both inside and outside of Pennekamp Park at the Key Largo Field Station. This program will be a part of the HBF/SI Coral Reef Program but the techniques developed will be applicable to the continental shelf reefs within the jurisdiction of the Indian River Program.

Personnel

R. Grant Gilmore - Has been an employee of HBF for the past three years and bears most of the responsibility and deserves the credit for the majority of the fish work thus far. He is presently serving as Assistant Fishery Biologist.

George R. Kulczycki - Was hired in the spring of 1974 to assist Gilmore in the beginning of the quantitative phase of this project. He is also responsible for purchasing and procurement of supplies and equipment for the fish program.

Wayne C. Magley - Was shifted from the R/V GOSNOLD crew to fish program after decommissioning of the vessel. He serves as a field and laboratory technician.

Barbara Graunke - Volunteer helper, signed on in October 1974 to assist in field and laboratory operations.

Doug Carlson - Assisted in the program as a summer volunteer.

TABLE. Sample data from shoreline seining technique (Entrapment area - 1,161 m^2). JI - Jim Island Flat, JB Jensen Beach Causeway. Both collections were made in July 1974.

SPECIES	JI No.	JB No.	JI No./M^2	JB No./M^2	JI Wt.g.	JB Wt.g.	JI Wt./M^2	JB Wt./M^2
1. Herengula pensacolae	5326	19	4.59	0.01	5103.0	19.36	4.4	0.01
2. Opisthonema oglinum	13	-	.01	-	24.0	-	.02	-
3. Sardinella anchovia	185	-	.15	-	237.4	-	.20	-
4. Oligoplites saurus	-	4	-	< .01	-	29.72	-	0.02
5. Anchoa hepsetus	1	1	< .01	< .01	3.0	2.55	< .01	< .01
6. Anchoa mitchilli	1120	109	.96	0.09	727.0	79.80	.63	.73
7. Anchoa lamprotaenia	-	3	-	< .01	-	7.07	-	< .01
8. Strongylura notata	-	1	-	< .01	-	13.74	-	< .01
9. Strongylura timucu	-	7	-	< .01	-	137.61	-	0.11
10. Floridichythys carpio	1	-	< .01	-	1.0	-	< .01	-
11. Lucania parva	-	3	-	< .01	-	0.09	-	< .01
12. Menidia berylina	-	1	-	< .01	-	1.32	-	< .01
13. Syngnathus louisianae	-	1	-	< .01	-	0.48	-	< .01
14. Centropomus undecimalis	1	-	< .01	-	108.0	-	.09	-
15. Mycteroperca microlepis	2	-	< .01	-	59.0	-	.05	-
16. Caranx hippos	6	-	< .01	-	6.0	0	< .01	-
17. Lutjanus analis	5	-	< .01	-	158.5	-	.13	-
18. Lutjanus synagris	19	-	.01	-	680.0	-	.58	-
19. Lutjanus griseus	6	-	< .01	-	136.5	-	.11	-
20. Ecinostomus gula	551	20	.47	0.01	918.5	62.24	4.53	0.05
21. Ecinostomus argenteus	5	17	< .01	0.01	18.5	26.65	.01	0.02
22. Diapterus olisthostomus	229	148	.19	0.07	1534.1	119.28	1.32	0.10
23. Haemulon parrai	-	1	-	< .01	-	1.39	-	< 0.01
24. Orthopristis chrysoptera	30	-	.02	-	452.16	-	.38	-
25. Lagodon rhomboides	706	17	.6	0.01	14,924.0	403.22	12.86	0.34
26. Bairdella chrysurus	1	60	< .01	0.05	101.5	307.79	.08	0.26
27. Leiostomus xanthurus	6	-	< .01	-	212.5	-	0.18	-
28. Mugil curema	17	2	.01	< .01	1193.0	0.06	1.02	< .01
29. Sphyraena barracuda	4	1	< .01	< .01	46.5	0.03	.04	< .01
30. Erotelis smaragdus	1	-	< .01	-	4.0	-	< .01	-
31. Bathygobius soporator	2	-	< .01	-	2.1	-	< .01	-
32. Gobionellus smaragdus	1	-	< .01	-	1.5	-	< .01	-
33. Citharichthys spilopterus	1	-	< .01	-	1.7	-	< .01	-
TOTAL	8242	415	7.01	0.25	26,655.96	1197.47	26.63	1.55

APPENDIX

A REGIONAL DESCRIPTION AND CHECKLIST OF FISHES OF THE INDIAN RIVER

R. Grant Gilmore, Jr.

Introduction

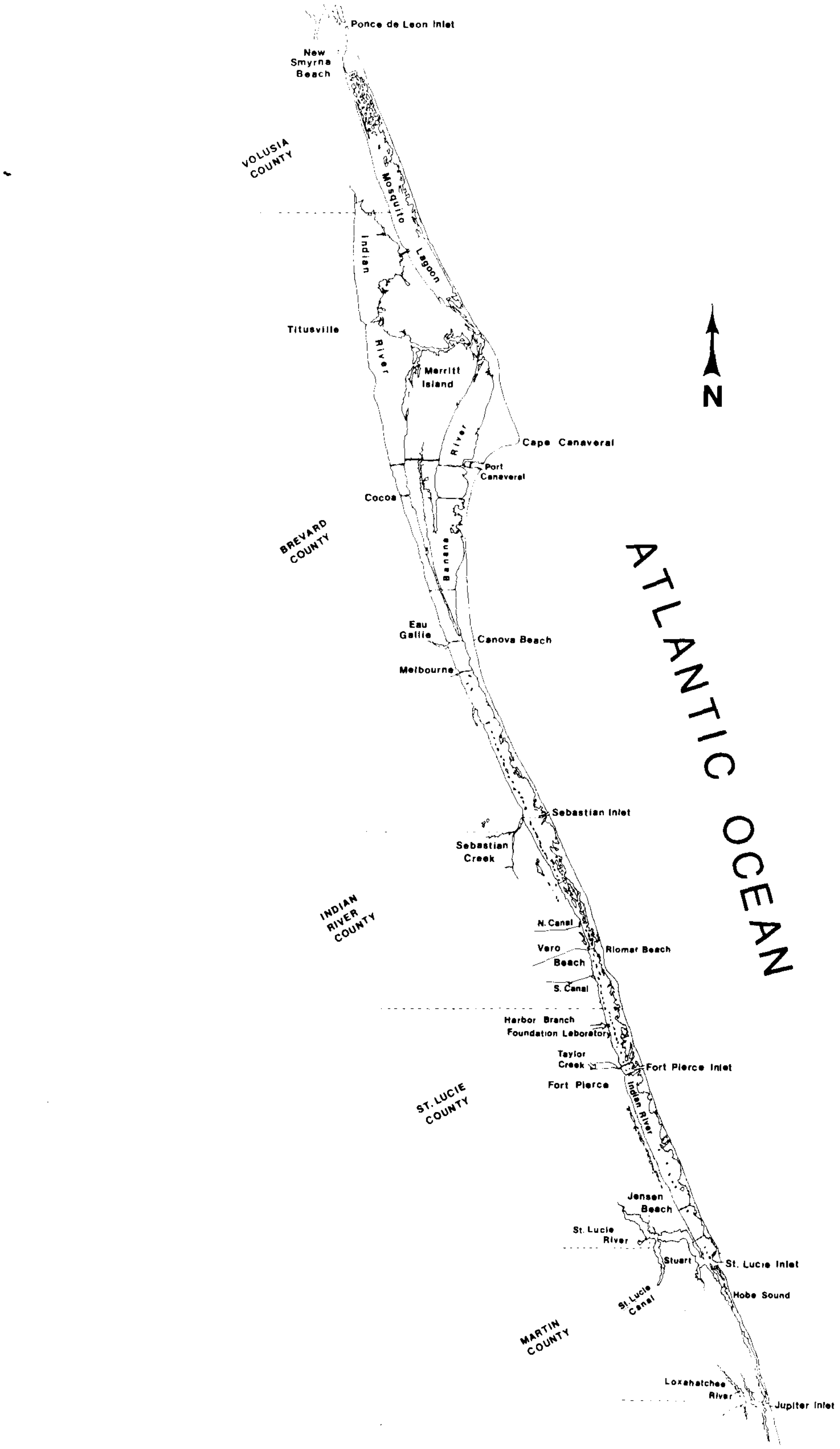
Although the fishes of the Indian River region of east central Florida (Fig. 1) belong to the relatively well known Western Atlantic shore fish fauna, the marine and estuarine species of the region have never been studied in detail. No comprehensive list, based on actual capture records, of the fishes that occur here has ever been published.

The Indian River is a narrow estuarine lagoon system extending from Ponce de Leon Inlet in Volusia County south to Jupiter Inlet in Palm Beach County (Fig. 2). It is situated within the zone of overlap between two well known faunal regimes (i.e. the warm temperate - Carolinian and the tropical - Caribbean). To the north of the region, Hildebrand and Schroeder (1928), Fowler (1945), Struhsaker (1969) and Dahlberg (1971) have made major faunal reviews of the coastal waters of the southeastern United States. McLane (1955) and Tagatz (1967) have made extensive surveys of the fishes of the St. Johns River including the estuarine portions. Southeast of the Indian River region Böhlke and Chaplin (1968) surveyed the fishes of the Bahamas The tropical fish fauna south of the Indian River lagoon has been thoroughly reported on the Herrema (1974), Starck (1968), and Longley and Hildebrand (1940) who have made extensive fish surveys in Palm Beach and Broward counties, the Florida Keys and Dry Tortugas, respectively.

Figure 1. Location of the Indian River Study area with respect to the Caribbean and Carolinian faunal provinces and to the major surface currents.

Cape Cod
Cape Hatteras
ATLANTIC OCEAN
Indian River Region
FLORIDA
GULF OF MEXICO
Cuba
YUCATAN
CARIBBEAN SEA

Figure 2. The Indian River Study area.


Ponce de Leon Inlet
New Smyrna Beach
VOLUSIA COUNTY
Mosquito Lagoon
Indian River
Titusville
Merritt Island
N
River
Cape Canaveral
Port Canaveral
Cocoa
BREVARD COUNTY
Banana
ATLANTIC OCEAN
Eau Gallie
Canova Beach
Melbourne
Sebastian Inlet
Sebastian Creek
INDIAN RIVER COUNTY
N. Canal
Vero Beach
Riomar Beach
S. Canal
Harbor Branch Foundation Laboratory
Taylor Creek
Fort Pierce Inlet
Fort Pierce
Indian River
ST. LUCIE COUNTY
Jensen Beach
St. Lucie River
Stuart
St. Lucie Inlet
Hobe Sound
St. Lucie Canal
MARTIN COUNTY
Loxahatchee River
Jupiter Inlet

The first major study of the fishes in the Indian River lagoon was conducted by Evermann and Bean (1897). This paper contains a list of 106 species found in the Indian River lagoon and its inlets. However, the report concentrated on species of commercial value and most of the observations were made in local fish houses where precise locality data are frequently lacking or inaccurate.

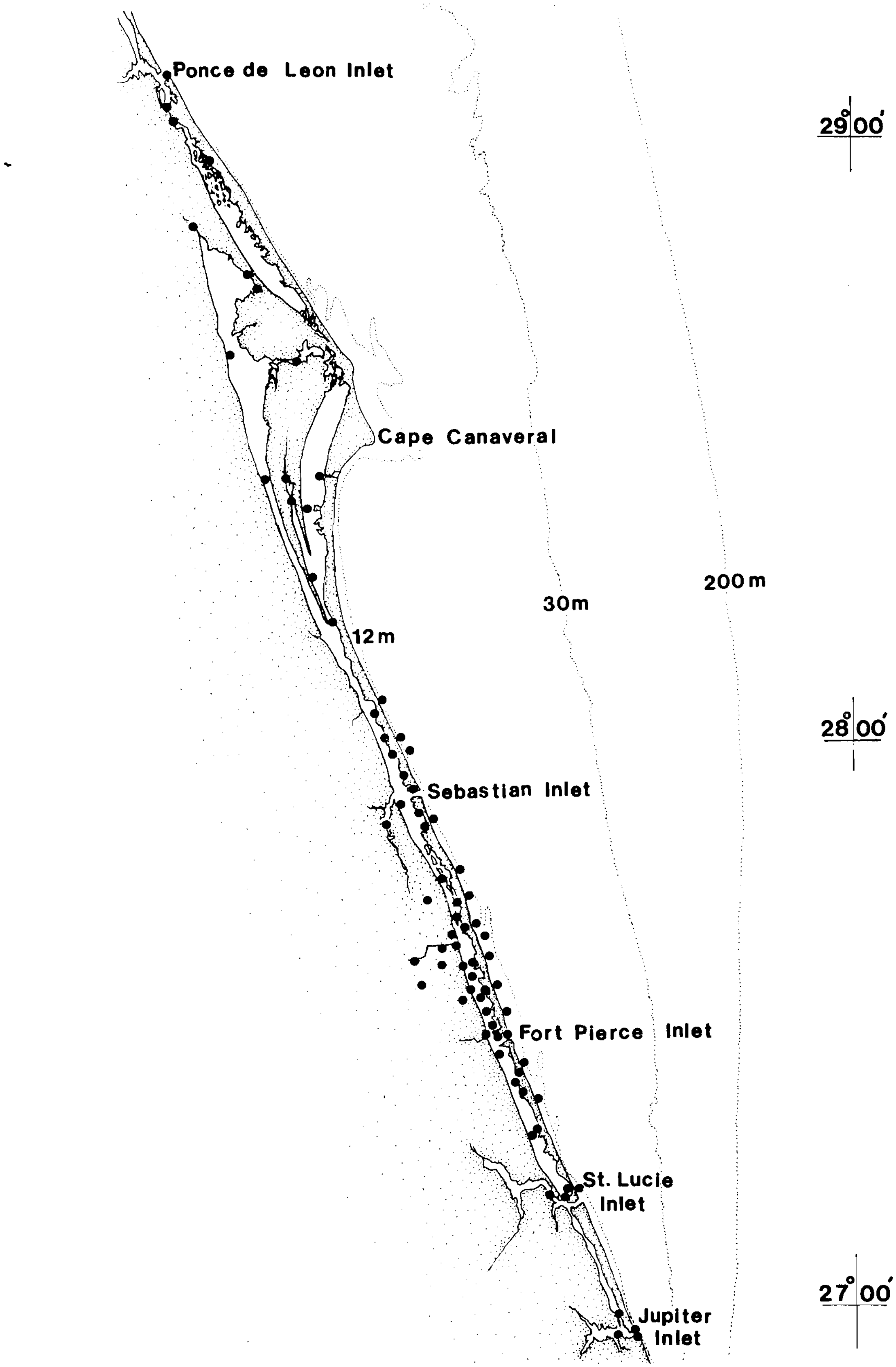
It was not until 1957-1959 that another ichthyological study was made within the Indian River lagoon. During this time Springer (1960) made several collections in the St. Lucie Inlet area (Fig. 2). His report contains a list of 62 species as well as temperature and salinity data from the area. Gunter and Hall (1963) also made fish collections in the St. Lucie River estuary during the same time period, primarily in an effort to assess the effect of freshwater releases from the St. Lucie Canal on the local fish fauna. Seasonal temperature and salinity data were taken along with the 83 fish species collected in their survey. From 1960 to 1965 Christensen (1965) made a qualitative seasonal survey of the fishes found in the Jupiter Inlet area and associated freshwater tributaries at the extreme southern end of the Indian River (Fig. 2). This was the most extensive survey to date in the Indian River region and presents data on 276 species, a number of which are tropical fishes not previously recorded as far north as jupiter. All of the Indian River regional collections above, combine to give 286 species.

Extensive fish collections from the continental shelf east of the Indian River lagoon are also lacking. From 1933 to 1935 the trawler R/V LAUNCH 58 made offshore fish stations (less than 94 trawling hours) on the continental shelf adjacent to the Indian River lagoon (Anderson and Gehringer, 1965). Quantitative trawl data were given on 64 species. From 1956 to 1957 and 1961 to 1964 the R/V SILVER BAY, R/V COMBAT, and R/V PELICAN made 421 trawl stations in this region. The 105 species collected by all three vessels were compiled in a publication by Bullis and Thompson (1965). Anderson and Gehringer (1965) published a report on both the offshore and inshore fishery in the Cape Canaveral area (134 species). However, their publication concentrated only on a few species of value to commercial and sportfisherman and reviewed the previous continental shelf collections made by the aforementioned research vessels. Stewart Springer (1963) published an account of sharks from data taken in an offshore shark fishery based in Salerno, Martin County (17 species). All of the continental shelf collections record approximately 209 fish species.

The combined total of fishes reported from the Indian River lagoon and adjacent continental shelf is 453 species. Although Briggs (1958) did not collect here, he lists some 453 species that should range through the region. The 453 species reported by Briggs are not necessarily the same reported by previous authors. The intent of the current investigation is to fill in the gaps left by the above papers and make an updated assessment of the local ichthyofauna along with the regional physical descriptions.

In November 1971 collecting of fishes began in the Indian River lagoon for the Harbor Branch Foundation as part of a field study program to qualitatively assess the estuarine and marine fauna of the Indian River region. By the end of 1972 over 1,000 collections were made at 79 different stations (Fig. 3). These species were placed in a catalogued reference collection. Collections were made

Figure 3. Collecting stations in the Indian River lagoon and nearshore Atlantic.


Ponce de Leon Inlet
29°00′
Cape Canaveral
200m
30m
12m
28°00′
Sebastian Inlet
Fort Pierce Inlet
St. Lucie Inlet
27°00′
Jupiter Inlet

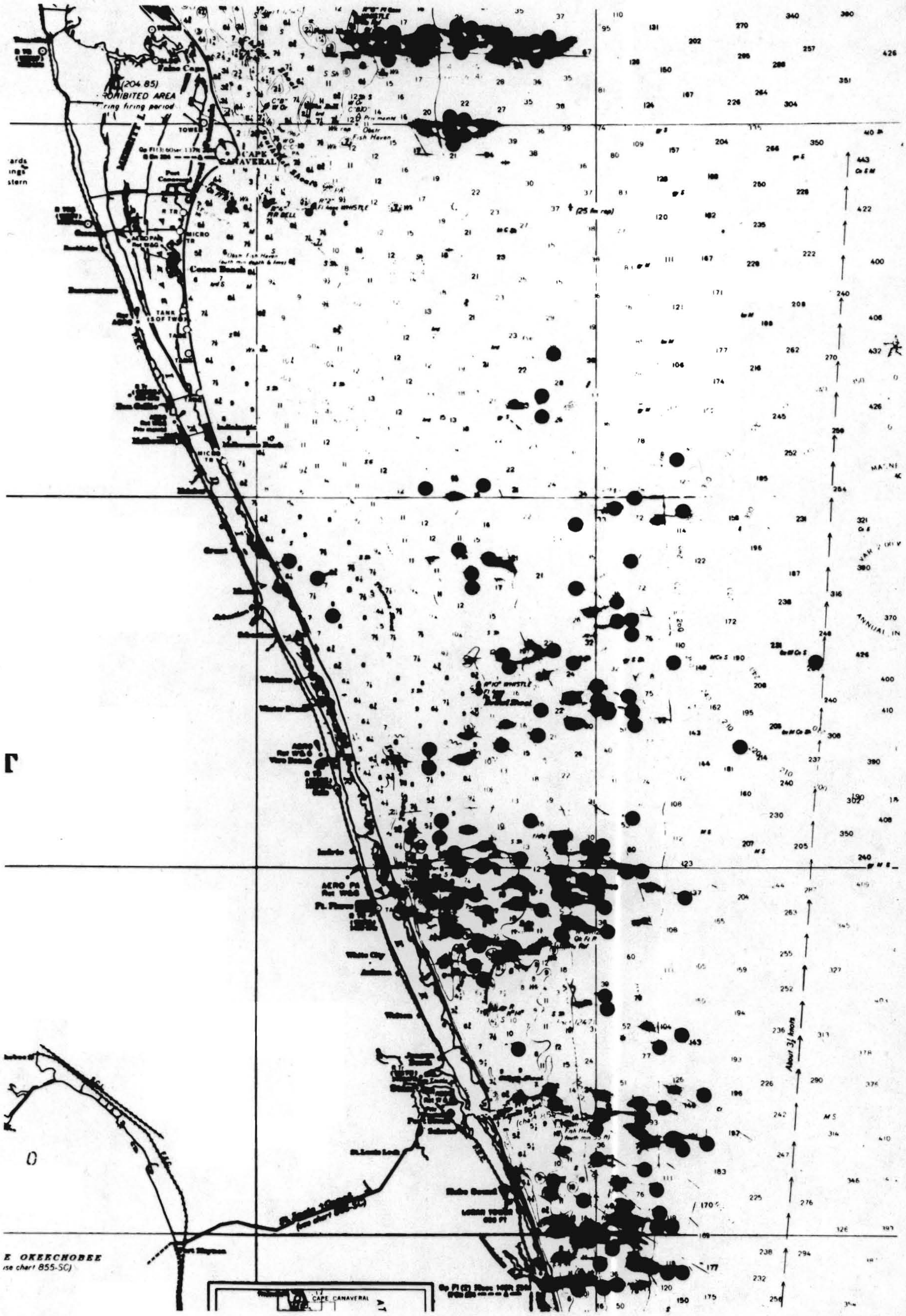
in the Indian River lagoon, its freshwater tributaries and nearshore Atlantic reefs along 155 coastal miles extending from New Smyrna Beach to Jupiter Inlet. Continental shelf collecting was minimal at this time as we had neither adequate surface vessels nor permits necessary to use trawl nets. The reference collection, containing 1,182 museum entries and over 300 species, was deposited in the Florida State Museum at Gainesville because space was limited at the Harbor Branch Foundation.

During the Fall of 1973 a collecting permit was acquired and offshore trawl stations were established as part of the Indian River Study. Although quantitative collections were initiated in the estuary as part of this program, the shelf collections remained exploratory and qualitative with periodic trawl sampling from the R/V GOSNOLD (on loan from Woods Hole Oceanographic Institute). Beginning in April 1974 fishes were also taken by a Florida State Department of Natural Resources vessel, the R/V HERNAN CORTEZ, operating in the Atlantic off of Cape Canaveral. The DNR kindly made these specimens available to the Indian River Study. The two vessels together resulted in 129 offshore collection stations (Fig. 4).

Equipment and Methods

Collecting techniques centered around juvenile fish populations in shallow water grass flats and mangrove areas. Therefore, small mesh (3 to 6.4 mm) minnow seines were used extensively in the Indian River, and on occasion in freshwater tributaries and the Atlantic surf zone outside the river. In areas of the Indian River

Figure 4. Continental shelf collection stations. The northern most grouping represents the R/V HERNAN CORTEZ cruises and the remainder are R/V GOSNOLD collections. Of the 129 stations, 76% are otter trawls and the other are dip nets and dredges (Nov. 1973 to Sept. 1974).



(204 85)
CAPE CANAVERAL
Cocoa Beach
Fish Haven
AERO
Ft. Pierce
White City
St. Lucie Lock
About 3½ knots
E OKEECHOBEE
(use chart 855-SC)

where seining was difficult because of water depth, physical obstructions, excessive vegetation, and so forth. Collecting was carried out with other gear including 2 m cast nets (6.4 0 12.8 mm mesh), crab traps, wire fish traps, dip nets and a 180 m (62 mm mesh) gill net.

Collecting was somewhat selective in the Indian River, with the shallow grass flats receiving the greatest collecting effort due to their accessibility, and known effectiveness as a fish habitat. However, observations and collections were conducted in the deeper areas of the river (e.g. 3-5 m depths in the Intracoastal Waterway) using SCUBA gear, spear guns and dip nets.

Fishes collected on the inshore Atlantic reefs and in Jupiter Inlet were all collected with the aid of diving gear, dip nets, spear guns, and quinaldine. Underwater photos were also used for documentation of fishes present. Field notes were kept on the location and approximate numbers of identifiable species observed during SCUBA dives. It should be noted here that reef collecting with rotenone was not allowed by our state collecting permits and therefore many nocturnal and cryptic fishes were not collected.

The sharks were collected principally from the surf zone or areas less than 600 m from the beach with either a longline or conventional fishing gear. The longline was fished near the surface in 10 to 15 m of water. It was constructed of about 600 m of nylon line with 8 to 15 evenly spaced droppers. The hooks ranged in size from 50 to 100 mm, measured from point to shaft. Because of the relatively large hook size employed, the longline selected for larger species of sharks. Most of the smaller specimens were taken with conventional fishing gear.

Offshore surface collections of pelagic species were made with dip nets and conventional fishing gear. A relatively concentrated fishing effort (10 fishing hours per week) was made from 1970 to 1973 by surface trolling east of Sebastian Inlet in depths of 50 to 200 m by LaVergne Williams. Mr. Williams conducted these surveys on his own time and kept accurate records of size and location of offshore catches of gamefish which were included in this survey. Rigged baits such as ballyhoo (*Hermiramphus brasiliensis* or *H. balao*) and artificial lures were used exclusively.

Limited offshore, benthic (over 20 m depths) trawling was accomplished using 2.4 to 7 m (12.7 mm mesh) trynets (otter trawls) from R/V JOIE DE VIVRE, R/V SEA HUNTER (both Florida Institute of Technology research vessels), and later, the R/V HERNAN CORTEZ, (Florida Department of Natural Resources), and the R/V GOSNOLD, (Woods Hole Oceanographic Institute). An all aluminum dredge with a one meter mouth width was also used. The gear and vessels for the majority of the offshore benthic sampling were not available until the latter part of this survey and therefore extensive collections were not made (see Introduction).

Station temperatures were recorded with a thermometer graduated in increments of one degree centrigrade. Salinities were recorded with a temperature compensated, Goldberg refractometer which can be read to 0.5 ppt. Bottom type (dominant vegetation, etc.), shore type, tidal state, weather conditions, water visibility and sea state were also noted at each station.

Results

Physical Description of the Indian River Region

As noted by Evermann and Bean (1897), the term "river" is a misnomer. The Indian River region encompasses a shallow estuarine lagoon extending for 253 km (157 mi) from latitude 29°05'N to 26°58'N (Fig. 3). The northern terminous for this region falls at Ponce de Leon Inlet in Volusia County and the southern at Jupiter Inlet in Palm Beach County (Fig. 2). The width of the lagoon varies from a few meters at the Jupiter Narrows and the south bridge at New Smyrna Beach to 8.9 km (5.5 mi.) north of Titusville. A barrier island forms a narrow strip of land on the east side of the lagoon which has been cut by five artificial inlets of varying size and depth; Ponce de Leon (previously known as Mosquito Inlet), Sebastian, Ft. Pierce (previously known as Indian River Inlet), St. Lucie and Jupiter. The land area on the east bank at Cape Canaveral is the most extensive with a large peninsula, Merritt Island, dividing the Indian River lagoon on the west from the Banana River lagoon to the east (Fig. 2). The average depth is approximately 1.5 m with the maximum occurring in dredged channels and harbors. The Intracoastal Waterway is dredged to an average depth of 3.7 m north of Ft. Pierce and to 3.1 m from Ft. Pierce south to Jupiter. This dredged channel has an average width of 30 m. There is a ship lock at Cape Canaveral connecting the Banana River lagoon with the Atlantic Ocean. However, the opening of this lock depends on daily boat traffic.

The Indian River lagoon north of Titusville is separated on the east bank from the Mosquito Lagoon by a narrow strip of land which is dissected by an open canal (i.e. the Haulover Canal). The northern end of the Banana River is only separated from the Mosquito Lagoon by a shallow marsh with waters coming within 0.8 km of a direct connection between the two. The Mosquito Lagoon and the North Indian River Channel near New Smyrna Beach have been included as part of the Indian River region since no extensive geological or hydrological barriers separate these bodies of water. The dominant plant growth on the banks of the Indian River, the mangroves, Rhizophora mangle, Avicennia nitida, Laguncularia racemosa; the buttonwood, Conocarpus erectus; and the grass Spartina alterniflora are also found from Ponce de Leon Inlet south thus giving this region some vegetative continuity.

Along the west bank of the Indian River lagoon there is a system of relict sand dunes up to 24 m in height. Beyond these dunes, coastal lowlands and marshes extend up to 96.7 km inland. These extensive marshes drain primarily into the northward flowing St. Johns River to the west of the relict dunes, into the southerly flowing Kissimmee River to the west and south, and Lake Okeechobee to the southwest. There are a number of smaller, low gradient rivers, creeks and canals flowing from these western marshes directly into the Indian River lagoon. Callalisa Creek at Ponce de Leon Inlet, Eau Gallie River at Eau Gallie, Crane Creek at Melbourne, Turkey Creek near Palm Bay, Sebastian Creek at Sebastian Inlet, the North, Main and South Canals at Vero Beach and Taylor Creek at Ft. Pierce Inlet all flow out of the St. Johns Marsh and associated freshwater drainages. The St. Lucie River drains 1165 sq. km (450 sq. mi.) in St. Lucie and Martin counties (Gunter and Hall, 1963). This river and adjacent canal system discharge freshwater overflow from Lake Okeechobee and marshes between the lake and the coast at St. Lucie Inlet. According to Christensen (1965) the extensive marshes east of Lake Okeechobee feed into the Loxahatchee River (drain 855 sq. km or 330 sq. mi.) which opens at Jupiter Inlet. The freshwater canals all have locks which are opened or closed depending on climatic conditions and associated water levels further inland. The time and amount of freshwater released from these canals is therefore variable.

Geology -- The barrier island on the east bank and the low-lands and marshes of the west bank, for several kilometers inland, are of Pleistocene age, primarily the Anastasia formation. This formation consists of coquinoid shell marl with varying amounts of quartz sand (Cook, 1945). The formation has been deposited by multiple marine invasions over the St. Johns drainage basin west of the Indian River region. There is a more recent deposit in the area which consists primarily of quartz sand with a maximum thickness of about 3.1m. Further south and out of the study area, the Anastasia formation intergrades into a more calcareous Miami oolite formation.

The lithified coquinoid rock of the Anastasia formation forms rock bluffs at the river's edge at Palm Beach, Melbourne, Eau Gallie and at the south end of Merritt Island on both sides of the Indian River lagoon in Brevard County. These same rock formations occur in the intertidal zone on the Atlantic side at Blowing Rocks on Jupiter Island in Martin and Palm Beach counties. Extensive Atlantic reef formations are found from north of Sebastian Inlet south to Jupiter Inlet, both near shore and out to the 110 m isobath. The deeper reef ledges may be as high as 10 m but are more commonly in the 0.5 to 1.5 m range at least on the inshore reefs. In the lagoon itself, either by dredging or by natural erosion, the coquinoid rock in the Intracoastal Waterway in northern St. Lucie County has been dissected so that along the edge of the waterway a small, 0.5 to 1.0 m high ledge has been undercut to the extent that it forms shelter for numerous invertebrate and fish species.

<u>Salinity</u> -- The salinity of the Indian River lagoon, because of its estuarine nature, varies to different degrees up and down the coast. These variations depend on rainfall, freshwater drainage systems (i.e. how frequently canal locks are opened), evaporation, and access to the Atlantic Ocean (Table 1).

Rainfall contribution fluctuates somewhat depending on the latitude. There is a definite trend for New Smyrna Beach, Volusia County and Cape Canaveral, northern Brevard County to receive more rain than the central counties (Fig. 5, Thomas, 1970). Stuart in Martin County and Jupiter Inlet in Palm Beach County also receive more rainfall than the central lagoon region. Both the northern and southern sections of the Indian River lagoon may receive up to 164 ml more average rainfall than the central region (including southern Brevard, Indian River and St. Lucie counties). The greater rainfall at the northern end of the lagoon and the apparent low volume of water exchanged between Atlantic and lagoon waters north of Titusville should, theoretically, cause this region to be quite brackish during the season of maximum rainfall. Yet to date, no unusually low salinity readings have been recorded from there (Table 1).

There have been many recent changes in the natural system of fresh and marine water exchange within the northern half of the Indian River. The canal connecting Mosquito Lagoon and the Indian River lagoon north of Titusville, the Canaveral Locks, Sebastian Inlet (dredged in 1921), Ft. Pierce Inlet (dredged in 1921), numerous mosquito impoundments (see mosquito impoundment section below), 19 bridges and causeways and many artificial freshwater flood canals (draining marshes and agricultural land west of the lagoon) have caused major changes in the lagoon hydrography and quite likely, species distribution.

Prior to these changes the northern section of the lagoon north of Ft. Pierce had even less exchange with the Atlantic Ocean than at the present time. There was a small, shallow, ephemeral inlet (Indian River Inlet) 3.5 km north of the present Ft. Pierce Inlet. Because of its shallow depths (Evermann and Bean, 1897) the water exchange that did take place must have been localized. This inlet was 154 km south of the northern end of the lagoon (Sebastian Inlet is now 111 km south). Furthermore, Ponce de Leon, Indian River, St. Lucie, and Jupiter Inlets were not dredged regularly and all were frequently closed due to sand deposition from parallel (southerly) nearshore ocean currents. Christensen (1965) notes that from 1942 to 1947 Jupiter Inlet was closed and the Indian River lagoon in this area became fresh. Thus, when the inlets were closed there was little possibility of estuarine discharge and salinities could change considerably depending on climatic conditions. This situation was often countered by turbulent fall and winter storms which sent ocean waters across the barrier islands forming small temporary inlets. It may therefore be presumed that these changing conditions led to extremes of salinity range which when combined with a greater variation in temperature in the northern section of the lagoon might have had a profound influence on faunal diversity, at least seasonally.

Contemporary salinity ranges in the Indian River lagoon are not great except near freshwater sources and are probably not representative of the large scale variations that may have occurred in the past.

It can be seen from Table 1 that major freshwater sources may lower wet season (May-October) lagoon salinities considerably at Wabasso, Vero Beach, North Bridge at Ft. Pierce and at St. Lucie Inlet. At Stuart in Martin County, the St. Lucie River and the St. Lucie Flood Control Canal empty into the Atlantic through St. Lucie Inlet. Here, especially when the locks of the St. Lucie Canal are opened, there may be a large drop in salinity, for example from 23.0 to 0.2 o/oo in less than 24 hours (seasonal range of 0.15 to 36.0 o/oo: Gunter and Hall, 1963; Springer, 1960).

A phenomenon commonly observed in the St. Lucie County and Indian River County area is that of marine waters flooding through the inlets and often extending some distance up the lagoon to the north and south with the tide. These intrusions may remain in the lagoon after tide reversal and result in visible pockets of relatively clear saline water (e.g. 35.0 o/oo) surrounded by more turbid, less saline water (e.g. 28.0 o/oo). The capture of several primary marine fish (e.g. *Caranx ruber*, *Scomberomorous maculatus*, and *Anisotremus virginicus*) at the Harbor Branch Foundation Laboratory, at least 8 km from the nearest inlet (Fig. 2) is indicative of the occasional marine influence, tidal and otherwise, on the Indian River fish fauna.

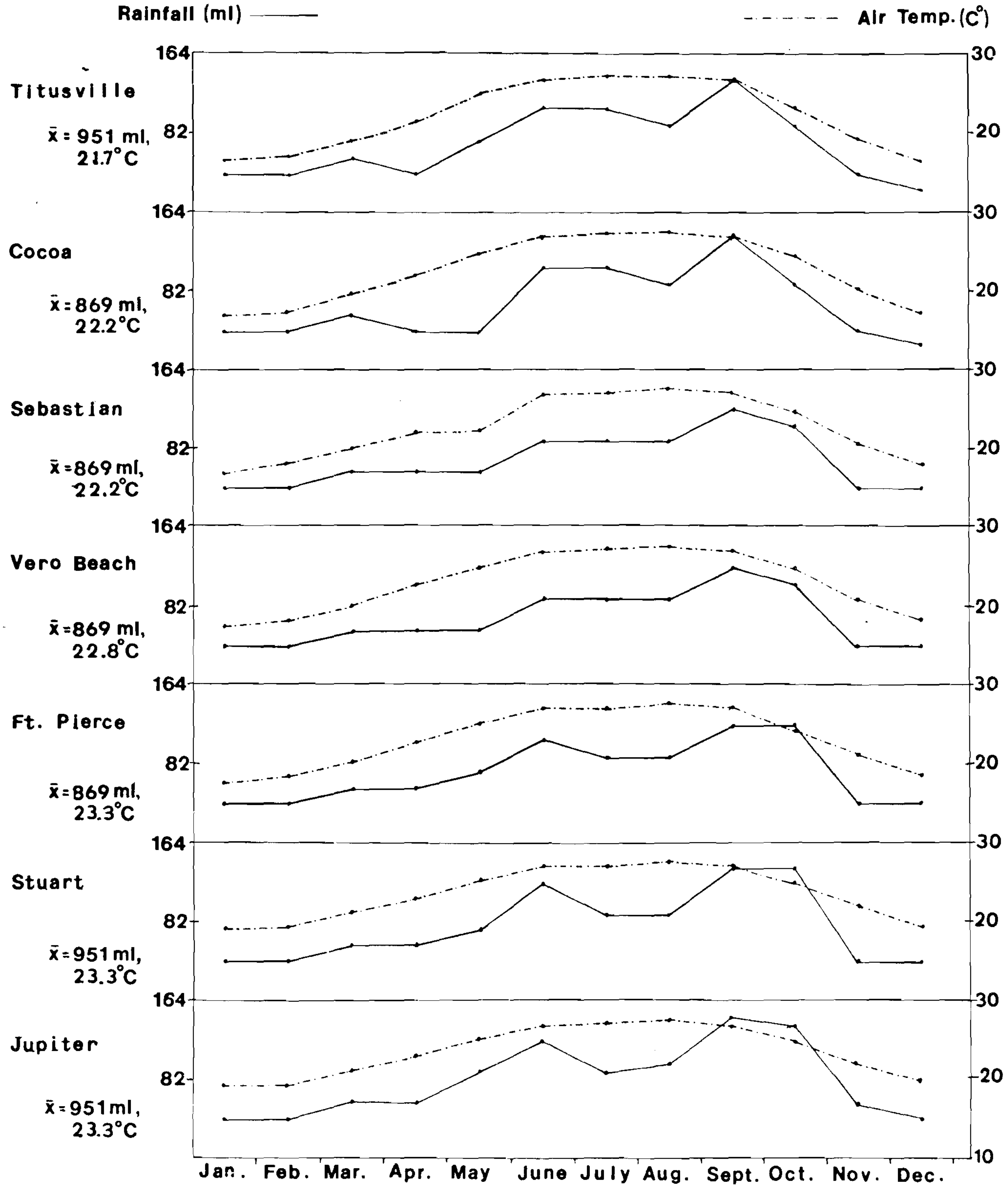
Temperature -- Due to the shallow average depth of the Indian River lagoon, air temperature variations appear to be most effective in controlling water temperature and therefore, the fish distribution within the lagoon. The mean annual air temperature at New Smyrna Beach is 1.6°C lower than at Jupiter (Fig. 5; Thomas, 1970). There is a greater range in annual temperature in the New Smyrna Beach, Ponce de Leon Inlet area than at Cape Canaveral and so on as one proceeds further south (although summer air temperatures, June-August, are relatively homogeneous for the entire lagoon). The fish fauna must therefore adjust its distribution according to the resultant river water temperatures (Table 1).

The lowest water temperature recorded for this region was 11.0°C from the Indian River lagoon in northern Brevard County, whereas Christensen (1965) never recorded a water temperature below 20.0°C in the Indian River lagoon at Jupiter Narrows. There have been periods (e.g. January to February, 1957 - 1958) of very low air temperatures to 0.0°C as far south as Stuart which in turn brought water temperatures down to a lethal low (water temperatures to 14.4°C) for those fishes of tropical and subtropical affinities (e.g. *Megalops atlantica*, *Elops saurus*, *Centropomus undecimalis* and several gerreids; Gunter and Hall, 1963). However, these were unusual conditions for this region of the lagoon.

Atlantic Ocean water surface and bottom temperature readings made adjacent to the coast over the 3 to 10 m isobaths show a trend similar to the air temperatures (Table 2). The low winter temperatures ranged lower in the northern section increasing the annual temperature range substantially over that for the Jupiter Inlet area.

An interesting temperature phenomenon found in this region of Florida was described by Taylor and Stewart (1958). During the summer months (July and August specifically) there is often an annual near shore decrease in water temperatures along the east coast from

Figure 5. Monthly rainfall and air temperatures for the Indian River region[1] (Mean annual rainfall and temperature data are given in the left hand margin ($\overline{x}$).



[1] Data from Thomas, 1970

Table 1. Salinity and temperature ranges for the Indian and Banana River lagoonal systems.

1 - Grizzle, 1968 - 1971
2 - Nevin and Lasater, 1971; Lasater and Carey, 1972
3 - Gore, Gilmore, Williams, et al., 1971 - 1973; Wilcox and Mook, 1972 - 1973
4 - Gunter and Hall, 1963
5 - Christensen, 1965

STATIONS	DATE	N	Salinity Range o/oo	$\bar{x}$	N	Temp. Range (°C.)	$\bar{X}$
Brevard Co.							
Haulover Canal	Jan. 1968 - May 1971	?	27.0 - 38.0	32.5	?	11.0 - 30.0	22.7
Indian R. Titusville[1]	Jan. 1968 - May 1971	?	20.0 - 37.5	30.2	?	11.0 - 30.0	22.7
Indian R. Titusville[2]	Nov. 1971 Aug. 1972	?	21.0 - 34.0	29.1	?	17.0 - 37.9	25.7
Indian R. Cocoa	Jan. 1968 May 1971	?	18.8 - 36.6	25.8	?	12.0 - 30.0	22.7
Banana R. S.R. 520[1]	Jan. 1968 May 1971	?	9.3 - 34.5	21.8	?	? - 30.0	22.2
Indian R. Melbourne[1]	Jan. 1968 May 1971	?	11.6 - 34.0	22.3	?	12.0 - 30.0	23.3
Indian R. 12.9 km N. of Sebastian Inlet	Jan. 1968 May 1971	?	11.6 - 37.2	25.1	?	14.0 - 29.0	22.2

Table 1 (cont'd).

STATIONS	DATE	N	Salinity Range o/oo	$\bar{x}$	N	Temp. Range (°C.)	$\bar{x}$
Brevard Co. (cont'd.)							
Indian R. 1.6 km N. of Sebastian Inlet[3]	Dec. 1971 Nov. 1972	(137)	16.0 - 35.0	28.6	(137)	15.0 - 29.0	24.0
Indian River Co.							
Indian R. Wabasso[3]	Dec. 1971	(137)	4.0 - 36.0	22.9	(137)	13.0 - 29.0	23.5
Indian R. Vero Beach[3]	Dec. 1971 Nov. 1972	(137)	6.0 - 32.0	22.5	(137)	16.0 - 30.0	24.1
St. Lucie Co.							
Indian R. HBF Lab[3]	Dec. 1971 Sept. 1973	(704)	18.5 - 37.0	29.8	(704)	13.0 - 31.0	24.3
Indian R. N. Bridge Rt. AIA[3]	Dec. 1971 Aug. 1972	(98)	16.0 - 36.0	31.0	(98)	17.0 - 30.0	24.7
Indian R. S. Bridge Ft. Pierce[3]	Dec. 1971 Jan. 1973	(122)	29.0 - 36.0	25.1	(122)	17.0 - 30.0	22.1
Indian R. 6 km S. of S. Causeway Ft. Pierce[3]	Jan. 1971 Feb. 1973	(142)	18.0 - 36.0	30.0	(137)	14.0 - 29.5	23.4

Table 1 (cont'd.)

STATIONS	DATE	N	Salinity Range o/oo	$\bar{x}$	N	Temp. Range (°C.)	$\bar{x}$
Martin Co.							
Mouth of St. Lucie River & Indian R. at Sewall Pt.[4]	Jan. 1957 Jan. 1959	(55)	0.15 - 32.8	10.7	(112)	14.4 - 30.9	23.3
Palm Beach Co.							
Jupiter Inlet	July 1960 Jan. 1965	(29)	16.5 - 37.5	31.8	(31)	20.5 - 36.0	27.5
Mouth of C-18 Canal S. Fork Loxahatchee R.[5]	July 1960	(4)	1.5 - 30.2	15.5	(4)	22.0 - 32.5	27.5

Table 2. Regional surface and bottom seawater temperatures, continental shelf (from Clark, et al., 1970)

Latitude and Date	Surface (s) and Bottom (b) Temperatures (°C.)											
Longitude	80°40'		80°30'		80°20'		80°10'		80°00'		79°50'	
29°00'	(s)	(b)	(s)	(b)	(s)	(b)	(s)	(b)	(s)	(b)	(s)	(b)
May	23,5	23,0	23.0	22.0	24.0	19.0	25.0	18.0	26.0	17.0		
July - Aug.	26.5	23.0	27.0	22.0	27.5	20.0	28.0	19.0	29.0	14.0		
Oct.	23.5	24.0	24.0	24.0	26.0	25.0	26.5	23.0	27.0	19.0		
Jan. 0 Feb.	15.0	14.0	18.0	15.0	21.0	17.0	22.0	17.5	24.0	18.0		
28°30'												
May			24.5	23.0	24.5	22.0	25.0	19.0	26.0	16.0		
July - Aug.			27.0	23.0	26.0	18.0	26.5	15.0	27.0	11.0		
Oct.			25.0	24.0	26.5	25.0	27.0	25.0	27.0	19.0		
Jan. - Feb.			16.0	15.5	20.0	17.0	22.0	18.0	22.0	16.0		
28°00'												
May			23.4	23.0	24.0	22.0	24.5	20.0	25.0	17.0		
July - Aug.			26.0	24.0	27.0	22.0	27.5	17.0	28.0	13.0		
Oct.			24.5	24.0	26.0	25.0	26.5	25.0	27.0	16.0		
Jan. - Feb.			17.0	17.0	19.0	17.0	21.0	18.0	22.0	18.5		

Table 2. (cont'd)

Latitude and Date	Surface (s) and Bottom (b) Temperatures (°C.)											
Longitude	80°40'		80°30'		80°20'		80°10'		80°00'		79°50'	
27°30'	(s)	(b)	(s)	(b)	(s)	(b)	(s)	(b)	(s)	(b)	(s)	(b)
May					23.5	24.0	24.0	21.0	25.0	18.0	26.0	16.0
July - Aug.					26.0	24.0	28.0	21.0	29.0	14.0	29.0	13.0
Oct.					24.5	24.0	25.5	25.0	26.0	18.0	27.0	11.0
Jan. - Feb.					20.0	19.0	21.0	20.0	23.0	20.5	24.0	21.0
27°00'												
May									26.0	20.0	26.0	16.0
July - Aug.									29.0	16.0	29.0	13.0
Oct.									26.0	24.0	27.0	11.0
Jan. - Feb.									23.0	22.0	24.0	22.0

Fernandina Beach to West Palm Beach, with the most dramatic drop in temperature occurring around Daytona Beach and Cape Canaveral. Readings made in the Canova Beach area (Brevard County), 34 km north of Sebastian Inlet, showed a steep temperature drop, that persisted through July and August, of from 26.7° in June to 22.3°C in July, well below the average surface temperatures taken there in 1956. The prevailing wind direction during these periods was offshore, pushing surface waters offshore with a subsequent upwelling of cooler bottom water near shore. Summer upwellings are also common in the St. Lucie area (S. Springer, 1963). Harbor Branch personnel observed an unusually low surface seawater temperature of 22.0°C in August 1972 at Sebastian Inlet (flood tide, salinity of 35.5 o/oo).

The seaward influence of these cold water upwellings is uncertain, but a decline in the fishing associated with this phenomenon has been reported by commerical and sport fishermen. The associated decline in fishing has been observed out to a depth of 40 m (6.4 to 33.6 km offshore) and has been blamed for fish kills (S. Springer, 1963). Atlantic surface and bottom temperatures are given in Table 2).

Studies have not yet been conducted to see that effect this upwelling of cold water might have on the nearshore reef fish fauna which has definite tropical affinities (see Atlantic reef biotope section below). Christensen (1965) has noted this cold water upwelling in June and August at Jupiter, He saw indications of "temporary distress in some shore fishes" but did not see "winter kill" as Gunter and Hall (1963) noted for the St. Lucie area. During the other months of the year the predominant wind direction is from the northeast or southeast pushing surface waters toward shore.

Regional Biotopes and Associated Fishes

Indian River Lagoon

Freshwater Tributaries and Canals -- The major freshwater rivers, streams and canals that feed into the Indian River lagoon fall into this biotope. Limited observations by the author have indicated that where stream vegetation has not been disturbed by man there is a dense shore cover of such plants as *Panicum*, *Typha*, etc.; a variable quantity of submerged plants such as *Elodea densa* and *Hydrilla verticillata*; and a surface cover of *Eichhornia crassipes*, *Pistia stratioites* or *Pontederia lanceolata*. The dominant plant depends on stream flow, substratum and other physical variables. All streams in this region of Florida have a shallow gradient and currents are generally moderate to sluggish, depending on rainfall or floodgate manipulation. The water level and flow rate may increase when a lock holding back significant amounts of stored water is opened.

Table 3 shows that 107 fish species have been collected from the freshwaters of this biotope. Fifty-nine of these fishes (55%) are euryhaline and also found in brackish to marine waters either in the Indian River lagoon or in the Atlantic Ocean (e.g. cyprinodontids, poeciliids, centropomids, etc.).

Canal and River Mouths -- This biotope is characterized by a wide salinity range (0.0 - 33.0 o/oo; mean salinity 15.0 o/oo) relative to adjacent marine and freshwater biotopes (Table 1). The predominant bottom type issand-mud and aquatic vegetation is not extensive. Halophilic species are lacking and where natural shore vegetation has not been destroyed there is a gradual transition from *Rhizophora* and Spartina to Taxodium and Typha. The water quality varies considerably with tide cycles but is generally turbid with organic detrital material, tannin and suspended sediments.

These areas are truly estuarine and the fish fauna consists of a euryhaline species group with marine affinities (Table 3). Of the 109 fish species that occur in this biotope, 38 (35%) are also known to occur in the strictly marine waters of the Atlantic as well as freshwater. Twenty-two species (20%) are found in freshwater and in the estuary but do not enter the Atlantic and 17 (16%) remain in the estuary but do not range into freshwater or the Atlantic. The remaining 30 species (28%) occur in the strictly marine Atlantic waters and the estuarine biotope but do not enter freshwater.

Local commercial and sportfishing interests claim that a large drop in salinity within a short period of time, such as the situation occurring periodically in the St. Lucie Estuary, may limit the number of marine invaders into the estuary and reduce their fish catches. Contrary to the opinion of local sport fishermen, Gunter and Hall (1963) state that "the St.Lucie Estuary is characterized as an area of high production of a wide variety of sport and food fishes a condition which has developed and has been enhanced by periodic discharges of freshwater and nutrient materials" (from the St. Lucie canal). They have found that the largest collections of Mugil, Brevoortia, Micropogon, Menidia and Anchoa mitchilli occurred during or after freshwater releases from the St. Lucie canal. On the other hand, Gunter and Hall did note that Trachinotus and small lutjanids left the estuary when very low salinities were prevalent.

Mosquito Impoundments -- The mangroves listed previously are the most dominant and conspicuous shore line vegetation throughout the Indian River lagoon. However, a recent development in this region which has had great effect on the mangrove community is the extensive impoundment of many acres of tidal mangrove stands (Provost, 1959 and 1967). Dikes were built around high marsh vegetation to stop tidal movement of water from the lagoon to the intertidal zone. This prevented the salt marsh mosquitos (i.e. Aedes sollicitans and A. taeniorhynchus) from laying their eggs in the intertidal sediments. In most instances an effort was made to impound only high marsh vegetation (i.e. Avicennia rather than Rhizophora, etc.). Tidal movement of detrital material from the impounded vegetation to lagoon waters has been precluded over thousands of acres throughout the Indian River region. In some cases water levels in the impoundments covered the pneumatophores of Avicennia nitida and the prop root lenticles of Rhizophora mangle thus killing many acres of mature trees in St. Lucie and Indian River counties. The ecological value of the mangrove community to an estuary cannot be overestimated. Many recent studies (e.g. Odum and Heald, 1972) have shown a significant contribution from mangroves to the primary productivity of the estuary. Remnant and recent mangrove growth can be found on the lagoon side of the impoundments but their contribution to the lagoon ecosystem is undetermined.

In general, the impoundment ichthyofauna consists of a small number of species but large numbers of individuals. This response is considered typical of ecosystems such as the impoundments that are under stress. The salinity regime, amount and type of vegetative growth, and so forth, of each impoundment can be very different and the capacity to support a diverse fish fauna will depend on such variables.

In some impoundments salinity varies considerably (0 - 41 o/oo) depending on rainfall, evaporation, ground water, artesian flooding and the salinity of the water pumped into the impoundment from the lagoon. However, the fishes found consistently in these areas are generally euryhaline and capable of living on the food resources available (e.g. Gambusia affinis, Poecilia latipinna, Lucania parva, Cyprinodon variegatus).

Although the total ecological effect of impounding is unknown, the current fish faunas of both the impoundments and the Indian River lagoon can be compared (Table 3). Twenty-six species have been collected from mosquito impoundments all of which also occur in the Indian River lagoon. However this is only 7.3% of the 356 species recorded from the unimpounded waters of the Indian River lagoon (Table 3).

Harrington and Harrington (1961) give an account of the feeding habits of 16 larvivorous fish species in the salt marsh-mangrove community before impoundment in St. Lucie and Indian River counties. Twelve of these species are still known to occur in the impoundments while four have been found only in the lagoon. Provost (1967), in referring to unpublished data taken by Harrington, notes that after impounding there was a decrease in fish species that prior to impounding lived in the mangrove community but spawned elsewhere (e.g. Mugil, Megalops, Centropomus, Eucinostomus, Diapterus). A similar decrease was noted in herbivorous fishes. Non-larvivorous species were reduced from 34% of the total mangrove fish community to 5% after impoundment, while predators on mosquito larvae comprised the remaining 95%.

Open Sand Bottom -- The majority of the lagoon bottom is a fine sand-shell mixture. There is generally a fine anaerobic mud ooze adjacent to the nearshore mangroves and a very fine silt layer over the exposed bottom in the Intracoastal Waterway. The salinities over these sand flats, away from freshwater tributaries, range between 18.0 and 37.0 o/oo (mean approximately 30 o/oo, Table 1).

Of the 111 fish species (Table 3) consistently found over this open bottom, 33 (30%) spend the majority of their time over or on the sand-mud substrate (e.g. dasyatids, synodontids, triglids, dactyloscopids, bothids, etc.) and only occur over grass beds or other substrate during limited movements and migrations.

Spermatophyte Grass Flats -- Lagoon flats (depths of less than 2 m) adjacent to shore support heavy to moderate growth of the marine spermatophytes, *Syringodium filiforme*, *Haldule wrightii*, *Ruppia maritima*, and *Thalassia testudinum*. The *Thalassia* beds are generally isolated and are apparently not found north of Melbourne. *Syringodium* is dominant in the lagoon as far north as Mosquito Lagoon. *Halodule* is found throughout the lagoon and is the next most abundant grass. *Ruppia* has been found at Sebastian Inlet and the mount of the St. Lucie River near St. Lucie. Harbor Branch investigators have also observed it in several freshwater lakes in the vicinity (e.g. Lake Hobart) and as far north as the Haulover Canal (N. Eiseman, personal communication). *Halophyla baillonis* is also found in the lagoon but is rare and associates with the more common spermatophyte species (*Halodule* and *Thalassia*).

During certain seasons of the year (i.e. generally late summer and fall) large amounts of algae (e.g. *Gracilaria foliifera* and *Acanthophora spicifera*) also accumulate in the grass beds. The epiphytic algal growth in these grass beds can be considerable. However, the actual contribution of algae to the primary productivity of this biotope is undetermined.

Salinities here are identical to those discussed in the previous open sand bottom biotope.

One hundred and eighty-five fish species have been collected in the grass flat biotope (Table 3). This biotope harbors the richest fish fauna in the Indian River lagoon. Of these species, 170 (92%) are found here primarily as juveniles (e.g. serranids, lutjanids, sciaenids, pomadasyids, etc.). The prominent role the grass flat biotope plays as a nursery for the local fishes is obvious.

Lagoon Reefs -- This biotope may consist of artificial (e.g. wrecks, pilings, etc.) or natural relief above the lagoon bottom. The submerged rock ledges cut in the Intracoastal Waterway (depths 3 to 5 m) show a relief up to 1.5 m and support a surprising gorgonian coral growth.

Eighty-six fishes have been collected in this biotope and 51 (66%) of these are considered primary reef fishes (e.g. chaetodontids, pomacentrids, pomadasyids, etc.; (Table 3). It is not known whether these fishes invade the lagoon seasonally or have permanent estuarine populations.

Inlets -- All five inlets and Port Canaveral have granite rock jetties extending seaward. The inlets are kept open to boat traffic by continual maintenance dredging. Prior to periodic dredging, the inlets in this region were ephermeral and when open were very shallow. All typically have a shallow (2 - 4.5 m depth) sand bottom. Tidal currents are generally swift with a 3.1 kn average ebb tide velocity recorded from mid-stream in Ft. Pierce Inlet. The salinity range in the inlets is generally not as great as that further up or down the river or in the back estuary (Table 1). However, this is obviously dependent on the amount of freshwater input from the hinterland plus the fact that those inlets associated with substantial river systems have the larger salinity ranges (e.g. St. Lucie and Jupiter inlets).

One hundred and twenty-nine (47%) of the 272 fish species recorded from the inlets (Table 3) are normally associated with the nearshore Atlantic reefs and occur around inlet jetties at least from Sebastian Inlet south. Those fishes that make periodic migrations from the lagoon to the Atlantic or vice versa are also occasionally found associated with the jetties. These fishes are either maturing and leaving the lagoon nursery grounds for adult feeding grounds offshore (e.g. serranids) or are making temporary offshore spawning migrations (e.g. sciaenids). Many larval and juvenile fishes enter the lagoon through the inlets.

Continental Shelf

Surf-Zone-Sand/Shell Bottom -- This biotope is characterized by a sand-shell bottom and is continuously under the influence of wave turbulence. The shallow sub-littoral (less than 2 m depth) and littoral zone are included in this region. Besides the surf, a major limiting factor is the lack of cover with the sand substrate. This becomes apparent when the surf zone reef fauna is compared with this open sand bottom fauna (see below). Little or no macroscopic, attached vegetation grows here, however, many burrowing invertebrates do occur (e.g. Emertia, Donax, etc.).

Because of the limiting nature of this biotope only 60 fish species have been found to occur here to date (Table 3). Although roving carnivores (jacks, mackerals, ladyfish, bluefish, etc.) and planktivores (herrings, anchovies, etc.) may occur in the surf zone, the dominant fishes are bottom feeding carnivores (catfishes, lizardfishes, croakers, threadfins, and pompanos) that feed on the burrowing invertebrate fauna.

Surf-Zone Reef -- Coquinoid rock forms a protective littoral and sub-littoral surf zone reef at the various localities given in the regional physical description section of this paper. This rock structure may support the growth of sabellariid worm colonies and the protection afforded may result in an increase of the fish species in the surf zone. Although some of these inshore rock ledges just south of Cape Canaveral have been observed to disappear from year to year due to shifting sand masses along the surf zone, the larger reefs appear to be permanent.

The predominant sabellariid reef builder in this area is Phragmatopoma lapidosa which may settle on old worm colonies, pier pilings (and other man-made structures), or on the coquinoid rock formations. In Brevard County the largest surf zone sabellariid reefs are found from Canova Beach to the Patrick Air Force Base pier. In Indian River County there are large nearshore sabellariid reefs 4.8 km south of Sebastian Inlet and at Riomar Point at Vero Beach. In St. Lucie County there is a large sabellariid reef at "Walton Rocks" 15.7 km south of Ft. Pierce Inlet. In Martin County another reef extends 1.6 km north from St. Lucie Inlet. All of these reefs are exposed to some extent at low tide and all give a 1 to 2.5 m relief above the bottom, providing cover for fishes.

The surf zone reef fish fauna is dominated by individuals capable of thriving in this turbulent high energy zone (Table 3). Although 83 fish species have been found to associate with these reefs they are numerically dominated by two benthic species, Labrisomus muchipinnis and Blennius cristatus; and three epibenthic species, Diplodus holbrooki, Anisotremus virginicus and Haemulon parrai. The majority of the other fishes that occasionally occur on the surf zone reef are primary reef fish that more commonly occur on the deeper (over 2m) coquinoid reefs offshore.

Offshore Reefs -- Extensive lithified coquinoid and other types of organic reefs are found parallel to shore and beginning on the average 100 to 300 m from shore. These reefs run north of Sebastian Inlet for at least 48 km and south beyond Jupiter Inlet. Near shore, these reefs show a relief from 0.5 to 3 m above the bottom and are in 2 to 7 m of water. Similar formations are found in 10 - 13 m, 20 - 23 m, 33 - 40 m 60 - 80 m and 100 - 110 m depths. A maximum relief of 10 to 20 m has been recorded from the deeper reefs. The nearshore reefs have a definite seaward slope to the reef top with the low end seaward and they may have multiple ledges running parallel to shore. Extensive formations of this type are found at several locations along the coast. Relatively large shallow reefs (at 3 to 7 m depths) are located 3.2 to 4.8 km south of Wabasso Beach, 12.9 to 21 km north of Ft. Pierce Inlet in Indian River County and off Pepper State Park in St. Lucie County. The reef ledges are eroded extensively forming elaborate interconnecting caves. This provides abundant shelter for many primary reef fishes (i.e. pomadasyids, chaetodontids, pomacentrids, serranids, labrids, etc.) and supports a popular and highly productive commercial/sports fishery (Moe, 1963) for snapper (mostly Lutjanus campechanus and Rhomboplites aurorubens) and groupers (mostly Epinephelus morio and Mycteroperca microlepis).

Very little coral has been found on these reefs with the exception of small coralla of Oculina and isolated spots of siderastraeid and montastraeid corals. There is an abundant algal growth (e.g. Sargassum, etc.) on the reefs south of Sebastian Inlet throughout the year. Many of the juvenile fishes associated with the reef are found schooling or hiding amid this prolific algal growth (e.g. Bairdiella sanctaeluciae, and many pomadasyid juveniles). Gorgonians, sponges and ascidians are also found amid the algae. The gorgonians are not as conspicuous or as abundant as they are on the rock ledges in the Introcoastal Waterway within the lagoon.

The water clarity during summer months gives 5 to 6 m visibility on a good day. During the rest of the year when periodic strong winds (10 - 25 kts) blow out of the northeast or southeast, the water over the reefs is turbid and turbulent and observations or collections on these reefs are difficult. Nearshore water turbidity decreases further south as the continental shelf narrows, water depths increase and the axis of the Florida Current comes closer to the coast (Fig. 1). During times of calm weather the water visibility in Jupiter Inlet at flood tide is between 5 and 10 m.

One hundred and eighty fish species have been recorded from the nearshore reefs (3 to 7 m depth; Table 3). One hundred and fifty-nine (88%) of these species are Caribbean reef fishes. However, because of collecting difficulties, this reef fauna has not been assessed completely and is probably richer than indicated.

The seasonality of the tropical representatives of this near shore reef fish fauna is speculative. A single examination of the Pepper Park reef in January indicated that at least 32 of these tropical fishes may remain on the reef throughout the year (Table 4). Further north, the tropicals might well make a seaward migration to deeper reefs where seasonal temperature change is not as dramatic. However, the offshore reef fish fauna (depths over 10 m)has not been investigated.

Benthic - Open Shelf -- This biotope is an open plain of sand and shell extending for several meters or kilometers between reef lines. The predominance of shell or sand is variable. Dredge samples have on occasion brought up large bottom samples consisting of the scallop *Aquipecten irradians*. In certain locations the clam *Chione* also made up a large portion of the shell hash bottom. Near the seaward edge of the shelf (to depths of 200 m) a fine sand-mud bottom predominates. The temperature patterns for this biotope are given in Table 2. The current patterns are basically unknown for this shelf zone but there appear to be variable eddies leaving the Florida Current (Fig. 1) which may change with season and wind direction.

The fish fauna of the open shelf, collected to date, consists of 140 species (Table 3). Pleuronectiform fishes, ophidids and triglids dominate this biotope. Other species, which have also adapted to an open bottom existence (e.g. ogcocephalids, dasyatids, etc.) are commonly found here. There are several groups which appear here in seasonal spawning aggregations (e.g. sciaenids). Some families characteristic

Table 3. Regional fishes and biotopes from which fishes have been collected. Asterisk (*) indicates a species or family collected during this study. Previous surveys are coded numerically and the authors and codes appear at the end of the table.

N = Neritic
B = Benthic-open shelf
R = Offshore Reefs
SR = Surf Zone Reef
SS = Surf Zone-Sand/Shell Bottom
I = Inlets

GF = Grass Flats
SB = Open Sand Bottom
LR = Lagoon Reefs
CRM = Canal and River Mouths
FTC = Freshwater Tributaries and Canals
MI = Mosquito Impoundments

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Branchiostomidae													
<u>Branchiostoma</u> <u>virginiae</u> (Hubbs)*	13		+						+				
Orectolobidae													
<u>Ginglymostoma</u> <u>cirratum</u> (Bonnaterre)*	6		+	+	+	+	+		+				
Rhincodontidae													
<u>Rhincodon</u> <u>typus</u> Smith*		+											
Odontaspididae													
<u>Odontaspis</u> <u>taurus</u> (Rafinesque)*	7,6	+		+									
Alopidae													
<u>Alopias</u> <u>superciliosus</u> (Lowe)*	11	+											
Lamnidae													
<u>Carcharodon</u> <u>carcharias</u> (Linnaeus)*	6	+											
<u>Isurus</u> <u>oxyrinchus</u> Rafinesque*	6	+											
Scyliorhinidae													
<u>Galeus</u> <u>arae</u> (Nichols)*	8,7		+										
<u>Scyliorhinus</u> <u>retifer</u> (Garman)*	6	+	+										

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Carcharhinidae													
Aprionodon isodon (Valenciennes)*	6	+											
Carcharhinus acronotus (Poey)*	6	+		+									
C. altimus (Springer)*	6	+		+									
C. falciformis (Bibron)*	7,6	+											
C. leucas (Valenciennes)*	6	+		+	+	+	+	+	+	+	+	+	
C. limbatus (Valenciennes)*	4	+		+	+	+	+	+	+	+	+	+	
C. longimanus (Poey)*		+											
C. maculipinnis (Poey)*	12	+		+									
C. milberti (Valenciennes)*	7.6,1	+											
C. obscurus (Lesueur)*	6	+		+									
C. springeri (Bigelow & Schroeder)*		+		+									
Galeocerdo cuvieri (Peron & Leusueur)*	6	+		+									
Mustelus canis (Mitchill)	4		+				+		+				
M. norrisi (Springer)	8		+										
Negaprion brevirostris (Poey)*	8,7,6	+	+	+									
Rhizoprionodon terraenovae (Richardson)*	7,1	+	+										
Sphyrnidae													
Sphyrna lewini (Griffith & Smith)*	6	+											
S. mokarran (Ruppell)*	6	+											
S. tiburo (Linnaeus)*	7,4,1	+					+	+					
S. zygaena (Linnaeus)	7,6,1	+											
Squalidae													
Squalis acanthias Linnaeus	7,1	+											
Pristidae													
Pristis pectinata Latham*	4,1							+	+				
P. perotteti Muller & Henle*	11							+	+				
Rhinobatidae													
Rhinobatos lentiginosus (Garman)	4		+			+							

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Torpedinidae													
Narcine brasiliensis (Olfers)*	8,5,4		+			+	+						
Torpedo nobiliana Bonaparte	8,7		+										
Rajidae													
Raja eglanteria Bosc*	8,7		+										
R. garmani Whitley	8		+										
R. texana Chandler	8		+										
Dasyatidae													
Dasyatis americana Hildebrand & Schroeder	7		+										
D. sayi (Lesueur)	8,7,1		+						+				
D. sabina (Lesueur)*	7,4,3,2,1		+					+	+		+	+	
D. centroura (Mitchill)	7		+										
Gymnura micrura (Bloch & Schneider)	8,7,1		+					+	+				
Myliobatidae													
Aetobatus narinari (Euphrasen)*	8,7,4	+					+	+	+				
Myliobatis freminvillei Lesueu	7,4	+					+						
Thinoptera bonasus (Mitchill)*	7	+											
Mobulidae													
Manta birostris (Walbaum)*		+											
Mobula hypostoma (Bancroft)*	11	+											
Acipenseridae													
Acipenser brevirostrum Le: ueur	1						+				+		
Lepisosteidae													
Lepisosteus osseus (Linnaeus)*											+	+	
L. platyrhincus (DeKay)*	4,3										+	+	
L. spatula Lacepede	1										+	+	
Amiidae													
Amia calva Linnaeus*	4											+	

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Elopidae													
Elops saurus Linnaeus*	9,5,4,3,2,1	+	+			+	+	+	+		+	+	
Megalops atlantica Valenciennes*	9,5,4,1	+	+			+	+	+	+		+	+	+
Albulidae													
Albula vulpes (Linnaeus)*	5,4						+	+	+				
Anguillidae													
Anguilla rostrata (Lesueur)*	5,4,2,1	+					+				+	+	
Muraenidae													
Anarchias yoshiae Kanazawa*	8		+	+									
Enchelycore nigricans (Bonnaterre)	5		+	+									
Gymnothorax funebris Ranzani*	5,4			+	+		+						
G. moringa (Cuvier)*	5,4			+	+		+						
G. nigromarginatus (Girard)*			+										
G. vicinus (Castelnau)	4						+						
Muraena retifera Goode & Bean*	5		+	+			+						
Muraenesocidae													
Hoplunnis tenuis	8		+										
Ophichthidae													
Ahlia egmontis (Jordan)*	5,4			+			+						
Bascanichthys scuticaris (Goode & Bean)	4			+			+						
B. teres (Goode & Bean)	4			+			+						
Letharchus velifer Goode & Bean	4		+	+									
Myrichthys acuminatus (Gronow)*	5,4		+	+			+			+			
Myrophis punctatus (Lutken)*	5,4,2		+	+			+			+			
Mystriophis intertinctus (Richardson)	8		+										
Ophichthus ocellatus (Lesueur)*	8,7,5	+	+										
Gordiichthys springeri Ginsburg	14							+					

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Clupeidae													
Alosa sapidissima (Wilson)	1	+					+	+	+		+	+	
Brevoortia smithi Hildebrand*	16,8,7,5,4,3,2	+					+	+	+		+	+	
B. tyrannus (Latrobe)*	16,7,5,4,2,1	+					+	+	+		+	+	
B. smithi X B. Tyrannus*	16	+					+	+	+		+	+	
Dorosoma cepedianum (Lesueur)*	4,3										+	+	
D. petenense (Gunther)	5,4,3,2										+	+	
Etrumeus teres (DeKay)	8,7	+											
Harengula clupeola Valenciennes*	4	+			+		+						
H. humeralis Cuvier*	5,4	+			+		+	+					
H. pensacolae Goode & Bean*	8,7,5,4,3	+			+	+	+	+	+				
Jenkensia sp.	4	+					+	+					
Opisthonema oglinum (Lesueur)*	8,7,5,4,1	+			+	+	+	+	+				
Sardinella anchovia Valenciennes*	8,7,5,4	+			+	+	+	+	+				
Engraulidae													
Anchoa cubana (Poey)	4	+			+	+							
A. hepsetus (Linnaeus)*	7,4,3	+			+	+	+	+	+		+		
A. lamprotaenia Hildebrand*	4	+				+	+	+	+				
A. lyolepis (Evermann & Marsh)*	5,4,2	+					+						
A. mitchilli (Valenciennes)*	7,5,4,3,2,1	+				+	+	+	+		+	+	
A. nasuta (Hildebrand & Carvalho)*	12	+			+	+	+	+					
Anchoviella perfasciata (Poey)	12	+											
Engraulis estauquae (Hildebrand)	12	+											
E. eurystole (Swain & Meek)	12	+				+							
Argentinidae													
Argentina silus Ascanius	8	+											
Synodontidae													
Saurida normani Longley	8		+										
Saurida sp.*			+										
Synodus intermedius (Agassiz)*	7		+										
S. foetens (Linnaeus)*	7,5,4,3,2		+			+	+		+		+		
Trachinocephalus myops (Forster)*	8,7		+			+	+						

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Chlorophthalmidae													
Chlorophthalmus agassizi Bonaparte	7		+										
Cyprinidae													
Notemigonus crysoleucas (Mitchill)*	4,3											+	
Notropis maculatus (Hay)	4,3											+	
N. petersoni Fowler	4											+	
Catostomidae													
Erimyson sucetta (Lacepede)*	4,1											+	
Ictaluridae													
Ictalurus catus (Linnaeus)	3,2											+	
I. natalis (Lesueur)	4											+	
I. nebulosus (Lesueur)*	4										+	+	
I. punctatus (Rafinesque)	3											+	
Noturus gyrinus (Mitchill)	4											+	
Ariidae													
Arius felis (Linnaeus)*	8,7,5,4,3,2,1		+			+	+	+	+		+	+	
Bagre marinus (Mitchill)*	8,7,5,4,3,1		+			+	+	+	+		+	+	
Batrachoididae													
Opsanus beta (Goode & Bean)*								+		+			
O. tau (Linnaeus)*								+		+			
Porichthys plectrodon (Valenciennes)*	7		+										
Gobiesocidae													
Gobiesox strumosus Cope*	5,4,2,1				+					+			
Antennariidae													
Antennarius pauciradiatus Schultz*				+				+					
A. scaber (Cuvier)*	4						+	+		+			
A. radiosus Garman	8,7			+									
Histrio histrio (Linnaeus)*	8,7,4	+					+	+					
Chaunacidae													
Chaunax pictus Lowe	8	+											

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Ogcocephalidae													
Halieutichthys aculeatus (Mitchill)*	8,7		+										
Ogcocephalus nasutus (Valenciennes)*	8		+										
O. radiatus (Mitchill)*	8		+										
O. vespertilio (Linnaeus)*	7		+										
Gadidae													
Urophyeis floridanus (Bean & Dresel)*	8		+										
U. regius (Walbaum)*	8,7		+										
Ophidiidae													
Lepophidium cervinum (Goode & Bean)*	8		+										
L. sp.	7		+										
Ophidion holbrooki (Putnam)	8,7		+										
O. sp. nov.	8		+										
O. grayi (Fowler)*	8,7		+										
Ogilbia cayorum Evermann & Dendall*	5,4						+			+			
Parophidion schmidti (Woods & Kanazawa)	4		+										
Rissola marginata (DeKay)*	7		+										
Carapidae													
Carapus bermudensis (Jones)*			+										
Hemiramphidae													
Eloptorhamphus velox Poey*		+											
E. viridis (van Hasselt)	8	+											
Hemiramphus brasiliensis (Linnaeus)*	7	+											
H. balao (Lesueur)	8,7	+											
Hyporhamphus unfasciatus (Ranzani)*	7,5,4,1	+					+						
H. sp. nov.*		+			+		+	+					
Exocoetidae													
Cypselurus heterurus (Rafinesque)*	7,5	+					+	+	+				
Parexocoetus brachypterus (Richardson)*	7	+											
Prognichthys gibbifrons Valenciennes	7,5,4	+											

Table 3. (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Belonidae													
Ablennes hians (Valenciennes)*	7	+											
Platybelone argalus (Lesueur)*		+											
Strongylura marina (Walbaum)*	5,4,1	+					+	+	+		+	+	
S. notata (Poey)*	5,4	+					+	+	+		+	+	
Strongylura timucu (Walbaum)*	2	+					+	+	+		+		
Tylosurus acus (Lacepede)*	7	+					+	+	+				
T. crocodiuls (Peron & Lesueur)*	4	+					+	+	+				
Cyprinodontidae													
Cyrpinodon hubbsi Carr	4											+	
C. variegatus Lacepede*	9,5,3,1						+	+	+		+	+	+
Floridichthys carpio (Gunther)*	5						+	+	+		+		
Fundulus chrysotus (Gunther)*	5,4,1											+	
F cingulatus Valenciennes	4											+	
F. confluentus Goode & Bean*	9,4,3								+		+	+	+
F. grandis Baird & Girard*	9,5,4,1						+	+	+		+	+	+
F. lineolatus (Agassiz)	4,1											+	
F. seminolis Girard	4,3											+	
F. similis (Baird & Girard)*	9,5,1					+	+	+	+		+	+	+
Jordanella floridae Goode & Bean*	4,3,1										+	+	
Leptolucania ommata (Jordan)	1											+	
Lucania goodei Jordan*	4,3											+	
L. parva (Baird)*	9,5,1						+	+	+		+	+	+
Rivulus marmoratus Poey	9											+	+
Poeciliidae													
Gambusia affinis (Baird & Girard)*	9,5,4,3,2,1							+			+	+	+
Heterandria formosa Agassiz*	5,4,3,2											+	
Poecilia latipinna (Lesueur)*	9,4,2,1							+	+		+	+	+
Poecilia (latipinna x velifera)	10											+	
Xiphophorus variatus (Meek)	10											+	
X. helleri (Heckel)	10											+	
X. maculatus (Gunther)	10											+	
X. helleri x variatus	10											+	
X. maculatus x helleri	10											+	
X. maculatus x variatus	10											+	

Table 3. (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Atherinidae													
Allanetta harringtonensis (Goode)*	5,4							+					
Labidesthes sicculus (Cope)*	5,4,1											+	
Membras martinica (Valenciennes)*	7,5,3	+			+	+	+	+	+				
Menidia beryllina (Cope)*	9,5,4,3,2,1	+			+	+	+	+	+		+	+	+
Polymixiidae													
Polymixia lowei Gunther	8,7		+										
Fistulariidae													
Fistularia tabacaria Linnaeus*	8,7,5,4,2						+	+					
Centriscidae													
Macrorhamphosus scolopax (Linnaeus)	8	+											
M. sp *		+		+									
Syngnathidae													
Hippocampus erectus Perry*	8,4,3	+					+	+		+	+		
H. obtusus Ginsburg*	4							+					
H. reidi Ginsburg*		+											
H. zosterae Jordan & Gilbert*	4							+			+		
Corythoichthys albirostris Heckel*		+	+										
C. brachycephalus (Poey)*		+											
Oostethus lineatus (Kaup)*	4											+	
Syngnathus dunckeri (Metzelaar)*	4	+					+	+					
S. elucens Poey*		+					+	+					
S. floridae (Jordan & Gilbert)*	4,3,2	+					+	+					
S. fuscus Store*	4	+					+	+					
S. louisianae Gunther*	5,4,3,2,1	+					+	+			+	+	
S. pelagicus Linnaeus*		+											
S. scovelli (Evermann & Kendall)*	5,4,3,2,1						+	+			+	+	
Scorpaenidae													
Pontinus sp.	7		+										
Scorpaena brasiliensis Cuvier*	8,7,5,4,1			+			+	+		+			
S. calcarata Goode & Bean*	8,7		+										
S. dispar Longley & Hildebrand*								+					

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Scorpaenidae (cont'd.)													
Scorpaena grandicornis Cuvier*	4,3			+			+	+		+			
S. plumieri Bloch*	5,4			+	+		+	+		+			
Setarches parmatus (?)	8		+										
Triglidae													
Bellator brachychir (Regan)*	5		+				+	+	+				
B. egretta (Goode & Bean)	8		+										
B. militaris (Goode & Bean)*	8,7		+										
Peristedion sp.	7		+										
Prionotus alatus Goode & Bean*			+										
P. carolinus (Linnaeus)	8,7		+										
P. evolans (Linnaeus)	8,7,1		+						+	+	+		
P. martis Ginsburg*			+										
P. ophryas Jordan & Swain*			+										
P. roseus Jordan & Evermann*	8,7		+										
P. scitulus Jordan & Swain*	8,5,4		+				+		+		+		
P. salmonicolor Fowler*	8,7,5		+				+						
P. tribulus (Cuvier)*	4,3,1		+				+		+		+		
Centropomidae													
Centropomus pectinatus Poey*	5,4,2							+			+	+	
C. undecimalis (Bloch)*	9,5,4,3,2,1	+		+			+	+	+	+	+	+	+
Serranidae													
Anthias sp.	7			+									
Centropristis ocyurus (Jordan & Evermann)*	8,7,5		+	+			+						
C. philadelphica (Linnaeus)*	8,7,5,4		+	+			+	+					
C. striata (Linnaeus)*	8,7,5,4			+	+		+	+					
Diplectrum vibittatum (Valenciennes)*	4		+	+				+					
D. formosum (Linnaeus)*	8,7,4		+	+			+	+	+	+			
Epinephelus fulva (Linnaeus)	5						+						
E. itjara (Lichtenstein)*	5,4,2,1			+	+		+	+		+			
E. morio (Valenciennes)*	4			+	+		+	+		+			

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Serranidae (cont'd.)													
Epinephelus nigritus (Holbrook)*				+			+	+					
E. niveatus (Valenciennes)*	7			+									
E. striatus (Bloch)				+			+	+					
Hemanthias vivanus (Jordan & Swain)*	8		+	+									
H. sp.	7		+										
Hypoplectrus nigricans (Poey)*				+									
H. puella (Cuvier)*				+									
H. unicolor (Walbaum)	4			+			+	+					
Mycteroperca bonaci (Poey)*	5,4			+			+	+					
M. microlepis (Goode & Bean)*	5,4			+	+		+	+		+			
M. phenax Jordan & Swain*				+			+	+					
Serraniculus pumilio Ginsburg	8		+	+									
Serranus baldwini (Evermann & Marsh)*	4			+			+	+					
S. octospilus Longley*	8		+	+									
S. phoebe Poey*	8,7		+	+									
S. subligarius (Cope)*	5			+	+		+	+					
Grammistidae													
Rypticus bistrispinus (Mitchill)*			+	+									
R. maculatus Holbrook*	4			+	+		+	+					
R. saponaceus (Bloch & Schneider)	5			+			+						
Centrarchidae													
Elassoma evergladei (Jordan)*	4,1											+	
Enneacanthus gloriosus Holbrook*	4,3											+	
E. obesus (Girard)	1											+	
Lepomis gulosus (Cuvier)*	4,1											+	
L. macrochirus Rafinesque*	5,4,3,2,1											+	+
L. marginatus (Holbrook)*	4,3											+	
L. microlophus (Gunther)*	4,3											+	
L. punctatus (Valenciennes)*	4,1											+	
Micropterus salmoides (Lacepede)*	4,1											+	+
Pomoxis nigromaculatus (Lesueur)*	3,2											+	+
Percidae													
Etheostoma fusiforme (Girard)*	4,1											+	

Table 3. (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Priacanthidae													
Priacanthus arenatus Cuvier*				+									
Pristigenys alta (Gill)*	8			+									
Apogonidae													
Apogon maculatus (Poey)*	5,4			+	+		+			+			
A. pseudomaculatus Longley*	5,4			+	+		+			+			
A. binotatus (Poey)*				+	+		+			+			
Astropogon stellatus (Cope)*	5,4						+	+					
Phaeoptyx conklini (Silvester)	5						+	+					
P. pigmentaria (Poey)	5						+	+					
Branchiostegidae													
Caulolatilus cyanops Poey*		+	+										
Pomatomidae													
Pomatomus saltatrix (Linnaeus)*	8,7,5,4,2,1	+			+	+	+						
Rachycentridae													
Rachycentron canadum (Linnaeus)*	7,4	+		+			+						
Echeneidae													
Echeneis naucrates Linnaeus*	7.5	+		+			+						
E. neucratoides Zuieuw*		+		+			+						
Remora biachyptera (Lowe)*		+											
R. osteochir (Cuvier)*		+											
R. remora (Linnaeus)*	1	+											
Remorina albescens (Temminck & Schlegel)*		+											
Carangidae													
Alectis crinitus (Mitchill)	8,5	+					+						
Caranx bartholomaei Cuvier*	7,4	+		+	+	+	+						
C. crysos (Mitchill)*	8.7.4.1	+		+	+	+	+						
C. hippos (Linnaeus)*	8,7,5,4,3,2,1	+		+	+	+	+	+	+	+	+	+	
C. latus Agassiz*	4,3	+		+	+	+	+	+	+	+	+	+	
C. ruber (Bloch)*	8,5,4	+		+	+	+	+	+	+	+			
Chloroscombrus chrysurus (Linnaeus)*	8,7,5,4,3,1	+		+	+	+	+	+	+		+		
Decapterus punctatus (Agassiz)*	7,4	+					+						

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Carangidae (cont'd.)													
Elagatis bipinnulata (Quoy & Gaimard)*	4	+											
Oligoplites saurus (Bloch & Schneider)*	4,3,1	+		+	+	+	+	+	+	+	+	+	
Selar crumenopthalmus (Bloch)	8,7,4	+					+						
Selene vomer (Linnaeus)*	8,7,5,4,3,2,1	+		+	+	+	+	+	+	+	+		
S. setapinnis (Mitchill)*	8,7,3,1	+		+	+	+	+	+	+	+	+		
Seriola dumerili (Risso)*	7	+				+							
S. rivoliana Valenciennes*	4	+											
Trachinotus carolinus (Linnaeus)*	8,7,5,4,3,1					+	+	+			+		
T. falcatus (Linnaeus)*	5,4,3,1					+	+	+	+		+		
T. goodei Jordan & Evermann*	5,4,1					+							
Trachurus lathami Nichols*	8,7	+											
Coryphaenidae													
Coryphaena equisetis Linnaeus*		+											
C. hippurus Linnaeus*	8,7,5,4	+		+	+	+	+						
Lutjanidae													
Lutjanus analis (Cuvier)*	4,2			+	+		+	+		+			
L. apodus (Walbaum)*	5,4,2,1			+	+		+	+		+			
L. campechanus (Poey)*	17	+		+									
L. cyanopterus (Cuvier)*	4			+			+	+		+			
L. griseus (linnaeus)*	5,4,3,2,1			+	+		+	+		+	+	+	+
L. jocu (Bloch & Schneider)*	4			+	+		+	+		+			
L. mahogoni (Cuvier)*				+	+		+						
L. synagris (Linnaeus)*	5,4,3,2,1			+	+		+	+		+			
Ocyurus chrysurus (Bloch)*	4			+	+		+	+					
Rhomboplites aurorubens (Cuvier)*	8,7	+	+	+									
Lobotidae													
Lobotes surinamensis (Bloch)*	7,4,1	+		+			+	+		+			
Gerreidae													
Diapterus olisthostomus (Goode & Bean*	5,4,3,2,1						+	+	+		+	+	+

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Gerreidae (cont'd.)													
D. plumieri (Cuvier)*	9,5,4,2						+	+	+		+	+	+
Eucinostomus argenteus Baird & Girard*	8,5,4,2	+	+	+	+	+	+	+	+		+	+	+
E. gula (Quoy & Gaimard)*	5,4,3,2,1	+	+	+	+	+	+	+	+		+	+	
E. havana (Nichols)	4					+	+	+					
E. lefroyi (Goode)*	4						+	+					
E. melanopterus (Bleeker)*	4						+	+			+		
E. pseudogula Poey*							+	+					
Gerres cinereus (Walbaum)*	4	+	+	+	+	+	+	+	+				
Pomadasyidae													
Anisotremus surinamensis (Bloch)*	5,4,1			+	+		+						
A. virginicus (Linnaeus)*	5,4			+	+		+	+		+			
Haemulon album Cuvier*							+						
H. aurolineatum Cuvier*	8,5,4	+		+	+		+	+					
H. carbonarium Poey*				+	+		+						
H. chrysargyreum Gunther	4			+	+		+						
H. flavolineatum (Desmarest)*	4			+	+		+	+					
H. macrostomum Gunther	4,1			+			+						
H. melanurum (Linnaeus)*				+	+		+						
H. parrai (Desmarest)*	5,4,2			+	+		+	+		+	+		
H. plumieri (Lacepede)*	7,4			+	+		+	+		+			
H. sciurus (Shaw)*	4			+			+	+					
Orthopristis chrysoptera (Linnaeus)*	7,5,4,3,2,1	+	+	+				+			+		
Pomadasys crocro (Cuvier)	15											+	
Sparidae													
Archosargus probatocephalus (Waldbaum)*	5,4,3,2,1		+	+	+		+	+	+	+	+	+	+
A. rhomboidalis (Linnaeus)*	5,4						+	+					
Calamus arctifrons Goode & Bean	4			+			+	+					
C. bajonado (Bloch & Schneider)*				+			+						
Diplodus holbrooki (Bean)*	5,1			+	+		+	+		+			
D. argenteus (Valenciennes)*	4			+	+		+						

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Sparidae (cont'd.)													
Lagodon rhomboides (Linnaeus)*	8,7,5,4,3,2,1		+	+			+	+	+	+	+	+	+
Stenotomus chrysops (Linnaeus)*	7	+	+	+									
Sciaenidae													
Bairdiella chrysura (Lacepede)*	7,5,4,3,2		+					+	+		+	+	
B. sanctaeluciae (Jordan)*	18			+									
Cynoscion nebulosus (Cuvier)*	8,7,5,4,3,2,1		+				+	+	+				
C. nothus (Holbrook)*	7,5		+				+	+	+				
C. regalis (Bloch & Schneider)*	8,7,5,4,3,2	+	+			+	+		+		+	+	
Equetus acuminatus (Bloch & Schneider)*	8,5,4			+	+		+			+			
E. lanceolatus (Linnaeus)	7			+									
E. umbrosus Jordan & Evermann*	5,4			+	+		+						
Leiostomus xanthurus Lacepede*	8,7,5,4,3,2,1		+				+	+	+		+	+	
Menticirrhus americanus (Linnaeus)*	7,5,3,1		+			+	+		+				
M. littoralis (Holbrook)*	5,4		+			+	+		+				
M. saxatilis (Bloch & Schneider)*	8,7,5,4,2		+			+	+		+				
Microposon undulatus (Linnaeus)*	8,7,5,4,3,2,1		+			+	+	+	+		+	+	+
Pogonias cromis (Linnaeus)*	8,7,5,4,3,2,1		+	+			+	+	+	+	+		
Sciaenops ocellata (Linnaeus)*	5,4,3,2,1		+			+	+	+	+	+	+		
Stellifer lanceolatus (Holbrook)	7,5,4,3,2	+	+				+	+	+		+		
Umbrina coroides Cuvier*	5,4		+			+	+						
Larimus fasciatus Holbrook	8,7		+										
Mullidae													
Mullus auratus Jordan & Gilbert*	7		+	+									
Pseudupeneus maculatus (Bloch)*	8,7,5,4			+	+		+	+	+				
Kyphosidae													
Kyphosus sectatrix (Linnaeus)*	8,7,5,4	+		+	+		+						
K. incisor (Cuvier)*	8,7,4	+		+	+		+						
Ephippidae													
Chaetodipterus faber (Broussonet)*	8,7,5,4,3,2,1	+		+	+		+	+	+	+	+		

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Chaetodontidae													
Chaetodon aya Jordan	8			+									
C. capistratus Linnaeus*	4			+			+						
C. ocellatus Bloch*	4			+			+						
C. sedentaris Poey*				+									
Holacanthus bermudensis Goode*				+	+		+			+			
H. ciliaris (Linnaeus)*	5,4			+			+			+			
H. tricolor (Bloch)*				+			+						
Pomacanthus arcuatus (Linnaeus)*	4			+	+		+			+			
P. paru (Bloch)*	5			+			+			+			
Cichlidae (all introduced)													
Hemichromis bimaculatus Gill	10											+	
Tilapia mossambica (Peters)	10											+	
T. melanopleura	10											+	
Pomacentridae													
Abudefduf saxatilis (Linnaeus)*	8,5,4,3,2			+	+		+			+			
A. taurus (Muller & Troschel)*	4			+	+		+						
Pomacentrus dorsopunicans (Poey)*	4			+			+						
P. leucostictus Muller & Troschel*	5,4			+			+			+			
P. partitus Poey*	5			+			+						
P. variabilis (Castelnau)*	5,4			+	+		+						
Chromis enchrysurus Jordan & Gilbert*			+	+									
Labridae													
Bodianus rufus (Linnaeus)*				+			+						
Doratonotus megalepis Gunther*	5,4			+	+		+	+		+			
Halichoeres bathyphilus (Beebe & Tee-Van)	8			+									
H. bivittatus (Bloch)*	5,4			+	+		+	+		+			
H. maculipinna (Muller & Troschel)*	5			+	+		+			+			
H. poeyi (Steindachner)*	8,5			+	+		+						
H. radiatus (Linnaeus)*				+	+		+						
Hemipteronotus novacula (Linnaeus)*			+	+									

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Labridae (cont'd.)													
Lachnolaimus maximus (Walbaum)*			+	+			+	+		+			
Thalassoma bifasciatum (Bloch)*				+			+						
Scaridae													
Cryptotomus roseus Cope*	4			+			+	+		+			
Nicholsina usta (Valenciennes)*	5,4,1			+			+	+		+	+		
Scarus taeniopterus Desmarest*				+			+	+					
S. croicensis Bloch	4			+			+	+					
S. guacamaia Cuvier	4			+			+						
S. coeruleus (Bloch)*							+						
Sparisoma radians (Valenciennes)*	4			+			+						
S chrysopterum (Bloch & Schneider)*	4			+			+	+					
S. rubripinne (Valenciennes)*	4			+	+		+	+					
Mugilidae													
Agonostomus monticola (Bancroft)*		+					+				+	+	
Mugil cephalus Linnaeus*	9,5,4,3,2,1	+	+			+	+	+	+		+	+	+
M. curema Valenciennes*	7,5,4,3,2,1	+	+			+	+	+	+		+	+	+
Sphyraenidae													
Sphyraena barracuda (Walbaum)*	8,5,4,3	+		+			+	+	+	+	+		
S. borealis DeKay*	8,4	+		+			+	+	+	+			
Polynemidae													
Polydactylus octonemus (Girard)	5,2					+	+						
P. oligodon (Gunther)*						+	+						
P. virginicus (Linnaeus)	5					+	+						
Ophistognathidae													
Ophistognathus whitehursti (Longley)*				+									
O. sp.	5,2									+			

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Dactyloscopidae													
Dactyloscopus crossotus Starks*	4				+	+	+		+				
D. tridigitatus Gill*	4						+		+				
Gillellus greyae Kanazawa	5,4						+		+				
G. rubrocinctus Longley	4						+		+				
G. sp.	2						+		+				
Uranoscopidae													
Astroscopus y-graecum (Cuvier)*	7,5,4		+		+	+	+		+	+			
Kathetostoma albigutta (Bean)	8,7		+										
Clinidae													
Labrisomus nuchipinnis (Quoy & Gaimard)*	5,4			+	+		+	+		+			
Malacoctenus macrops (Poey)	5			+			+			+			
M. triangulatus Springer*	5			+			+			+			
Paraclinus fasciatus (Steindachner)*	4							+	+	+			
P. nigripinnis (Steindachner)*	5,4				+		+						
Starksia ocellata (Steindachner)*							+						
Blenniidae													
Blennius cristatus Linnaeus*	5,4			+	+		+						
B. marmoreus Poey*	5,4						+						
B. nicholsi Tavolga	5,4,2							+		+	+		
Chasmodes saburrae Jordan & Gilbert*	5,1							+		+			
Entomacrodus nigricans Gill*								+		+			
Hypleurochilus aequipinnis (Gunther)*	4						+	+					
H. bermudensis Beebe & Tee-Van	5						+				+		
H. geminatus (Wood)	5						+						
Hypsoblennius sp.	7		+	+									
Callionymidae													
Callionymus pauciradiatus Gill	4						+	+					

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Eleotridae													
Dormitator maculatus (Bloch)*	9,5,4,2										+	+	
Eleotris pisonis (Gmelin)*	5						+	+	+	+	+	+	
E. sp.	5,4,2				+		+				+	+	
Erotelis smaragdus (Valenciennes)*	4				+		+	+	+	+	+	+	
Gobiomorus dormitor Lacepede*	4											+	
Gobiidae													
Awaous tajasica (Lichtenstein)*	15											+	
Bathygobius curacao Metzelaar	5										+	+	
B. soporator (Valenciennes)*	5,4,3,2,1						+	+		+	+		
Coryphopterus glaucofraenum Gill*	4			+				+					
Evermannicythys spongicola (Radcliffe)*			+										
Evorthodus lyricus (Girard)	9,5,4,1							+	+		+		
Gobioides broussoneti (Lacepede)	5,4,3							+			+	+	
Gobionellus boleosoma (Jordan&Gilbert)*	5,4,3,2,1							+			+	+	
G. gracillimus Ginsburg	5,3							+			+		
G. hastatus Girard	5,3							+			+	+	
G. oceanicus (Pallas)*	2							+	+				
G. smaragdus (Valenciennes)*	5,4,2							+			+		
G. stigmaturus (Goode & Bean)*	4,1							+					
Gobiosoma bosci (Lacepede)	5,4,3,2,1							+			+		
G. ginsburgi Hildebrand & Schroeder	4							+			+		
G. robustum Ginsburg*	5,4,2							+		+	+		
Lophogobius cyprinoides (Pallas)*	5,4,2							+	+	+	+	+	+
Microgobius gulosus (Girard)*	5,4,2,1							+	+	+	+		
M. microlepis Longley & Hildebrand	4							+					
Microdesmidae													
Microdesmus floridanus (Longley)	4							+					
Acanthuridae													
Acanthurus bahianus Castelnau*	5,4			+			+	+					
A. chirurgus (Bloch)*	5,4			+	+		+	+		+			
A. coeruleus Bloch & Schneider*				+			+						

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Trichiuridae													
Trichiurus lepturus Linnaeus*	8,7,4,3	+	+	+			+	+	+	+	+		
Scombridae													
Acanthocybium solanderi (Cuvier)*	7	+											
Auxis thazard (Lacepede)*		+											
Euthynnus alletteratus (Rafinesque)*	7	+		+			+						
E. pelamis (Linnaeus)*		+											
Scomber japonicus Houttuyn	7	+											
Scomberomorus cavalla (Cuvier)*	7	+		+			+						
S. maculatus (Mitchill)*	8,7,5.1	+		+			+	+	+				
S. regalis (Bloch)*	5	+											
Thun?us albacares (Bonnaterre)*		+											
T. a?lanticus (Lesson)*		+											
Xiphiidae													
Xiphias gladius Linnaeus	7	+											
Istiophoridae													
Istiophorus platypterus (Shaio & Nodder)*		+											
Makaira nigricans Lacepede*		+											
Tetrapterus albidus Poey*		+											
Stromateidae													
Nomeus gronovii (Gmelin)	4	+					+						
Peprilus alepidotus (Linnaeus)	8,7	+					+						
P. triacanthus (Peck)	8,7,5	+					+						
Psenes cyanophrys Valeciennes*	8,4	+											
Bothidae													
Bothus ocellatus (Agassiz)*	8,4		+				+		+				
Bothus robinsi Jutare*			+				+		+				
Anclopsetta quadrocellata Gill	8,7		+										
Citharichthys arenaceus Evermann & Marsh	4								+				

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Bothidae (cont'd.)													
Citharichthys artifrons Goode	8,7		+										
C. macrops Dresel*	8,7,5,4,3		+				+	+	+				
C. spilopterus Gunther*	7,5,4,3,2,1							+	+		+	+	
Cyclopsetta chittendeni Bean	8		+										
C. fimbriata (Goode & Bean)*	8		+										
Etropus crossotus Jordan & Gilbert*	7,5,3		+				+		+				
E. rimosus Goode & Bean	8		+										
Paralichthys oblongus (Mitchill)	7		+										
P. albigutta Jordan & Gilbert*	8,7,5,4,2		+			+	+		+		+		
P. dentatus (Linnaeus)*	7,5		+			+	+		+		+		
P. lethostigma Jordan & Gilbert*	8,7,4,1		+			+	+		+		+		
P. squamilentus Jordan & Gilbert*	8,7,5,4		+			+	+		+		+		
Scophthalmus aquosus (Mitchill)	7		+										
Syacium micrurum Ranzani	4		+				+		+				
S. papillosum (Linnaeus)*	8		+										
S. sp.	8,7		+										
Soleidae													
Achirus lineatus (Linnaeus)*	5,4,3,2,1		+				+		+		+	+	+
Gymnachirus melas Nichols*	7		+										
Trinectes maculatus (Bloch & Schneider)*	7,5,3,2		+						+		+	+	+
Cynoglossidae													
Symphurus diomedianus (Goode & Bean)*	8		+										
S. plagiusa (Linnaeus)*	8,7,5,4,3,2,1		+				+		+		+		
S. urospilus Ginsburg*			+										
Balistidae													
Aluterus heudelotti Holland	4	+					+						
A. schoepfi (Walbaum)*	7,4	+		+			+						
A. scriptus (Osbeck)*	4	+		+			+						
Balistes capriscus Gmelin*	8,5,4	+		+			+						
Canthidermis maculatus (Bloch)*		+											

Table 3 (cont'd.)

SPECIES	PREVIOUS SURVEYS	N	B	R	SR	SS	I	GF	SB	LR	CRM	FTC	MI
Balistidae (cont'd.)													
Canthidermis sufflamen (Mitchill)*	4	+					+						
Monacanthus ciliatus (Mitchill)*	8,5,4	+		+			+	+		+			
M. hispidus (Linnaeus)*	8,7,5,4	+		+			+	+		+	+		
M. tuckeri Bean*		+											
M. setifer Bennett*	8,4	+											
Ostraciidae													
Lactophrys quadricornis (Linnaeus)*	8,7,4			+			+	+		+			
L. trigonus (Linnaeus)*	7,5,4,2			+			+	+		+			
L. triqueter (Linnaeus)*				+			+	+		+			
Tetraodontidae													
Lagocephalus sp.*		+		+			+						
Sphoeroides dorsalis Longley*	8	+											
S. maculatus (Bloch & Schneider)	3,1						+	+	+	+	+		
S. nephelus (Goode & Bean)*	5,4,3,2	+		+			+	+		+	+		
S. spengleri (Bloch)*	8,5,4,1	+		+			+	+		+	+		
S. testudineus (Linnaeus)*	5,4,3,2,1						+	+		+	+		
Diodontidae													
Chilomycterus antennatus (Cuvier)	5			+			+						
C. schoepfi (Walbaum)*	8,7,5,4,3,2,1			+			+	+	+	+	+		
Diodon holacanthus Linnaeus*	4			+			+						
D. histrix Linnaeus	1			+			+						
Molidae*													
TOTAL SPECIES		167	140	180	83	60	272	185	111	86	109	107	266

Total Continental Shelf	406
Total Indian River	356
Combined Species	533

1 - Evermann and Bean (1897), 2- V. Springer (1960)

3 - Gunter and Hall (1963), 4- Christensen (1965)

5 - Powell et al (1972), 6- S. Springer (1960, 63, 66)

7 - Anderson and Gehringer (1965, 8- Bullis and Thompson (1965)

9 - Harrington and Harrington (1969), 10-Courtney et al (1972)

11 - Bigelow and Schroder (1947), 12- Daly (1970)

13 - Cory & Pierce (1967), 14- Briggs (1958)

15 - Harrington, R. H. (personal communication) Florida State Entomological Research Laboratory, Vero Beach, Florida

16 - Dahlberg (1970, 17- Moe (1963)

18 - Dailey, et al (1970)

Table 4. Reef fishes observed during the winter (January) 1974 on nearshore coquinoid reefs at depths to 5 m. (Indian River County)

Key: a = abundant (>30)
c = common (15 - 30)
p = present (<2)
juv = juvenile
adult

SPECIES	OCCURRENCE	AGE
Ginglymostoma cirratum	p	juv
Epinephelus morio	p	adult
Mycteroperca bonaci	p	adult
M. microlepis	p	adult
Rypticus maculatus	c	adult
Apogon maculatus	c	adult
Caranx bartholomaei	c	adult
C. crysos	a	adult
Lutjanus analis	p	adult
L. apodus	p	adult
L. griseus	a	adult
L. mahogoni	p	adult
Ocyurus chrysurus	c	juv & adult
Haemulon parrai	p	juv & adult
H. plumieri	a	juv & adult
H. sciurus	c	adult
Anisotremus surinamensis	a	adult
A. virginicus	a	juv & adult
Calamus sp.	p	adult
Eucinostomus sp.	a	adult

Table 4 (cont'd.)

SPECIES	OCCURRENCE	AGE
Diplodus sp.	a	juv
Equetus acuminatus	c	adult
Holacanthus bermudensis	p	juv & adult
Pomacentrus variabilis	a	juv & adult
Abudefduf saxatilis	p	adult
Halichoeres bivittatus	a	juv & adult
H. maculipinna	c	juv & adult
Sparisoma rubripinne	c	juv & adult
Malacoctenus triangulatus	p	adult
Labrisomus nuchipinnis	a	juv & adult
Coryphopterus sp.	p	adult
Acanthurus chirugus	c	adult

Total 32 species

of a reef environment have representatives here as well (e.g. *Chromis enchrysurus*, Pomacentridae; *Hemipteronotus novacula*, Labridae; *Diplectrum formosum*, *D. radiale*, *Centropristis ocyurus*, Serranidae).

Neritic Zone -- This biotope consists of the open waters above the benthic habitats. The Florida Current (Fig. 1) plays an important role in determining the physical character of this biotope. Occasional weed lines of floating *Sargassum* sp., and so forth, may be seen at the interface between the Florida Current waters and coastal waters. Many fishes associate with this weed line (e.g. dolphin and jacks) and other floating debris that may afford food and shelter.

Of the 167 species that occur here the sharks, mackerals and tunas, jacks, billfishes, herrings and anchovies dominate this biotope. Large North-South seasonal migrations of dolphin (*Coryphaena*) in spring and summer months; mackerals and tunas (e.g. *Scomberomorous*, *Euthynnus*), and billfishes occur in the neritic shelf region adjacent to the Indian River lagoon, primarily during the fall through spring. An over-wintering population of sailfish, *Istiophorus platypterus*, occurs annually off of Jupiter Island, from St. Lucie Inlet south. *Mugil cephalus* and *M. curema*, *Brevoortia smithi* and *B. tyrannus* and numerous sciaenids make seasonal migrations from the lagoon out into neritic waters to spawn.

Many juvenile fishes are transported by the Florida Current into the neritic zone of this region from South Florida and the Caribbean (Fig. 1). This is a continual source of recruitment for the local representatives of the tropical fish fauna.

Discussion

Briggs (1958) estimates that the total fish population of Florida consists of 1,120 species including those found at depths over 200m. Of these, 453 are considered to range over the Indian River region (continental shelf and estuary). Harbor Branch Foundation collections and the combined records of other collections from the Indian River region have established that at least 533 species of fishes occur in the Indian River lagoon, its' freshwater tributaries and the adjacent continental shelf at depths less than 200 m. Of these, 75 were not previously recorded from this region (Table 3 and 5). One hundred and four fish species in Briggs' list have not yet been collected in the Indian River region but are known to range both north and south of here. If the 104 additional species from Briggs' list are added to the current regional total, at least 637 species should eventually be collected or observed.

The Indian River region encompasses several biotopes all of which effect the distribution and composition of the local fish fauna. The study area is broad (Latitude 27°00' - 29°00' N) and encompasses nearly all of the aquatic fish communities in east Florida (lacustrine biotopes were omitted). The fish distribution is further complicated by its transitional nature as the warm-temperate and the tropical Caribbean fish faunas overlap considerably in the Indian River region. Twenty-six percent of the fish fauna is considered tropical. Twenty-one percent is warm-temperate and 49% are eurythermic tropicals and continental species having a wide distribution both north and south of this region. Nine fishes (1.8%) are endemic to Florida and 10 (2%) are exotic freshwater tropicals introduced and breeding here.

Tropical Caribbean fishes on inshore reefs are apparently not found

Table 5. Fishes collected or observed during the Harbor Branch Foundation survey that were not previously recorded from this region.

Rhincodon typus
Isurus oxyrinchus
Carcharhinus longimanus
C. springeri
Manta birostris
Lepisosteus osseus
Gymnothorax nigromarginatus
Opsanus beta
O. tau
Antennarius pauciradiatus
Carapus bermudensis
Euleptorhamphus velox
Hyporhamphus sp.
Platybelone argalus
Hippocampus reidi
Corythoichthys albirostris
C. brachyoephalus
Syngnathus elucens
S. pelagicus
Prionotus alatus
P. martis
P. ophryas
Epinephelus nigritus
E. striatus
Mycteroperca phenax
Hypoplectrus nigricans
H. puella
Rypticus bistrispinus
Priacanthus arenatus
Apogon binotatus
Caulolatilus cyanops
Echeneis neucratoides
Remora brachyptera
R. osteochir
Remorina albescens
Coryphaena equisetis
Lutjanus mahogoni
Eucinostomus pseudogula
Haemulon album
H. carbonarium
H. melanurum
Calamus bajonado
Chaetodon sedentaris
Holacanthus bermudensis
H. tricolor
Chromis enchrysurus
Bodianus rufus
Halichoeres radiatus
Hemipteronotus novacula
Lachnolaimus maximus
Thalassoma bifasciatum
Scarus taeniopterus
S. coeruleus
Agonostomus monticola
Polydactylus oligodon
Opistognathus whitehursti
Starksia ocellata
Entomacrodus nigricans
Evermannichthys spongicola
Acanthurus coeruleus
Auxis thazard
Euthynnus pelamis
Thunnas albacares
T. atlanticus
Istiophorus platypterus
Makaira nigricans
Tetrapterus albidus
Bothus robinsi
Etropus microstomus
Syacium micrurum
Symphurus urospilus
Canthidermis maculatus
Monacanthus tuckeri
Lactophrys triqueter
Lagocephalus sp.

throughout the year north of Sebastian Inlet, yet observations indicate a permanent population from Sebastian south. Thirty-one (76%) of the 41 tropical species that Christensen (1965: 248) lists as new to the Jupiter area are found throughout the year on shallow nearshore reefs or in the Indian River lagoon at least as far north as Wabasso, 29.6 km north of Ft. Pierce Inlet, and possibly to reefs in the vicinity of Sebastian. In addition, 95 tropical species have been recorded from the Indian River lagoon and continental shelf areas north of Jupiter by the present survey and/or Powell, _et al_ (1972). A total of 136 (26% of the total fauna) tropical fishes range at least to latitude 28°00' N. and apparently have a permanent population within this region either on shallow reefs or further out on the continental shelf and in the Indian River lagoon. This extends the northerly limit of permanent tropical fish populations northward 93 km from Jupiter Inlet.

Many benthic, Carolinian, continental shelf species penetrate into the Indian River region and a few Carolinian estuarine species are found at New Smyrna Beach and occasionally stray to the southern reaches of the lagoon (e.g. _Alosa sapidissimi_, _Brevoortia tyrannus_). The successful penetration of either Carolinian or Caribbean species may depend on recruitment occurring during successive, or alternating cold and warm winters. The transitional character of the lagoon fish fauna is obvious as fishes found in grass beds adjacent to St. Lucie Inlet are never qualitatively or quantitatively representative of a similar grass bed (both dominated by _Syringodium_) over 160 km north in Mosquito Lagoon.

Of the 107 fishes recorded from freshwater tributaries, the majority of these (59, 55%) were euryhaline, secondary freshwater species or marine invaders from tropical families or genera. The primary freshwater species (48, 45%) were mostly warm-temperate fishes that have migrated down the peninsula.

It may be concluded that the fish fauna of the Indian River region is a diverse assemblage dominated by tropicals and eurythermic tropicals. These fishes originated in the Caribbean faunal province and were apparently distributed into the region via the Florida Current. Warm-temperate Carolinian fishes are more commonly found in the open bottom continental shelf biotope and in the primary freshwater fish families. Distribution of the Carolinian species must be explained by adult migrations, with some aid from larval fishes transported via south-bound counter-currents of the Florida Current and other inshore water mass movements.

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