

DISTRIBUTION AND ABUNDANCE OF LARVAL AND JUVENILE FISHES IN THE TIDAL WATERS OF THE MYAKKA RIVER, SARASOTA AND CHARLOTTE COUNTIES, FLORIDA

Final report to Sarasota County Office of Environmental Monitoring

> by the MOTE MARINE LABORATORY Sarasota, Florida

> > January 1991

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Mote Marine Laboratory Technical Report Number 197

Suggested reference Estevez ED. 1991. Distribution and abundance of larval and juvenile fishes in the tidal waters of the Myakka river, Sarasota and Charlotte counties, Florida. Sarasota County Office of Environmental Monitoring. Mote Marine Laboratory Technical Report no 197. 31 p and appendices. Available from Mote Marine Laboratory Library. PREFACE

The beginning phases of our investigation into the ecology of the tidal Myakka River, namely wet and dry-season surveys, came at a time when the Laboratory was conducting similar research in several other west coast rivers. The results of the first two Myakka River surveys impressed us in terms of the apparent health and productivity of the tidal reach, even in comparison to other Florida rivers, and this impression resulted in a voluntary investigation of ichthyoplankton (fish eggs and larvae) described by this report. All of the design, field work, sample processing, quality assurance and data management involved in this project was made possible through the support of Mote Marine Laboratory. Sarasota County funded the analysis of data and production of this report.

The project was structured so as to provide insight into the use of tidal rivers in general for spawning and larval growth because such data are few for Florida streams. Traditionally, estuarine studies have stopped at the mouths of rivers whereas riverine studies ended at the first sign of tidal effects. This practice has resulted in a paucity of information on the ecological role of tidal rivers, not only for fishes, but in many other arenas as well.

Due in part to Sarasota County's concern for the tidal river, including waters of Charlotte county that could be affected adversely by upstream projects, the Myakka studies have helped to fill the state-wide gap in information critical to the management of brackish-water areas. After the Myakka River projects began, similar research was undertaken in the Littler Manatee River (Hillsborough County), which is also a relatively natural stream These projects will be important for several reasons. First, they will document the actual role of specific rivers, in maintaining regional diversity and productivity. Second, they will provide much-needed guidance for the restoration of impacted streams. Last, these studies [have and] will advance our basic knowledge in estuarine ecology, and will be broadly applicable to a number of different coastal environments.

Acknowl edgements

This project would not have been possible without the generous time of numerous staff, volunteers, and student interns. For their assistance in collecting samples we thank Brad Bennett, Bill Burger, Ramon Caruz, Kellie Dixon, Therese East, Bruce Fortune, Jennifer Frederick, Allan Horton, Shelly Heidelbaugh, Beth Hussey, Mary-Jo Kehl, Marianne Klingel, Jennifer Kormendy, David Lucas, Mary Matosky, Pete Nabor, Tim Phillips, Donna Reeve, Chris Sellers, Dan Shader, Jason Weeks, and Katie Reeves, For their assistance in processing samples and entering data we thank Ilus Bene, Caryl Cameron, Andrea Frank, Leonard Jahnke, Elizabeth Kiraly, Larry Malis, John McCallum, Jack Orzach, Mike Sutherland, and Herbert Walker. Karen Burns, Duane Phillips and Therese East provided expert taxonomic assistance. Drs. Win Siler and Don Hayward provided valuable data and model output concerning the geometry and hydrology of the river. We are grateful to Sarasota County for the support to analyze the data and produce this report. CONTENTS

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INTRODUCTION

Objectives

This project was conducted to provide background information on the composition, distribution and abundance of fish eggs, larvae and juveniles within the fresh to marine salinity gradient, downstream of the T. Mabry Carlton (Ringling-MacArthur) Reserve. Objectives of the study were:

- To characterize the salinity, temperature, and oxygen structure of the tidal river over a 24 month period;

- To document the diversity, abundance and distribution of ichthyoplankton in relation to river geometry, hydrology and chemistry;

- To establish a baseline of data on the river's role as fish nursery and juvenile habitat, against which the possible impacts of future proposals may be evaluated.

Project History

This project is a corollary investigation in a series of studies concerning the ecology of the tidal Myakka River. Phases 1 and 2 were wet and dry season reconnaissances, respectively. The last task of Phase 2 involved and independent peer review of progress to date (Browder, 1987). Phase 3 involved wetland mapping and monitoring (Estevez, Evans and Palmer, 1990). These studies were expanded by Sarasota County when the opportunity arose to inventory shorelines, and the results of the extra surveys were reported in Estevez, Palmer, Evans and Blanchard (1990). Phase 4 of the project involved the calibration and verification of a one-dimensional hydrologic model of the tidal river, the results of which are reported in Siler and Blanchard (1990) and Siler, Hayward and Blanchard (1990).

Definition of the Study Area

For this study, tidal waters of the Myakka River were sampled at discrete stations that originally included an upstream station between the Interstate and Border Road, but that station was discontinued for logistic reasons. As a result, the effective study area for this report is the tidal river between Snook Haven and Cattle Dock Point (Figure 1).

Description of Relevant River Features

Because the river runs at low grade and the diurnal tide range is 1.9 feet (NOAA, 1990), tidal effects penetrate several miles upstream Sea level is believed to intercept the bed of the river near Rocky Ford (Hammett, Turner and Murphy, 1978) and backwater effects upon stage have been recorded there (Hammett, in press). Between the river mouth and Rocky Ford, the tidal river may be subdivided into these zones of relative tidal effect:

Sal t	<u>Tidal S</u>	<u>tage Respon</u> se
Sart	with turrent reversa	its without turrent reversars
always present	Yes	No
high tides only	Yes	No
dry seasons only	Yes	No
droughts only	Yes	No
never present	Yes	Yes

Above Rocky Ford the river continues into reaches that are permanently fresh water and there are no tidal effects on currents or stage. Discharge affects stage throughout the river system and, during flood conditions, tidal planes may be elevated or eliminated as far downstream as El Jobean.

Bathymetry, sediments, and vegetation also change along the length of the tidal river (Fortune, 1985). The river is widest and deepest near Cattle Dock Point and both ebb and flood channels are evident in cross sections. The ebb channel reaches upstream about a mile north of El Jobean. Mangroves and the submerged species, Halodule wrightii, are the dominant primary producers. Beyond this point, to the Sarasota-Charlotte County line, the river is a broad embayment with gently-sloping, almost level bottoms. The embayment contains a large measure of very shallow water during low tides, especially along the eastern side. There are no islands and relatively few wetlands or beds of submerged aquatic vegetation in the embayment reach of the tidal river. Oyster reefs are common, however. Another type of river structure occurs upstream of the embayment (and county line), in the form of braided channel and tidal wetland. This reach extends to Big Bend and is the zone of transition from mangrove and salt marsh to tidal freshwater marsh; it is also a zone of high diversity for submerged aquatic vegetation (Estevez, Evans and Palmer, 1990). It is the reach with the most tributaries and the highest ratio of river edge to river mile.

The last reach in the tidal river extends upstream from Big Bend to Rocky Ford. It is a highly meandered stream with steep banks and level bottom interspersed with holes and rock outcrops. Except for Curry Creek (Blackburn Canal) tributaries are minor and sloughs are more common near Rocky Ford than in lower parts of the reach. The floodplain forest canopy is open over the river and submerged aquatic vegetation is sparse. Rafts of floating plants occur in this reach.

Overall, the river's width changes from 13,500 feet to 250 feet over a length of about 20 miles (Fortune, 1985). Depth and wetland area also decrease upstream (Estevez, Evans and Palmer, 1990) and the combined effect of these changes is a logarithmic decrease in cross-sectional area and standard volume of the river, with upstream distance (Figure 2). Consequently, physical, chemical and biological features have non-linear distributions along the river.

Salinity ranges from 20-25 parts per thousand (ppt) in Charlotte Harbor to less than 1.0 ppt upriver. Depending on river discharge, the salt wedge may occur anywhere between the Sarasota-Charlotte County line (high discharge) to upstream of Interstate 75 (low discharge). Salt intrusion during droughts may move the salt wedge even farther upstream and such movement may be facilitated by the Blackburn Canal. Tidal excursions of 1 to 2 river miles are typical for the salt wedge or other isohalines of interest.

The tidal river exhibits little density stratification except during discharges associated with tropical storms, and even then, significant vertical differences in salinity are restricted to the river mouth and lower river areas. Factors responsible for well-mixed conditions in the tidal river include wind-driven circulation in the shallow and wide waters of Myakka Bay, and several river and tidal deltas. The river is very shallow between Deer Prairie Creek and Ramblers' Rest, and this geometry promotes mixing. Dense, salty water may accumulate in a +20.0 ft. hole in the river at the entrance to Big Slough.

PREVIOUS INVESTIGATIONS

Fishes and fishery-related topics in and near the tidal Myakka River have been investigated by Woodburn, 1960; Wang and Raney 1971; Texas Instruments, Inc., 1978; Fraser, 1981; Harris et al., 1983; Phillips, 1985 and 1986; Reeve and Fortune, 1986; Burns, Estevez and Frank, 1987; and East, Phillips and Estevez, 1987. The two 1987 reports were based in part or entirely upon results of the first year of sampling in the project described herein.

Woodburn (1960) reported on sport fisheries in Charlotte County, because "in recent months sports fishing interests in Port Charlotte, a new waterfront community, have alleged that fish catches have declined and that commercial fishing is the cause". The survey was begun 10 days after the passage of Hurricane Donna, which was the second wettest September in 46 years. Twelve stations were sampled with a bagged minnow seine and a pushnet, and 41 fish species were collected. One station (5) was located in the Myakka River, at the southeast side of the El Jobean bridge. The station was sampled at 0900 hours, at slack low water. The water was 2.5 ft. deep and had a temperature and salinity of 27.2°C and <1.0 ppt, respectively. Widgeon grass (Ruppia maritim) was present at the site. Five species (12% of the total for all stations) were caught: Cynoscion nebulosus (spotted seatrout), Fundulus confluentus (marsh killifish), Lagodon rhomboides (pinfish), Lepomis macrochirus (bluegill), and Eucinostomus argenteus (spotfin mojarra).

Finucane (1965) produced an unpublished ichthyofaunal survey of Charlotte Harbor and Pine Island Sound, for the one year period beginning in January 1964. He trawled at two stations and seined at five stations in the Myakka River estuary and upper Charlotte Harbor, and recovered 89 species. Overall catch of individuals (79.2% total) was dominated by <u>Anchoa mitchill</u>i (bay anchovy, 46.2%), <u>Lagodon rhomboides</u> (12.2%), <u>Leiostomus xanthurus</u> (spot, 6.5%), <u>Eucinostomus gula</u> (silver jenny, 5.4%), <u>Menidia beryllina</u> (tidewater silversides, 5.0%), and <u>Brevoortia</u> spp. (menhaden, 3.9%). About 46% of the total Charlotte Harbor catch was bay anchovy. For the entire area, catch decreased as salinity decreased because of high river discharge.

In 1971 Wang and Raney published an account of fishes in Charlotte Harbor that remains the definitive and seminal work on the subject. Conducted as a research project of Cornell University and the Mote Marine Laboratory, the survey involved 1169 trawls, 32 seine hauls, and 33 dip-net samples. Samples were taken from February 1968 to May 1969 at 33 regular stations and several other occasional sites. A total of 125 species were collected. Only one (No. 31) was in the Myakka River, east of the El Jobean bridge in 14 feet of water. It produced 12 species, most commonly Anchoa mitchilli, Bairdiella chrysura (silver perch), Cynoscion arenarius (sand seatrout), and Chaetodipterus faber (spadefish). Other species not already mentioned above include <u>Syngnathus</u> <u>scovell</u>i (gulf pipefish), <u>Micropogo</u>n undulatus (Atlantic croaker), <u>Sardinella aurita</u> (Spanish sardine), <u>Bagre</u> marina (gafftopsail catfish), <u>Menticirrhus americanu</u>s (southern kingfish), and Synodus foetens (lizardfish). For the harbor in general, catch fell as salinity decreased, and low winter temperatures also suppressed winter catches.

Texas Instruments, Inc. (1978) performed a river and estuary characterization study as part of the planning phase for a new power plant proposed for construction on the Peace River. One station (No. 9, also called Region IV) was in the tidal Myakka River, immediately downstream of the El Jobean bridge. It was sampled monthly in 1976, and also weekly from March to May, with 153 and 505 micron mesh nets, trammel nets, trawls, seines, and benthic drags.

The Myakka River station produced 72 species (Appendix I), several times more species than reported for this area by earlier investigators. Catch varied according to sampling gear: species caught by fine mesh nets (16) represented only 22% of the total diversity of fully-identified species collected near the river mouth, testimony to the selectivity of different sampling gear and methods. Only butterfish (Peprilus triacanthus) was uniquely caught by fine mesh nets. Despite the large number of species reported by Texas Instruments, Inc. (1978) some species known to occur in the river (eg., <u>Pristis pectinata</u>, or smalltooth sawfish; <u>Megalops</u> atlanticus, or tarpon; <u>Sciaenops ocellatus</u>, or redfish, and <u>Centropomis</u> <u>undecimalis</u>, or snook) were not collected. Conclusions from the 1978 report relevant to the Myakka River are quoted below for life stages and one species.

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Eggs and Larvae

"The estuarine waters of northern Charlotte Harbor (stations 8 and 9) supported a large variety and abundance of fish eggs and larvae; approximately 21 taxa were represented in catches at these two river-mouth stations . . . Eggs were collected from February through September. Larvae catches were dominated by anchovies, drums/croakers, gobies, hogchoker, and skilletfish. Greatest abundance occurred during April when total larvae densities exceeded 13,000 per 1000 cubic meters. Lowest larvae densities occurred during October."

Juveniles and Adults

"More saline inshore waters of Regions III and IV (mouths of the Peace and Myakka rivers, respectively) produced the greatest number of [fish] species and individuals of any habitat within the DeSoto Site study area. Bay anchovy, tidewater silverside, Sheepshead minnow, rough silverside, and young-of-the-year striped mullet and spot comprised the majority of the shore-zone community at the river mouths during the year. Juvenile pinfish and silver perch replaced mullet and anchovy as the dominant forms in the more saline waters of the harbor proper. The high productivity and dominance of forage and young-of-the-year fishes in inshore waters throughout the study area and particularly the brackish and estuarine portions of the study area reflect the valuable nursery function of this habitat."

Tidewater Silverside

"Tidewater silverside was one of the dominant fish species in the shore zone of the Myakka and Peace river estuaries and Charlotte Harbor. This species was abundant in both the upper estuary and at river mouths during the summer and early fall. Tidewater silverside apparently spawned over a protracted season extending throughout most of the year."

Fraser (1981) reported the results of a five year trawl survey at one deep (3.5-4.5 meter) station in upper Charlotte Harbor, an area affected greatly by discharges of the Peace River. This study is useful for insight to the effects of the Peace River, characteristics of benthic fish communities in the harbor, and the role of cyclic events. Forty-three taxa were collected, of which 12 comprised 98% of the catch. The most abundant wet season species were <u>Cynoscion arenarius</u>, <u>Leiostomus xanthurus</u>, Arius felis (hardhead catfish), and <u>Bagre marinus</u>. Wet season abundance decreased as mean Peace River flow in June increased. Abundant dry season species were <u>Anchoa mitchilli</u>, <u>Menticirrhus americanus</u>, <u>Lagodon rhomboides</u>, <u>Trinectes maculatus</u> (hogchoker), <u>Symphurus plagiusa</u> (blackcheek tonguefish), <u>Eucinostomus gula</u>, <u>Prionotus scitulus</u> (leopard searobin), and <u>Bairdiella</u> <u>chrysura</u>. Dry season (December through May) abundance increased as mean Peace River flow in December plus January increased. Overall, abundance in a given season affected abundance in later seasons. Fraser (1981) concluded that river discharge and tidal cycles may have multi-annual periods that affect catch, probably in estuary-specific ways.

Harris et al. (1983) reported on "fishery habitat" distribution, abundance and trends since 1945 for the Charlotte Harbor area, including the "El Jobean" topographic quadrangle that includes the tidal Myakka River upstream to the Charlotte-Sarasota County line. In 1982, this area contained 4, 321 acres of mangrove, 1, 528 acres of salt marsh, and 894 acres of seagrass beds. Since 1945, mangroves increased in area by 26%, while salt marsh and seagrass decreased by 13% and 45%, respectively. Harris et al. attributed salt marsh losses to urbanization and noted that mangrove increases coincided with a 631 acre decrease (-83%) in unvegetated tidal flats. Because the El Jobean map includes part of the Peace River and upper Charlotte Harbor, data from this study cannot be applied directly to the lower Myakka River but do serve to describe overall wetland and seagrass conditions in the area upstream and immediately adjacent to the river mouth. Details of wetland and seagrass distribution and abundance in the tidal Myakka River are given by Estevez, Evans and Palmer (1990).

Phillips (1985) surveyed macroinvertebrates and fishes throughout the tidal river, immediately after the passage of a tropical storm that ended a two year drought. Gear included plankton nets, gill and cast nets, seines, and trawls and samples were taken during day and night. A total of 22 fish species was collected. Freshwater ichthyoplankton (4 species) was collected upstream of Tarpon Point and estuarine ichthyoplankton (4 species) was collected downstream of Tarpon Point. Juveniles and adults comprised three groups: freshwater (upstream of Big Slough); estuarine-marine (downstream of Tarpon Point); and euryhaline (throughout the river). Significantly more species were trawl-caught at night than at day, and more individuals were caught at night, but not with statistical significance.

Subsequent sampling was conducted during the following spring (Estevez, 1986), which was a relatively wet dry season. Densities of fish eggs and larvae were greatest at the mouth of the river, and density decreased with upriver distance. Anchovy eggs and larvae dominated the catch. Sciaenid (drum) eggs, which may have represented as many as 7 species, accounted for the remainder of the catch. Goby larvae represented most of the remaining larval catch. Juvenile fishes were most abundant in the middle reach of the study area, and juvenile catches were dominated by anchovy (Phillips, 1986).

Trawls collected 30 fish species in April and more macroinvertebrate and adult fish species were caught at downriver stations and more individuals at upriver stations. The hogchoker accounted for 81% of the total catch and was the dominant species at upriver stations. Other numerically dominant fish species included Leiostomus xanthurus, Micropogonias undulatus, Anchoa mitchilli, Lagodon rhomboides, Bairdiella chrysoura, and Cynoscion arenarius. The river was divided into three zones based on trawl catches. The freshwater or upper river zone produced 10 species, with 4 unique to this zone, and was dominated by hogchoker. The middle river zone had 3 unique species of 12 species total and was dominated by Brevoortia, Cynoscion arenarius, and Micropogon undulatus. The lower river zone had 12 unique species out of a total of 18 species. Hogchoker, bay anchovy and spot were larger in the lower river zone than in other zones (Reeve and Fortune, 1986).

To recapitulate, most ichthyofaunal surveys conducted in the tidal Myakka River and vicinity were made near the mouth of the river. Only a single wet season and a single dry season survey by Mote Marine Laboratory have described the adult fish community of river reaches upstream of El Jobean and none has surveyed the use of the entire tidal river by larvae or juveniles, through time. Likewise, there has yet to be a thorough seasonal survey of fishes in all of the many different habitats represented in the tidal river, much less the river as a whole.

METHODS

Stations

Nine stations were established between the mouth of the river and Interstate 75 (Figure 3). Most stations had been used during wet and dry season characterization studies. Each was located by reference to local landmarks or day beacons. The most seaward station was located by motoring northeast from Cattle Dock Point until a minimum depth of 12 feet was reached. Station locations are described in Appendix II.

Schedul e

All field trips were made on nights of new moons or as close thereto as weather permitted. The timing of new moons and low tides in the winter of 1987 resulted in 2 January trips and no March trip. Trips were timed so that sampling began at slack low water at Cattle Dock Point. Upriver stations were visited in ascending order so that local conditions were as close to slack low water as possible.

Field Sampling and Measurement

Four ichthyoplankton samples were collected at each station using one meter (mouth diameter) 505 micron mesh nets. Two nets were towed in tandem from the port and starboard aft-quarters, respectively. The nets were fitted with pre-calibrated General Oceanics Model 2030 digital flow meters to record volume of the river actually fished. Flow meter readings were taken before and after each tow. Because the river is very shallow at low tide, nets were rigged for horizontal rather than oblique tows. Nets were towed for 3 minutes after they were fully deployed. Tows were made into the current, if any, and tows that hit bottom were repeated.

In practice, two samples were collected while approaching the station; physical measurements were made on station, and then two more samples were collected while leaving the station. Samples were concentrated into 1 liter wide mouth jars attached to the end of the net. Ctenophores were wrung through the net if their volume was excessive, and the net was rinsed with seawater before detaching the jar. Formalin was added to each jar to make 10% by volume prior to leaving the station. Each jar had internal and external labels. Depth was measured by fathometer or lead line. Physical measurements were made one foot below the surface and one foot above the bottom In very shallow water only one set of measurements was made at mid-depth. Dissolved oxygen was measured with a YSI Model 57 meter. Temperature, conductivity, and salinity were measured with a Beckman Model RS5-3 or a YSI Model 33 meter.

Sample Processing

Three of the four samples per station were processed. The fourth was used as a back-up sample as needed. Each processed sample was rinsed with fresh water over a 505 micron mesh net and then placed in a 1000 ml Erlenmeyer flask, after the volume had been adjusted to allow efficient sorting. A random plankton splitter was used to subdivide large samples or samples with extensive detritus, algae or plankton. The sample was thoroughly agitated and measured aliquots were transferred to a reticulated Petri dish. To process eggs, each aliquot was examined twice under a stereo-microscope, with thorough agitation between examinations. Eggs were identified to lowest practical taxon and counted, and densities were backcalculated to standard densities. To process larvae and juveniles, all specimens in the Petri dish were enumerated, identified to lowest practical taxon, staged (Hubbs, 1943), and densities were back-calculated.

Quality Assurance

Entries to log books were initialed in the field and reviewed for completeness after returning to the Laboratory. Sample custody followed standard operating procedures. All sorters were trained and tested and their daily work was supervised. Laboratory staff conducted random spot checks of processing. Staff were consulted for difficult identifications. Bench sheets were double checked and all keyed data were 100% verified. Data were screened for statistical outliers, which data were confirmed with project staff.

RESULTS

Because the data resulting from this study are extensive, the reader is encouraged to review the Table of Contents in order to understand the topics of this section and their order of presentation. In general, the convention is used of presenting spatial patterns and trends, then temporal ones. Biological data are presented in life-stage order and the complete fish community is presented before individual species are discussed. Extensive reference is made to figures, mostly graphs, which are presented between the tables and appendices of this report.

Physical Parameters

All measurements were made on or near new-moon nights, as close as possible to slack low water at each station. Surface temperature ranged from 14.8°C to 32.2°C (Appendix III). For the period of record, mean river salinity was approximately 25.3°C and there was essentially no difference in mean water temperature as a function of station location (Figure 4). Surface to bottom differences in water temperature were usually less than one degree (Figures 5 and 6). Water temperatures were seasonal with relatively short periods of low temperature (<20°C) and longer periods of high temperature (25-30°C). The winter of 1987 was colder than winter 1986 and the second summer was also warmer than the first.

Salinity ranged from fresh water to 29.0 ppt. Surface to bottom differences were greatest at the mouth of the river: the largest difference (10.18 ppt) occurred at the Charlotte Harbor station in July 1987. Vertical differences attenuated with upstream distance and differences larger than one ppt did not occur upstream of the Tarpon Point station. Mean surface salinity was about 3 ppt lower than mean bottom salinity at the mouth of the river and mean salinity at the surface and bottom were the same at and upstream of Tarpon Point (Figure 7). Mean salinity for the period of record was greater than 10 ppt in Myakka Bay and lower river reaches, and less than 5 ppt at Warm Mineral Springs and in upriver reaches. Mean surface salinity at Ranblers' Rest Resort was less than 2 ppt; at Big Bend it was less than 1.5 ppt, and at Snook Haven it was less than 0.5 ppt. Salinity varied in relation to discharge and was higher in 1986 than in 1987 because discharge in the first year was less than in the second. Salt water was present throughout the river in the winter of 1986 but was intermittent at midriver stations in 1987 (Figure 8).

Salinity was more responsible for combined physical gradients than temperature at downstream stations and the reverse was true at upstream stations. Figure 9 integrates the two parameters through time for the El Jobean and Big Bend stations. The stations represented two significantly different reaches of the river in 1986 and 1987, with the largest temperature excursion at Big Bend at the largest salinity excursion at El Jobean. Excursions for combined data from stations between El Jobean and Big Bend were intermediate in distribution and broadly overlapping, as expected from river continuum theory (Welcomme, 1985).

Dissolved oxygen (DO) concentration ranged from 2.90 to 10.98 mg/l (Appendix III). Mean surface DO was higher in the lower reach of the river than the upper reach, but not significantly so. Surface to bottom differences in mean DO were less than 0.5 mg/l and these differences were greatest downstream (Figure 10). The mean saturation of DO was not greatly different as a function of depth but was about 10% higher near the river mouth than at upriver stations (Figure 11). Seasonal variations in DO concentration and saturation followed the inverse of temperature: data for the two DO parameters were always greater at low temperature (Figures 5 and 6). Concentrations of DO were lower than 4.0 mg/l, and DO saturation values were higher than 100%, on only a few visits.

Overall Abundance

All samples were collected on or near new-moon nights, as close as possible to slack low water at each station. For all stations and months, mean egg density was approximately 1000/m³ and the mean densities of prolarvae, postlarvae and juveniles were two orders of magnitude less, or 3, 11, and 6 individuals/m³, respectively (Table 1). On average, there were between 1 and 135 ichthyoplankters per cubic meter of tidal river, with an average standard density of about 8 plankters.

Overall Diversity

For all stations, months, and life stages, a total of 47 species was collected (Table 2). Seven identifiable species were collected as eggs. Eighteen species were represented as prolarvae. Forty-six postlarval species were identified and 35 species were identified among juveniles. A listing of overall species densities by life stage appears in Appendix IV. Spatial Variation in Overall Abundance

Eggs were most abundant, on average, near the mouth of the river and were least abundant upriver (Figure 12). The opposite pattern was seen in juvenile abundance (Figure 13), with prolarval and postlarval patterns intermediate between the two extremes (Figures 14 and 15; note scale differences in Figures 12-15). The three most downstream stations --Charlotte Harbor to and including Myakka Bay-- had similar egg densities and it was not until Tarpon Point did mean overall egg density decline with upstream distance. Mean overall density of juveniles increased with upstream distance with a strong local peak at Tarpon Point.

Spatial Variation in Overall Diversity

Overall egg diversity (Figure 16) had a pattern similar to that of overall mean egg density in that values were highest at the Charlotte Harbor station and declined with upriver distance, including a small increase at Snook Haven. Diversity among larval and juvenile stages combined was also highest downriver and decreased with upriver distance (Figure 17). The increase in larval and juvenile diversity through the middle reach of the study area paralleled transitional density values for these stages.

Temporal Variation in Overall Abundance

Eggs were strongly seasonal (Figure 18) with peak densities in the spring of 1986 and high, erratic densities in the winter and spring of 1987. All prolarvae combined were highly abundant in spring of 1986 and had low, erratic values for the remainder of the study (Figure 19). As would be expected, spring of 1986 was a period of postlarval abundance but other peaks occurred in winter of 1986 and spring and fall of 1987 (Figure 20). Peaks in juvenile abundance were more closely tied to winter periods (Figure 21). No consistent phase-lags were evident between successive stages when all species were pooled.

Despite the presence of winter spawners in the river, relative larval abundance was definitely controlled by spring spawners. At downriver stations, peaks of relative larval abundance occurred from April till July in both years, as illustrated for the Charlotte Harbor station in Figure 22.

¹ Defined as the sum of pro- and postlarvae divided by the sum of all larvae plus juveniles.

Upstream stations had a similar spring pulse but in 1986 it extended from March till August, as illustrated for the Snook Haven station in Figure 23. Relative larval minima at Snook Haven appear greater than relative larval minima at Charlotte Harbor only because of vertical scale differences.

Temporal Variation in Overall Diversity

Diversity of fish eggs was greatest in the spring of each year and there were five months when no species was represented by eggs (Figure 24). The strongest component to egg seasonality was the influence of downstream stations although a clear spring-summer signal was evident throughout the river in both years (Figure 25). Prolarval (Figure 26) and postlarval (Figure 27) diversity followed density trends although the difference between maximum and minimum postlarval diversity was not as great as the difference between maximum and minimum postlarval densities. Diversity of juvenile fishes generally ranged between 5-10 species but exceeded 10 species about 25% of the time (Figure 28). Seasonality of juvenile fish diversity was less pronounced than diversity trends for larvae. However, overall species diversity (larvae plus juveniles) was clearly seasonal with spring maxim and minimum in fall and winter (Figure 29). Seasonality was more pronounced in lower river and middle river reaches than in the upriver reach (Figure 30).

Relative Species Abundance

Only a few taxa were numerical dominants and <u>Anchoa mitchill</u>i was more abundant, as determined by several measures, than other dominant taxa (Table 3). Bay anchovy was collected 1000 times compared to 368 collections of the next most abundant species, <u>Trinectes maculatus</u>. Median, mean and maximum densities of bay anchovy were at least an order of magnitude greater than the same statistics for any other species. Bay anchovy was caught on every sampling trip whereas the other numerical dominants were caught as follows:

> Collected over 20 months or more: <u>Gambusia affinis, Gobiosom</u> sp. and <u>Trinectes maculatus</u>

> > Collected over 15 to 19 months: Clupeidae, Cyprinodontidae and <u>Syngnathu</u>s sp.

Collected over 12 to 14 months: Blenniidae, Ictaluridae, <u>Cynoscion arenarius</u>, and <u>Microgobius gulosus</u> It is evident that the numerically dominant species were also common, insofar as each was present on at least half of the sampling trips. Data on these dominant taxa are presented together in a separate section. Given the overriding prevalence of bay anchovy, the next two sections provide details of their spatial and temporal distribution. Hogchokers are also treated separately.

Spatial Variation in Anchovy Abundance

Because bay anchovy so heavily dominated the total catch it was responsible for most of the spatial variation depicted in Figures 12 through 15. Eggs were most abundant near the river mouth and juveniles increased in abundance with upriver distance: prolarval and postlarval abundances were intermediate between these extremes.

Temporal Variation in Anchovy Abundance

Egg densities varied through time following the pattern illustrated by Figure 18 except that bay anchovy eggs were less abundant in the last half of 1987 than combined egg abundance. In general, anchovy larvae density varied consistently with total larvae abundance (see Figures 19 and 20) but was less important in explaining total larval catch in 1987. Relative to other <u>Anchoa</u> life stages, larvae were present on each sampling trip (Figure 31). Relative larval abundance exceeded juvenile abundance only in the spring of 1986 and in the fall seasons of 1986 and 1987 (Figure 32). Juvenile catch varied as shown by Figure 21.

Combined Spatial and Temporal Variation in Anchovy Abundance

A dynamical pattern of anchovy recruitment for 1986 appears in Figure 33, as a three dimensional response-surface in which larvae and juveniles were separately highlighted. White sectors represent a response floor of eggs, larvae and juveniles. Juvenile anchovy were a significant part of total anchovy catch at upriver stations in winter. Larvae entered the river from Charlotte Harbor beginning in the spring and recruitment to the river continued through summer. The majority of larvae penetrated upriver reaches in summer.

Hogchokers

Data from the dry season characterization (plankton nets and trawls) and this project's plankton net sampling in 1986 were combined to produce a picture of annual recruitment to and use of the tidal river by the hogchoker, <u>Trinectes maculatus</u> (East, Phillips and Estevez, 1987). Hogchokers had a protracted spawning season beginning in May and ending in November, with peak larval densities from June through October. Smallest larvae (<3 mm SL) were most abundant in the higher salinity area of the lower river during early summer months. Hogchokers were planktonic until about 18 mm SL after which they became benthic. Late postlarvae and early juveniles (10-18 mm SL) were most abundant in fresh water 12 river miles or more upstream Trawl-caught juveniles and adults ranged in size from 16 to 99 nm SL. Young-of-the-year hogchokers were most numerous at the farthest upstream stations in the spring but were commonly taken in the fall at downstream stations. The largest individuals occurred near the river mouth (East, Phillips and Estevez, 1987).

Other Species

Burns, Estevez and Frank (1987) examined the distribution of fish diversity in the river during 1986. Because annual trends in diversity were similar for 1986 and 1987 their spatial analysis is reviewed here. The nine stations were assigned to down-, mid- and upriver reaches, each with 3 stations representing 5 to 6 river miles. The lower river had 31 taxa compared to 35 in the middle river and 29 in the upper river. Shared taxa are listed in Table 4 and were distributed by reach as follows:

	Upper	Mi ddl e	Lower
Lower	1	8	6
Mi ddl e	8	3	
Upper	4		

There were also 16 species that occurred in all three river reaches. Unique and shared species over the relatively compressed length of the tidal river illustrate the strong sorting effect of salinity. No river zone was notably richer than others but the composition of ichthyofauna changed in a pattern consistent with documented salinity dependence of estuarine fishes (Bulger, Hayden, McCormick-Ray, Monaco and Nelson, 1990).

Reproduction among other numerical dominants was seasonal with peaks in the spring and summer (Figure 34). Larval recruitment was greater in 1986 than in 1987. The seasonality is not an artifact of recruitment of bay anchovy, as can be seen by comparing Figure 34 with Figure 31. Actually, particular dominant species had maximum larval abundances that spanned the year. Five of the dominant species produced most larvae in winter-spring, spring-summer, or spring-fall periods. The sum of relative larval abundance was biased by these species, resulting in the pattern of relative larval abundance for all species that is Figure 34. Examples of dominant species with seasonally different periods of relative larval abundance are given below. It should be recalled that 1986 was a drier year and hence the river had higher salinity in 1986 than in 1987.

Clupeid larvae were most abundant in winter and were less common than juveniles throughout the summer and fall of both years (Figure 35). Larvae of <u>Gobiesox strumosus</u> were also abundant in winter but persisted through spring, especially in 1986; juveniles dominated their catch in late summer and early fall (Figure 36). A good example of a species whose larvae dominated the catch in spring and summer was <u>Gobiosoma</u>, even though its larvae were common year around (Figure 37). The cyprinodontid larvae outnunbered juveniles for most months but were most abundant over the broad period of spring-fall (Figure 38). <u>Microgobius gulosus</u> was an excellent example of larval recruitment in summer (Figure 39). Finally, <u>Gambusia</u> <u>affinis</u> larvae outnunbered juveniles year-round but larval abundance peaked in summer and fall (Figure 40).

Invertebrates

Mysids were extremely common during the 2 years of sampling. They were most abundant during summer in the upper river and most abundant during fall in the lower river. Two species may be represented in the mysid collection. Ctenophores also were common and abundant, especially in the lower river. Ctenophores penetrated upstream as far as Big Bend in 1986 but in 1987 the comb-jellies were limited by higher discharges to the river below Tarpon Point. For the two years as a whole, the average upriver limit of ctenophore penetration fell between the Myakka Bay and Tarpon Point stations, and the mean salinity at their upriver limit was 9.6 ppt (s.d. 3.7 ppt).

DISCUSSION

Physical factors affecting ichthyoplankton include velocity, salinity, the river location of particular velocities and salinities, and the volume of river reaches occupied by different life stages of particular species. These parameters also are affected by antecedent events. To a lesser extent, temperature and dissolved oxygen affect the river system by imposing seasonal signals that were relatively independent of river discharge or antecent conditions.

The responses of fish population structure and size to physical conditions in the river are species-specific and strongly affected by antecedent events, including the size of previous years' populations. Biological processes such as carbon fixation and predation are also cyclic and affected by antecendent conditions. Superimposed on these physical and biological characteristics are cycles of longer term, such as tidal epochs, which affect salinity intrusion and marsh inundation. The combination of short to long-term variables creates patterns of river structure -- and usage by fishes-- that are complex and difficult to decompose on the basis of 24 consecutive monthly samples. For example, large catches of tidewater silversides (<u>Ménidia beryllina</u>) were reported by Finucane (1965) and Texas Instruments (1978) but this species was not a numerical dominant in 1986-87.

It should be recalled that 1986 was a drier year and hence the river had higher salinity in 1986 than in 1987. Figure 41 illustrates the interpolated positions of selected isohalines for the period of record. In 1986, the river reach bounded by an upper salinity of 5.0 ppt had an average length of 3.9 miles during the spring and summer (April - September), compared to a mean reach of 3.6 miles with comparable salinity in 1987. The location and volume of low salinity water were significantly different, however. In 1986 the usual position of brackish (<5.0 ppt) water was between river miles 7.7 and 11.6, compared to river miles 4.0 to 7.5 in 1987. In 1986 the mean tide volume of the brackish reach was approximately 100 million cubic feet whereas in 1987 the brackish reach had a volume of about 220 million cubic feet. Thus there was a smaller volume of brackish water in 1986, located farther upstream, than in 1987.

Approximately the same results obtain for other bands of salinity up to 15.0 ppt. Water bounded by a lower salinity of 15.0 ppt penetrated farther

into the tidal river in 1986 than in 1987 (Figure 41). The length and volume of this salinity band were also greater. Species utilizing salinities higher than 15 ppt had a larger habitable reach in 1986 than in 1987 and this may have contributed to the larger number of eggs and larvae at downstream stations during the 1986 spring and summer. By the same reasoning, juveniles --normally having greater tolerance to varying salinity-- had a larger habitable reach through most of 1986 than in 1987.

The use of plankton concentration as a measure of abundance can be distorted by the distribution of species in a sample or by the distribution of individuals of a species between samples (see Peebles and Davis, 1989). In this analysis we have continued the use of concentration (density) for comparative purposes (see below). Moreover, our analyses have concentrated more on diversity and relative larval abundance than on absolute abundances, particularly in light of volume considerations made above. Peebles and Davis (1989) transformed density to abundance for ichythyoplankton catches in the Little Manatee Rive; near Ruskin, and found that weighted abundance indices varied differently than standard densities. They were also able to illustrate migration toward low salinity reaches by successive life-stages of estuarine-dependent fish species, but did not evaluate the effect of river volume on density or abundance.

The evaluation of volume-weighted stocks is useful in understanding river-wide utilization patterns and the relation of "dynamic" habitat to "stationary" habitat. These concepts were developed by Browder and Moore (1981) thusly:

"The river in its interaction with the tides determines the 'slope' of the salinity gradient and, therefore, the area of water within the favorable salinity range for a given species. Steeper slopes mean smaller areas between isohalines; gradual slopes mean broad areas between isohalines. River flow also positions the area of favorable salinities relative to important stationary habitat factors such as shoreline, water depth, and bottom type. The size of the area of overlap of these factors, integrated over the nursery season, as well as food concentration, may determine the survival and growth rates of juvenile organisms."

² In terms of amplitude, although overall seasonality patterns were generally unaffected.

Browder and Moore (1981) identified at least 3 reasons why production of fishery species may correlate with the overlap in dynamic and stationary habitat. In two cases (food supply and growth rate), more favorable habitat increases food or lowers density dependent mortality. Conversely, mortality is higher for juveniles in suboptimal areas when the size of favorable habitat is small. Later, Browder and Wang (1987) were able to demonstrate the usefulness of the new approach by explaining variation in fish abundance in terms of the area of specific salinity bands.

Browder and Moore (1981) also concluded that "most fishery biologists conducting research in estuaries seem to be unaware of the nonlinear effects of freshwater flow on mixing". The dependence of Myakka River cross sections and volumes on upriver distance is a useful example of nonlinearity, especially when used to compare apparent stock sizes in ichthyoplankton. Because a tidal river's geometry compounds non-linearity of tide-discharge interactions, volume rather than area is probably the index of preference in applying the new concept.

The lower Myakka River is a shallow, low-flow, well-mixed blackwater stream Few studies of ichthyoplankton have been made in these coastal environments, although evidence from this study is consistent with the physical, chemical and ichthyofaunal characteristics of the lower-most reaches of the world's large and well-studied rivers (Welcomme, 1985.) Because the study area encompassed estuarine, brackish, and tidal freshwater reaches, results of this research can offer riverine details for the emerging regional picture of fishery dynamics in coastal and inshore waters of the eastern Gulf of Mexico (Williams, et al., 1990). The data may also find value for testing new estuarine classification systems (Bulger et al., 1990).

This study was made in 1986 and 1987. Beginning in 1988, a similar project began in the tidal reach of the Little Manatee River and an interim report for the first year (of 2) is available (Peebles and Davis, 1989). The Little Manatee project is part of a more comprehensive study involving simultaneous physical, chemical and biological sampling and measurement. Thus it should eventually be able to identify causal relationships for ichthyofaunal patterns and trends there and these insights will be valuable in application to the Myakka. There are some differences between the two projects. The Myakka survey was more intensive spatially (9 stations) than the Little Manatee survey is (6 stations), but the latter survey is more intensive temporally (twice-monthly sampling) than the former (monthly sampling). Nets of different sizes were used and replication was greater in the Myakka survey.

Despite these differences (and hydrological differences between years and rivers), it is noteworthy that the general picture of diversity, density, recruitment, and river use of fishes is similar. In 1988, 68 species were collected in the Little Manatee. The mouth of the river (and Tampa Bay) was the spawning site for the same suite of species found near the mouth of the Myakka. Young of several species were found to migrate upriver during early developmental stages. Specific species utilized the Little Manatee's estuarine, brackish and tidal fresh water reaches in a manner like that seen for the same species in the Myakka. Peebles and Davis (1989) concluded that fishes "most likely to be impacted by changes in the quantity or quality of freshwater discharge" were those represented in the river as eggs or newly-hatched young, plus species with estuarine-dependent early juvenile stages in low salinity areas.

If river discharge changes, changes in the diversity, abundance or condition of fishes in tidal rivers such as the Little Manatee or Myakka may not be limited solely to species that reproduce or mature there. Snedaker and de Sylva (1977) adunbrated the types of community level changes that may occur among fishes when river discharges are reduced. Much of the impact to fishes of altered river flow will be manifested through changes in the abundance and types of food-stuffs delivered to the tidal reach. Browder (1988) showed that a significant part of the diet of fishes in the tidal Myakka River was of benthic origin. Changes in discharge that affect sedimentation patterns, through-put of detrital and dissolved organic material, or bottom salinities will affect benthic productivity, and this in turn will affect many fish species whether or not spawning or maturation is directly affected.

The impact of altered river flow on several estuarine ecosystems in the world were reviewed by Mahmud (1985). Significant changes have occurred in geological, chemical and biological attributes of the studied estuaries. Ecosystem decline of the Caspian Sea because of flow reduction has also been documented by Rozengurt and Hedgpeth (1989). This analysis thoroughly documented the impacts to fisheries caused by salinity changes in tidal tributaries. It is also significant for proposing the first conceptual model relating flow reductions to estuarine impacts. In Florida waters, Browder et al. (1989) evaluated ichthyoplankton responses to altered freshwater inflow³ in the Ten Thousand Islands. Changes in fish diversity and abundance were documented. Incidentally, the effects upon Florida fishes of increased flow have been demonstrated by Gunter and Hall (1965) and Van Os, Carroll and Dunn (1981).

Summary and Conclusions

Objectives of the study were:

- To characterize the salinity, temperature, and oxygen structure of the tidal river over a 24 month period;

- To document the diversity, abundance and distribution of ichthyoplankton in relation to river geometry, hydrology and chemistry;

- To establish a baseline of data on the river's role as fish nursery and juvenile habitat, against which the possible impacts of future proposals may be evaluated.

Data collected by this and corollary studies in the tidal Myakka River support a view that the lower river's geometry and physical features are not presently disturbed by dredging, channelization, significant shoreline alteration, or chronic variations from natural discharge patterns. Except during droughts, the lower river is a transitional reach from estuarine conditions of Charlotte Harbor to tidal freshwater conditions upriver from U.S. 41.

Species richness was intermediate between one similar river to the north and three estuarine areas to the south. Seasonal variation in species richness occurred during both years and differences due to annual discharges were found. The identity of fish communities in lower, middle, and upper river reaches was consistent with the known salinity and habitat requirements of individual species. The lower reach of the tidal river is an extension of the upper Charlotte Harbor fauna. In this way, changes in the flow of the Peace River and Charlotte Harbor's responses to Peace River flow may affect recruitment into the Myakka River. Conversely, changes in the habitability for fishes of the lower Myakka River could affect the upper Harbor area. Ongoing hydrodynamic modeling of the Harbor by the U.S. Geological Survey will provide additional insight into the relative roles of the two rivers.

³ Quantity, timing and location

The tidal freshwater reach of the river supported a distinct resident ichthyofauna and was the nursery-ground for several species with estuarine and marine ranges as adults. The dynamics of fishes in the Myakka River State Park have been the subject of a 3 year study by the University of Florida (Mr. Ken Langeland, Center for Aquatic Plants, personal communication). It will be necessary to compare this study with the Park survey to identify river-wide patterns of fish occupation and movement. In light of the recovery of snook (Centropomis undecimalis) as far upstream as Fort Meade in the Peace River (Champeau, 1990), small instream dams in the Myakka River may be truncating the total habitable reach of snook in the Myakka.

Snook and other species of recreational or commercial value were not represented in the present study's catch because of the types of gear used. These species are known to use the tidal Myakka River and were caught in previous investigations using different gear. At present there are no data on larvae, juveniles and adults of these species but a fishery-independent stock assessment program will begin in 1991 (Mr. Chuck Idelberger, Florida Department of Natural Resources, personal communication). Such monitoring is necessary to identify trends and departures in long-term use of the Myakka River by valued species.

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Table 1.	Standard	density	statistics,	nunber	per	cubi c	neter.
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	N	<u>Mi ni mu</u> m	e <u>an Overa</u> ll <u>M</u> ean	<u>Maxi mu</u> m
Eggs	230	1.11	964.11	9572.98
Prolarvae	56	1.94	3.09	6.67
Postlarvae	2043	0.94	10. 92	97.69
Juveniles	1137	1.11	6.40	249. 41
All life stages	3236	1.18	7. 90	134. 78

Achirus lineatus Anchoa hepsetus Anchoa hepsetus (eggs) Anchoa mitchilli Anchoa mitchilli (eggs) Archosargus probatocephalus **Atherinidae** Bairdiella chrysura Bathygobius soporator Bl enni i dae Callinectes **Carangi** dae Centrarchi dae Chaetodipterus faber (eggs) Chlorosconbrus chrysurus **Clupei dae** Clupeidae (eggs) Cumacea **Cynoscion** arenarius Cynoscion nebulosus Cypri ni dae Cyprinodonti dae **Elops** saurus Etheostoma fusiforme Gambusia affinis Gerri dae Gobiesox strumosus Gobi i dae Gobiosoma sp. Heterandria formosa Hippocampus sp.

Ictaluridae Lagodon Rhonboidae Leiostomus Lepi sostei dae Lolliguncula brevis Membras martinica Menidia beryllina Menticirrhus sp. Microdesmus longipinnis Microgobius gulosus Micropogonias undulatus Micropterus salmoides Mugilidae Myrophis punctatus **Mysids Oligoplites saurus** Palaemonetes sp. Penaeus sp. Pogonias cromis Prionotus sp. Sciaenidae (eggs) Sciaenops ocellata Soleidae/Triglidae (eggs) Sphaeroides sp. Symphurus plagiusa Syngnathus sp. Synodontis Trinectes naculatus Unid. & Damaged Unidentified (eggs)

Table 3. Numerically dominant ichthyoplankton species in 1986 and 1987, all stages combined. OBS, number of observations; density statistics are in number of individuals per cubic meter.

			<u>Overall Mean</u>			
Taxa	<u>0 B S</u>	<u>Min.</u>	<u>Medi an</u>	<u>Mean</u>	<u>Max.</u>	
Anchoa mitchilli	1000	0. 5	19. 1	132.7	8264.6	
Trinectes maculatus	368	0. 5	2.6	7.2	118.9	
Gobiosoma sp.	317	0.8	4.7	19.7	349. 7	
Cl upei dae	172	0.9	3.5	13.6	303. 6	
Gambusia affinis	131	0.8	1.3	1.7	5.4	
Cypri nodonti dae	129	0.7	1.4	2.1	9.7	
Cynoscion arenarius	109	0. 9	3.5	11.4	103.1	
Sygnathus sp.	91	0.5	1.5	2.4	11.0	
Ictaluridae	90	0.5	1.5	2.8	12.8	
Microgobius gulosus	81	0.8	2.5	9.2	165.8	
Gobiosox strundsus	74	1.0	1.5	2.5	20. 7	
Bl enni dae	59	0.8	3.8	6.8	30. 1	

Table 4. Unique distributions of ichthyoplankton species by river zone in 1986. Downriver: Charlotte Harbor to Myakka Bay stations; Middle River: Tarpon Point to Warm Mineral Springs stations; Upper River: Ramblers' Rest Resort to Snook Haven stations.

LOWER RIVER ONLY

Chlorosconbrus <u>Hippocanpus erectus</u> <u>Mcrodesmus longipinnis</u> <u>Sphaeroides sp.</u> <u>Symphurus plagiusa</u> <u>Synodus foetens</u> LOWER AND MIDDLE RIVER ONLY

Anchoa hepsetus Bathygobius soporator Blenniidae Gobiosox strumosus Menidia beryllina Menticirrhus sp. Myrophus punctatus Oligoplites saurus

MIDDLE RIVER ONLY

<u>Fundulus sp.</u> <u>Gobiosom bosci</u> <u>Micropogonias undulatu</u>s

UPPER RIVER ONLY

<u>Cyprinodon variegatus</u> <u>Ictalurus nebulosus</u> <u>Jordanella florida</u>e Lepisosteidae

LOWER AND UPRIVER ONLY

Sciaenops ocellatus

MIDDLE AND UPRIVER ONLY

Centrarchidae Cyprinidae <u>Elops saurus</u> <u>Ganbusia affinis</u> Heterandria formosa Ictalurus punctatus Lucania parva Mugil cephalus



Figure 1. Location of the tidal Myakka River.



Figure 2. River volume (cubic feet) in the first 30 miles of the tidal Myakka River. Based on outputs of a model by Siler et al., 1990.



Figure 3. Ichthyoplankton sampling stations. Lower Myakka Bay (LMB), Shallows (SHW), and I-75 stations were discontinued and are not treated in this report. The Myakka Bay station is labelled UMB.



Figure 4. Mean station temperature (and standard deviation), January 1986 to December 1987.







Surface Salinity Variation







Figure 7. Mean station salinity (and standard deviation), January 1986 to December 1987.





Figure 9. Mean monthly excursions of temperature and salinity for El Jobean and Big Bend stations.



Figure 10. Mean station dissolved oxygen concentration (and standard deviation), January 1986 to December 1987.



Figure 11. Mean station saturation of dissolved oxygen (and standard deviation), January 1986 to December 1987.









Myakka Ichthyoplankton Study Charlotte Harbor

Figure 22. Relative larval abundance of all species over 2 years at Charlotte Harbor.

Myakka Ichthyoplankton Study

Relative larval abundance of all species over 2 years at Snook Figure 23. Haven.

Myakka Ichthyoplankton Study Fish Egg Diversity Variation

Figure 24. River-wide variation through time of egg diversity.

Figure 25. Variation through time of egg diversity at Charlotte Harbor (CHH), Tarpon Point (TRP) and Ramblers' Rest (RBR).

River-wide variation through time of prolarval diversity. Figure 26.

Myakka Ichthyoplankton Study Fish Post. Diversity Variation

Month

Figure 27. River-wide variation through time of postlarval diversity.

Myakka Ichthyoplankton Study Fish Juv. Diversity Variation

Figure 28. River-wide variation through time of juvenile diversity.

Myakka Ichthyoplankton Study Fish Diversity Variation

Month

Figure 29. River-wide variation through time of diversity among all stages.

Figure 30. Variation through time of larval and juvenile fish diversity at Charlotte Harbor (CHH), Tarpon Point (TRP) and Ramblers' Rest (RBR).

Myakka Ichthyoplankton Study Anchoa mitchilli

Figure 31. Relative larval abundance of bay anchovy over 2 years throughout the tidal Myakka River.

Figure 32. Relative abundance difference between juvenile and postlarval bay anchovy.

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Figure 33. Larval and juvenile bay anchovy recruitment in 1986, from Burns, Estevez and Frank (1987).

Myakka Ichthyoplankton Study All Fish Spp.

Manth

Figure 34. Relative larval abundance of all fish species over 2 years throughout the tidal Myakka River.

Myakka Ichthyoplankton Study Clupeidae

Figure 35. Relative larval abundance of Clupeidae over 2 years throughout the tidal Myakka River.

Myakka Ichthyoplankton Study Gobiesox strumosus

Figure 36. Relative larval abundance of <u>Gobiesox strumosus</u> over 2 years throughout the tidal Myakka River.

Myakka Ichthyoplankton Study

Figure 37. Relative larval abundance of <u>Gobiosoma</u> \underline{sp} . over 2 years throughout the tidal Myakka River.

Myakka Ichthyoplankton Study Cyprinodontidae

Figure 38. Relative larval abundance of Cyprinodontidae over 2 years throughout the tidal Myakka River.

Myakka Ichthyoplankton Study Mierogobius gulosus

Figure 39. Relative larval abundance of <u>Microgobius</u> gulosus over 2 years throughout the tidal Myakka River.

Myakka Ichthyoplankton Study Gambusia affinis

Figure 40. Relative larval abundance of <u>Gambusia</u> <u>affinis</u> over 2 years throughout the tidal Myakka River.

APPENDICES AND MISSING FIGURES

AVAILABLE UPON REQUEST