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ASSESSMENT OF FISHERIES HABITAT

FINAL REPORT
for
TASKS 1, 2, 3, 4, and 5

APRIL, 1989

These projects were supported by a grant from the Florida Office of Coastal Management, Department of Environmental Regulation, with funds provided by the United States Office of Ocean and Coastal Resource Management, NOAA, under the Coastal Zone Management Act of 1972, as amended.

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FINAL REPORT

for

GRANT PERIOD 10/1/87 THRU 3/31/89

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Department of Natural Resources
Division of Marine Resources
Florida Marine Research Institute

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INTRODUCTION

This report contains Tasks 1-5 of the Coastal Zone Management program at the Florida Marine Research Institute. Tasks 1 work products focus on a project that relates potential environmental stresses (i.e., sediment, light) to physiological correlates of <u>Thalassia</u> <u>testudinum</u>. This work complements previous CZM work that identified environmental stress and loss of seagrass habitat as a major problem in long term resource management. Task 2 work products are centered around the development of the Marine Resource Geographic Information Systems (MRGIS) and the dissemination of both digital and hard copy data into the user community. A focus of this Task has been the development of a detailed GIS database for the Little Manatee River Watershed. Task 3 work products are based on the goal to link and quantify the relationship between fisheries species to estuarine habitats. A major effort, linked to Task 2, to study distribution of fishes in the Little Manatee River has been initiated in this Task. Task 4 concludes the goal of defining population dynamics of juvenile snook and red drum in a specific and quantifiable estuarine habitat to understand the complexities of population size, growth, mortality, immigration, and emigration. These four tasks now represent a major thrust of the Florida Marine Research Institute to develop techniques and provide information to more effectively manage our marine resources.

Since sound information on habitat quantity, location, and importance to Florida's fisheries and non-game resources has never been addressed with a methodical, holistic approach, this type of information has not been available to the researcher or resource manager. Although much of what we are doing will require long term database development, the preliminary information has been and continues to be requested by agencies, planners, and researchers. We expect this program to grow and the knowledge gained to be of critical importance to the future of our coastal natural resources.

Task 5 is providing the vehicle to get our information and project results to the general public. The most effective approach to resource management is by an informed public guiding the governmental processes. By providing factual non-technical information to the public, they can make better decisions when facing tough issues regarding our marine environment. Through brochures, presentations and other forms of media, we are accomplishing these goals and the results can only be positive for Florida's future.

TASK 1 COMPLETION REPORT: PHYSIOLOGICAL AND STRUCTURAL CORRELATES OF STRESS IN <u>THALASSIA</u> <u>TESTUDINUM</u> IN FOUR FLORIDA ESTUARIES.

P. R. Carlson, W. B. Sargent, L. A. Yarbro, and H. A. Arnold.

INTRODUCTION

Seagrasses are distributed worldwide in shallow subtidal environments along coasts and within estuaries. Seagrass meadows provide important juvenile and adult habitat for hundreds of fish and invertebrate species, many of which contribute to commercial or sport fisheries. The complex food webs of seagrass meadows are based in part on the productivity of the seagrasses themselves and partly on the productivity of epiphytic and epipelic algae.

Human development of estuarine shorelines has coincided, worldwide, with areal declines in seagrass beds and submerged aquatic vegetation. Dramatic losses of aquatic macrophytes have occurred in West Australia, the Caribbean, Europe, and the continental United States. In the past 50 years, extensive declines of seagrass beds have been documented in the Northeast United States, Chesapeake Bay, and Florida. A re-examination of the so-called "wasting disease" which decimated East Coast <u>Zostera marina</u> beds in the 1940's suggests that the fungal pathogen which was blamed for the disease may have opportunistically attacked seagrass populations stressed by anthropogenic and natural factors.

The decline of seagrasses in Florida has occurred at an alarming rate. As much as 80% of the seagrass present in Tampa Bay in 1886 has been lost. While some seagrass area has been lost directly to dredge and fill, much of the loss has been due to gradual "die-back' of seagrass beds in response to poorly-understood stresses. We use the term "die-back' to describe the gradual decrease in size, density, and productivity of seagrass beds. For reasons which are not clear, turtle grass, <u>Thalassia</u> <u>testudinum</u> is more susceptible to die-back than the other two seagrass species (<u>Halodule</u> <u>wrightii</u> and <u>Syringodium</u> <u>filiforme</u>).

Previous research by DNR personnel, funded by the CZM program has documented seagrass losses in Tampa Bay, Charlotte Harbor, and the Indian River. Areal declines in seagrass beds have been estimated at one third for Charlotte Harbor and one half for Tampa Bay for the 40 years prior to 1982. Seagrass losses have also occurred in the Indian River lagoon.

The mechanism most frequently suggested as the cause of seagrass die-back is decreased productivity due to shading. Shading, in turn, may result from sediment resuspension, phytoplankton blooms, or epiphyte growth. All of these processes, in turn, may be accelerated or exacerbated by human activity, perhaps explaining the anthropogenic contribution to seagrass dieback.

We have previously tested the effects of shading on _Thalassia_ growth and found that reduction of ambient light levels over a shallow seagrass bed resulted, in less than one month, in decreased blade width, blade length, blade number, and shoot density. These shading responses occurred in spite of light in excess of 4 to 8 times the reported compensation value, the light intensity at which photosynthesis is sufficient only to meet the respiratory needs of the plant, suggesting that synergistic stressors may contribute to seagrass die-back.

Subsequent research in our laboratory, funded by the CZM program has focused on the causes and etiology of seagrass die-back processes, based on the underlying hypothesis that natural and anthropogenic stressors, such as shading, cause seagrass die-back by induction of hypoxia (ie. suffocation) or sulfide toxicity in roots or rhizomes. By this mechanism, die-back might occur at light levels that appear sufficient to support _Thalassia_ growth when roots or rhizomes are deprived of photosynthetically-produced oxygen necessary to maintain an aerobic rhizosphere in anaerobic, reducing sediments.

The phenomena of hypoxic stress and sulfide toxicity have been demonstrated in terrestrial and wetland plant species. _Spartina alterniflora_, the salt marsh cordgrass, frequently experiences hypoxic episodes, and hypoxia may be responsible for the extensive die-back of Louisiana salt marshes. Sulfide toxicity is known to reduce yields and kill rice plants at concentrations far less than those typically found in seagrass sediments. Stable sulfur isotope analyses of _Spartina_ tissue indicates that sediment sulfide enters _Spartina_ roots by diffusion or mass flux.

Last year, CZM-funded research last year examined the susceptibility of _Thalassia_ to sulfide toxicity. Clumps of plants collected from natural seagrass beds were grown in pots containing perfusers to manipulate sediment sulfide concentrations. We were surprised to find no significant inhibition of growth by high sulfide concentrations. Stable sulfur isotope analyses of _Thalassia_ tissue from this experiment and natural populations indicate that sulfide is taken up by seagrasses and that _Thalassia_ populations with the strongest sediment sulfide isotope "signal" in their tissue are often more vigorous than populations with a less pronounced contribution from sediment sulfide. We conclude that healthy _Thalassia_ can effectively detoxify sulfide.

Terrestrial plant species are often classified as flood-tolerant or intolerant, depending on their ability to survive inundation and hypoxia. Flood-tolerant species possess physiological adaptations enabling them to continue ATP production in the absence of oxygen. Most adaptations result in the accumulation of glycolytic end-products in compounds which are not toxic and can be introduced into the respiratory Krebs cycle when oxygen again becomes available. Malate and the amino acid alanine are common hypoxic metabolites in flood-tolerant species. Under hypoxic conditions, flood-intolerant species frequently produce ethanol which is auto-toxic and cannot be recycled for respiration. The complex evolutionary history of seagrasses in the family Hydrocharitaceae offers no insight into their hypoxic adaptations.

OBJECTIVES

The primary objective of this study was to identify physiological correlates of chronic stress in *Thalassia testudinum* that might be useful as diagnostic indicators of populations "at risk" of die-back. Secondary objectives included the following:

1. to select several sites in three estuaries (Tampa Bay, Charlotte Harbor, and Indian River) to reflect gradients in environmental parameters such as salinity, nutrient inputs, and turbidity which might result in hypoxic and sulfide stresses.

2. to measure hydrographic and sedimentary characteristics which might characterize the capacity for hypoxic and sulfide stress at each site.

3. to measure a suite of structural and physiological parameters in *Thalassia* tissue from each site.

4. to test the utility of the enzyme, alcohol dehydrogenase, as a stress indicator in *Thalassia*.

METHODS

Field sampling- Ten sites in three estuaries were selected during preliminary sampling in November and December, 1987 (Figure 1). These sites were sampled first in May 1988 under conditions we assumed to be near optimal for seagrass growth: clear skies, minimal rainfall, and moderate water temperatures. The same sites were sampled again in August under poor environmental conditions: lowered salinity, higher water temperatures.

In early June, 1988, we learned of a massive *Thalassia* die-back of which had occurred in Florida Bay near Flamingo. Because the die-back episode seemed an ideal opportunity to test the validity of our physiological stress indices, we sampled one die-back area in the vicinity of Johnson Key on June 29 and 30, 1988.

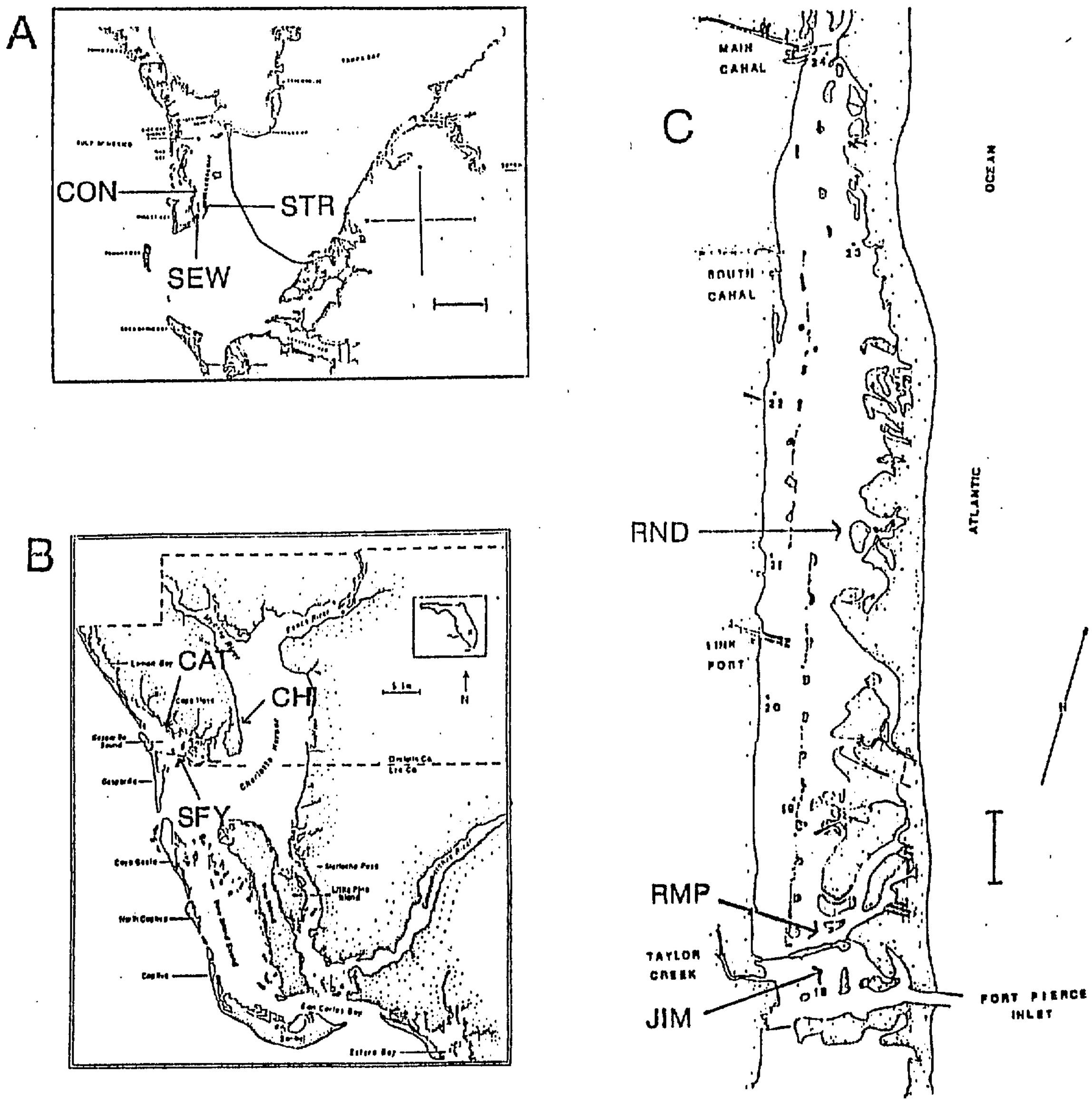


FIGURE 1. LOCATION OF SEAGRASS STUDY SITES.

A. Tampa Bay: CON= Control site, SEW= Sewage site, and STR= Stress site.

B. Charlotte Harbor: CAT= Catfish Creek, CHI= Cape Haze, and SFY= Sandfly Key.

C. Indian River: RND= Round Island, RMP= Boot Bay, and JIM= Jim Island.

Profiles of photosynthetically-active radiation (PAR) were measured at each site on both sampling dates with LI-COR flat (2 pi) and spherical (4 pi) sensors. Vertical extinction coefficients were used to compare light attenuation characteristics of the water column at each site in spring and summer. Coefficients (k) were calculated from the expression

$$L_z = L_{surf} \times e^{-k z}$$

where L_z is the light measured at depth z, L_{surf} is the light measured at the surface of the water, and z is the depth measured in meters. K was estimated for each light profile by linear regression of the natural logarithm of L_z divided by the natural log of L_{surf} against depth (z).

Four porous teflon samplers were purged with helium and inserted into the sediments at each site to collect pore water for dissolved sulfide analysis. Pore water samples were collected in syringes 1-12 hours after the samplers were set out. Pore water samples for sulfide analysis were preserved with a sulfide anti-oxidant buffer (SAOB).

Sediment cores collected for sediment sulfide analysis were preserved with an equal volume of zinc hydroxide (0.1 M) or SAOB. Sediment samples for sediment oxygen demand measurements were collected with piston corer (2.7 cm diameter x 15 cm long. The piston was withdrawn after sampling, and the core was stored in the open corer barrel. The surface floc layer of each core was carefully preserved, and a layer of seawater was kept on top of the core at all times to prevent oxidation of this sediment.

At each site, four replicate quadrat frames (0.04 m^2) were placed on the bottom, and all the _Thalassia_ shoots within each quadrat were marked. A syringe needle (19 ga. or 22 ga.) was jabbed through each shoot 1-2 cm above the sediment surface. Shoots from each quadrat were harvested 6-12 days later, and the growth of each blade in each marked shoot was determined by the distance between the needle mark on each blade and the needle mark on the outermost (=oldest) blade.

Samples for physiological analyses were collected at mid-day and just before dawn the following day at each site in May and August. Rhizome gas samples were collected by vacuum extraction of rhizome segments in glass syringes purged with helium gas. Gas samples were transferred to 2.5 ml glass syringes, which were capped and stored in deionized water at 2^{o}C until analysis. Rhizome tissue for analysis of hypoxic metabolites was cut into small pieces and dropped into 15-ml, polypropylene, centrifuge tubes containing cold, 8% perchloric acid. The tubes were capped and immersed in liquid nitrogen. Once frozen, the tubes were transferred to a dry ice cooler. Tissue samples for enzyme and amino acid analysis were placed in zip-loc bags and stored on dry ice.

Laboratory Methods-

Sediment oxygen demand measurements were made within 24 hours of sampling. The top 2 cm of each core was placed in an opaque 300 ml B.O.D. bottle filed with clean seawater adjusted to the salinity of individual collection sites and incubated at field temperatures. Dissolved oxygen concentrations were monitored for five hours: measurements taken at 0, 1, 2, 5, and 10 minutes elapsed time represented chemical oxygen demand of the sediment, while measurements taken at 60, 90, 120, 240, and 300 minutes represented biological oxygen demand. Dissolved oxygen concentrations of the slurry were regressed against elapsed time to compute oxygen consumption rates.

Pore water and sediment sulfide concentrations were measured with an ion-specific sulfide electrode (Orion Corp.). The electrode was calibrated daily with a three-decade standard curve of sulfide solutions in SAOB, ranging from 10 mM to 10uM. The standard stock was titrated with 0.1 M $PbClO_4$.

Rhizome gas samples were analyzed using a Carle 311 gas chromatograph with a two-valve, two-column configuration for the determination of permanent and light hydrocarbon gases on the same sample. Most samples were analyzed by direct injection, however water vapor contamination made on-column injection tedious. We solved the contamination problem by injecting later samples into a valved sample loop containing silica gel (20-40 mesh). A helium carrier flow rate of 30 ml min^{-1}, a column temperature of 70 ^{o}C, and a thermal conductivity detector were used for gas analysis. Peaks were quantified with a Spectraphysics 4270 integrator.

Amino acid samples were freeze-dried, ground to pass a 20 mesh screen, and frozen until analysis. Amino acid analyses were performed by Mr. Steve Benford of the USF pediatrics laboratory, using an AminoStat high pressure liquid chromatography system. Individual amino acids were detected by fluorescence with o-phthaldehyde.

Determination of Alcohol Dehydrogenase (EC 1.1.1.1)

Extraction and assay of alcohol dehydrogenase (ADH) activity were optimized by using known additions of standard yeast ADH (Sigma Chem. Co.) during every step of the method and determining the optimum pH, buffer concentrations and components and homogenization procedures. Three tissue homogenization techniques were investigated (Table 1): 1) grinding in cold extraction buffer with a Tekmar tissumizer; 2) grinding samples in liquid nitrogen (LN2) with a mortar and pestle, followed by adding 5 ml of extraction buffer to the frozen powder and further homogenization; and 3) grinding of freeze-dried tissues in LN2 in mortar and pestle, followed by adding extraction buffer to the frozen powder and further homogenization. The extraction buffer consisted of 100 mM Tris (pH 7.3), 5 mM $MgCl_2$, 40 mM 2-mercaptoethanol and 5% polyvinyl-polypyrrolidone (PVPP). 2-mercaptoethanol stabilizes the sulfhydryl linkages found in the enzyme and PVPP eliminates the inhibitory effects of endogenous phenols. The second technique gave the best results, although problems with standard enzyme inhibition at some sites continued to be a problem.

After grinding, samples were centrifuged at 12,000 rpm (2 C) for 20 minutes, and the supernatants were assayed immediately. All extracts were kept at 2 C until assayed. The assay was conducted spectrophotometrically at 340 nm using the following reaction mixture in a 1 cm cuvette (3.0 ml total volume): 2.8 mls containing 5.4 mM $MgCl_2$, 0.26 mM NADH, and 0.40 mM acetaldehyde in 14 mM Tris buffer (pH 8.0) to which 0.2 ml of sample extract was added. The reaction was recorded for four minutes and the slope (abs/min) was calculated. Activity (umol $min^{-1}g$ fresh wt^{-1}) was calculated as:

$$\text{Activity} = \frac{A}{E} \times DF \times \frac{\text{Vol}}{\text{fresh wt}} \times 1000$$ where

A = change in absorbance per minute
E = molar absorptivity coefficient, 6.22 x 1000
DF = dilution factor, $\frac{3.0 \text{ ml reaction}}{0.2 \text{ ml sample extract}}$
Vol = total volume of extract, 5.5 mls
Fresh wt = weight of tissue homogenized

Despite efforts to optimize the assay, some sites (e.g., the sewage site in Tampa Bay) consistently demonstrated inhibition of known amounts of standard ADH added during grinding and extraction. pH of the extract and reaction mixtures were checked and optimized. Desalting and removal of metal ions by ammonium sulfate precipitation of the enzyme (using a 60% of saturation solution), followed by re-solution of the enzyme in extraction buffer did not eliminate the inhibition problem. The inhibition might be caused by a hitherto undiscovered contaminant or by proteases present within the rhizome tissue which destroy ADH during the grinding process. Further optimization efforts will include 1) the substitution of Tricine for Tris in the extraction and reaction buffers, because in some cases Tris is inhibitory to some plant enzyme systems; 2) reduction of the 2-mercaptoethanol concentration to 15 mM in the extraction buffer; and 3) possibly the use of a protease inhibitor added during grinding and extraction.

RESULTS AND DISCUSSION

Hydrographic and Sedimentological Characteristics of Study Sites- The summary table of hydrographic observations at the study sites (Table 2) does not reflect the full magnitude of difference between spring and summer conditions at most sites. Water temperatures at Tampa Bay sites varied only slightly between spring and summer samples, although Charlotte Harbor and Indian River water temperatures were approximately 5^{o} C higher than spring values. Only Cape Haze and Round Island sites showed summer salinity decreases despite rainfall values in June, July, and August near long-term average values. Dissolved oxygen concentrations in both spring and summer were supersaturated at all sites. Dissolved oxygen concentrations at night were considerably lower in summer than in spring. Dissolved oxygen levels at night decreased on ebb tides and increased on flood tides. Reaeration by wind and wave action raised night-time values over quiescent values.

Vertical extinction coefficients of PAR showed a pronounced seasonal difference at several sites (Table 3), although the direction of oxygen change (increase or decrease) varied, even at the same site, depending on the sensor used. Only at the Cape Haze site could light possibly have been considered limiting to seagrass photosynthesis.

Pore water sulfide concentrations were highly variable within a given site and among sites (Table 4), ranging from 32uM, at Cape Haze during August, to over 2000uM at the Florida Bay die-back site. Overall, concentrations appeared lowest in the Indian River, intermediate in Tampa Bay, higher in Charlotte Harbor and highest in Florida Bay.

Sediment sulfide concentrations ranged from 0.92 to 3.14 micromoles sulfide per cubic centimeter of mud (Table 4). Overall values were highest in the Indian River, lower in Charlotte Harbor, lower still in Florida Bay, and lowest in Tampa Bay. The fraction of total sulfide comprised by dissolved sulfide was lowest in the Indian River (2-5%), higher in Charlotte Harbor (2-10%), higher still in Tampa Bay (11-21%), and highest in Florida Bay (58-108%). We felt the abundance of sediment sulfide and the dissolved fraction of total sulfide reflected the interaction of pH and the abundance of ion-bearing fine sediment and silt. In the calcium carbonate-rich seiments of Florida Bay, there was little ion available to bind dissolved sulfide. In the Indian River, fine silt was imported from upland drainage canals and settled in seagrass beds, as a result the standing stocks of particulate sediment in the Indian River were high.

Sediment oxygen demand rates varied among sites (Table 5), with most of the variation derived from chemical oxygen demand (COD) rather than biological oxygen demand (BOD) as COD exceeded BOD values by 10 to 24 times. Summer COD values were higher than spring COD values at all sites. Overall COD rates were highest in Indian River sediments, lower in Charlotte Harbor, and lowest in Tampa Bay sediments - the same trend observed in sediment sulfide concentrations. BOD values were much lower and more consistent than COD values. No seasonal changes in BOD values were noted. Values overall ranged from a minimum of 0.18 to 0.43, without pattern among estuaries.

Structural Attributes and Growth Rates of *Thalassia*- varied with season, estuary, and site. In the spring, blade widths at most sites ranged from 7.1 to 8.6 mm, with exception of Cape Haze in Charlotte Harbor, where blade widths ranged from 3.9 to 4.9 mm (Table 6). The thinning of *Thalassia* blades in response to lower salinity has been well documented and was probably responsible for the slender blades at Cape Haze. Indian River blade widths decreased markedly between spring and summer collections, while blade widths at other sites changed little.

Mean blade length and maximum blade length at most sites increased between spring to summer collections. Blades typically were longest at Tampa Bay sites, intermediate at Charlotte Harbor sites, and lowest in the Indian River. Decreases in both maximum and mean blade length were measured at the Jim Island site in the Indian River. This site was virtually denuded of *Thalassia* before the August sample was taken, apparently as the result of hyperthermia, dessication, or freshwater runoff from Taylor Creek (C-25). Summer low tides in the Indian River frequently exposed seagrass beds to high temperatures and dessication, but the exact cause of stress at Jim Island was not readily apparent.

The percent of green leaf area at all sites ranged from 60% to 35% (Table 7), increasing between spring and summer collections at most sites. Shoot densities were highest at Charlotte Harbor sites and low to moderate at Tampa Bay and Indian River sites.

Leaf area indices at all sites ranged from 3.9 to 27.5 in spring collections and 1.8 to 11.1 in summer collections (Table 8). Green leaf area comprised from 30% to 75% of total leaf area in spring and 50% to 70% of total leaf area in the summer.

Summer growth rates of new blades in Charlotte Harbor and Tampa Bay were considerably higher than spring growth rates (Table 9). Growth rates at all Indian River sites declined between spring and summer, however. Seasonal trends in *Thalassia* were even more pronounced when whole-shoot growth rates were examined (Table 10). Surprisingly, both new-blade and whole-shoot growth rates were highest in Tampa Bay sites.

Comparison of environmental data and anatomical and growth rate measurements for all of our sites revealed a seasonal continuum of synergistic stresses. *Thalassia* appeared to be well adapted to chronic environmental stresses. Against the background of constant stress, episodes of acute stress may have caused mortality or the duration and intensity of chronic stress may have exceed the survival threshold of the plant.

Rhizome Gas Analyses-showed pronounced diurnal, seasonal, and site differences in the concentrations of gaseous oxygen in rhizome aerenchyma (Table 11). Mid-day oxygen concentrations ranged from 27.5% to 42.3% in the spring. Summer values were lower than spring values at most sites, ranging from 15.8% to 38%. Late-night values were low at most sites during spring and summer, indicating that episodes of anoxia and hypoxic stress probably occurred frequently.

Diurnal measurements of rhizome oxygen concentrations at three sites in Tampa Bay (Table 12) provided a more complete record of seasonal and diurnal variations. Maximum oxygen concentrations typically occurred between 3 pm and 6 pm, while minimum concentrations occurred between 3 am and 6 am.

Standing Stocks of Amino Acids in *Thalassia* Rhizomes- are presented for 16 major acids in Table 13 a-h. We expected to see a strong diurnal fluctuation in the abundance of four amino acids (glutamic acid, glutamine, gamma amino butyric acid (GABA), and alanine) which have been identified as hypoxic metabolites in the seagrass *Zostera marina*. Analyses of variance (Table 14 B) indicated that glutamic acid and glutamine both showed a diurnal variation which was statistically signficant. However, the standing stocks of glutamic acid and glutamine (Table 13 a.) showed no clear diurnal pattern. Alanine and glutamic acid also showed a significant seasonal effect, while alanine, glutamic acid, and glutamine showed a strong estuary effect. The variation of these three amino acids among estuaries was shown further in Table 14 a. Values of all three acids were typically lowest in Florida Bay samples, intermediate in Charlotte Harbor rhizomes, and highest in Tampa Bay and Indian River samples. Seasonal variations of amino acids in *Thalassia* rhizomes at three Tampa Bay sites were presented in Table 15. Our analysis of amino acid data was incomplete at that point, but glutamic acid, glutamine, alanine, aspartic acid, ornithine, arginine, and proline warranted further study.

Alcohol Dehydrogenase Activity- Data describing the activity of alcohol dehydrogenase in *Thalassia* rhizomes were incomplete (Table 16) because of methodological problems discussed earlier. However, data were available for sites in all three estuaries and, in general, varied around 1 umol min^{-1} g fresh wt.$^{-1}$. These values were lower than most comparable data found in the literature for roots of seagrass and wetland plants and might possibly have reflected basic differences in activity between tissue types.

In Tampa Bay in May and June, lowest activities were found at the stress or sewage sites and highest activities were at the control site. However, most sewage samples demonstrated inhibition of added ADH standard, eliminating most data from this site.

In Charlotte Harbor in August, lowest activities were observed at Sandfly and Cape Haze and highest activities were at Catfish. No day to night trends were observed. Data from the Indian River in August were similar to values found at Charlotte Harbor sites. Jim Island had highest activities whereas Round Island and Boat Ramp rhizomes had considerably lower activities. No consistent trends from day to night were observed.

Further analysis will fill out the missing data, eliminate the inhibition problem, convert the units of enzyme activity to an expression based on the milligrams of protein present in the rhizome, and investigate the relative activities in roots versus rhizomes.

SUMMARY AND CONCLUSIONS

In the absence of persistent and severe events, hydrographic and sedimentological characteristics of a given site are poor indicators of seagrass stress or vigor. We found *Thalassia* surviving, and even flourishing, in areas with widely varying sediment sulfide, COD, and BOD levels. At only one site (Cape Haze), was light attenuation sufficiently great to stress *Thalassia*. The Boat Ramp and Jim Island sites were severely stressed by tidal emersion, hyperthermia, or rapid salinity changes. The exact cause of stress could not be determined without more extensive monitoring.

While structural parameters of *Thalassia*, such as leaf length and shoot density, are not useful as stress indices *per se*, they do describe the standing stock of the community. *Thalassia* standing stocks may, in turn, influence the carrying capacity of fish and shellfish species. Structural parameters may be useful in diagnosing stress only when a long-term database is available for a given site.

Productivity of new *Thalassia* leaf tissue, measured by the leaf marking technique, is probably the best measure of stand productivity and vigor. When summer blade elongation rates (Table 10) are multiplied by the shoot densities for each site (Table 7), the sites are ranked in the following (descending) order of vigor: Sandfly Key, Catfish Creek, Control Site, Stress Site, Sewage Site, Round Island, Cape Haze, Boat Ramp, and Jim Island. With the exception of the low ranking assigned to the Cape Haze site, this index coincides with our subjective impressions of vigor. While the productivity of the Cape Haze site is low, the community is well established and gives no indication of die-back.

The enzyme, alcohol dehydrogenase, shows promise as an indicator of hypoxic stress. Highest activities measured in this study occurred at the Jim Island site after its die-back in August. Sandfly Key and Catfish Creek have relatively high levels despite their high productivity, perhaps indicating their susceptibility to hypoxia and sulfide stress. Stands with lower productivity and lower stand densities may actually have a lower susceptibility to hypoxia and sulfide stress.

The most promising physiological stress indices are the amino acids glutamic acid, glutamine, alanine, aspartic acid, ornithine, and arginine. Glutamic acid concentrations, in particular, show signficant diurnal variations (Table 14 b). Both glutamic acid and alanine vary significantly among estuaries and between seasons. These acids may well comprise non-toxic, hypoxic, metabolites. The value of these stress indices will be tested next year by experimentally stressing populations of Thalassia and monitoring changes in the concentrations of these key amino acids and the enzyme, alcohol dehydrogenase.

Table 1. Effects of Handling Techniques on the Activity of Standard ADH.

Technique	Activity (umol min-1) Treatment	Control	% Loss in Activity
A. Grinding with Tissumizer			
Standard ADH	1.03	1.53	33
B. Grinding in LN2 with mortar and pestle			
Standard ADH	1.60	1.57	-2
C. Freeze-drying, then grinding in LN2 with mortar and pestle			
Rhizome samples:			
1. stress-day 24 May 1988	0.48	0.64	25
2. control-day 24 May 1988	0.20	0.25	20
D. Desalting with Ammonium Sulfate			
Standard ADH	1.50	1.50	0
Recovery of standard ADH added to sample	0.43	0.49	12

TABLE 2: HYDROGRAPHIC CHARACTERISTICS OF SEAGRASS STRESS STUDY SITES. Spring sampling performed May 4, 1988 in Charlotte Harbor, May 24 in Tampa Bay, and May 11 in Indian River. Summer samples collected August 1 in Indian River, August 10 in Charlotte Harbor, and August 30 in Tampa Bay. Florida Bay samples collected June 29, 1988.

	WATER TEMPERATURE (°C)				SALINITY (PPT)				DISSOLVED OXYGEN (PPM)			
	SPRING		SUMMER		SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
TAMPA BAY												
Control Site	29.9	28.3	30.8	29.7	35	35	32	32	7.98	4.93	7.36	3.25
Stress Site	29.2	29.9	30.8	29.4	35	35	32	32	6.68	9.77	13.43	1.39
Sewage Site	29.4	29.2	30.0	29.7	35	35	32	32	8.28	5.94	6.22	3.30
CHARLOTTE HARBOR												
Catfish Creek	24.1	23.6	31.9	30.7	33	33	34	34	8.84	4.94	8.00	3.76
Sandfly Key	25.4	23.7	33.0	30.0	--	32	33	31	7.70	6.64	10.27	2.17
Cape Haze	26.2	23.3	31.9	28.1	25	23	21	21	12.32	5.84	7.61	5.35
INDIAN RIVER												
Jim Island	26.4	23.8	31.4	27.8	35	35	33	33	9.60	4.94	9.13	3.76
Boat Ramp	26.2	23.9	31.4	28.3	34	35	33	33	10.24	4.92	9.13	5.00
Round Island	26.9	23.8	31.5	28.4	32	32	26	25	10.30	3.48	8.34	0.93
FLORIDA BAY												
Johnson Key	--	--	32.3	30.6	--	--	32	32	--	--	7.47	4.74

TABLE 3: VERTICAL EXTINCTION COEFFICIENTS OF PHOTOSYNTHETICALLY - ACTIVE RADIATION MEASURED AT SEAGRASS STRESS STUDY SITES. Values Labelled "2 pi" were measured with a flat sensor. Values labelled "4 pi" were measured with a spherical sensor.

SITE	WINTER/SPRING		SUMMER	
	2 pi	4 pi	2 pi	4 pi
<u>Tampa Bay</u>				
Control Site	0.102	--	--	--
Stress Site	0.129	0.117	--	--
Sewage Site	0.120	0.110	--	--
<u>Charlotte Harbor</u>				
Catfish Creek	0.143	0.134	0.134	0.102
Sandfly Key	0.164	0.121	0.144	--
Cape Haze	0.213	0.258	0.349	0.362
Cape Haze Bar	--	--	0.387	0.382
<u>Indian River</u>				
Jim Island	0.193	0.227	0.119	0.145
Boat Ramp	0.111	0.245	0.207	0.067
Round Island	0.028	0.004	0.316	0.266

TABLE 4: PORE WATER AND SEDIMENT SULFIDE CONCENTRATIONS AT SEAGRASS STRESS STUDY SITES. Spring pore water and sediment sulfide data are means (std.) of 4 replicate samples, summer data are based on 8 replicates.

SITE	PORE WATER SULFIDE (uM) SPRING	SUMMER	SEDIMENT SULFIDE (umoles/cm3)
TAMPA BAY			
Control site	--	122 (23)	0.92 (0.12)
Sewage site	--	--	1.35 (0.39)
Stress site	--	333 (70)	1.29 (0.31)
Charlotte Harbor			
Catfish Creek	255 (188)	228 (139)	2.02 (0.62)
Sandfly Key	89 (110)	279 (139)	2.16 (0.32)
Cape Haze	266 (132)	32 (14)	1.40 (0.26)
Indian River			
Jim Island	90 (52)	64 (60)	2.78 (0.30)
Boat Ramp	36 (16)	123 (68)	3.14 (0.09)
Round Island	122 (51)	158 (89)	2.59 (0.17)
Florida Bay			
Dieback Site	--	2143 (664)	1.58 (0.54)
Healthy Site	--	1321 (1321)	1.84 (0.74)

TABLE 5. SEDIMENT OXYGEN DEMAND RATES MEASURED AT SEAGRASS STRESS STUDY SITES. Units of chemical oxygen demand (COD) and biological oxygen demand (BOD) are mg O_2/liter/hour/100 cubic centimeters sediment.

SITE	SPRING COD Estimate (S.E.)	SPRING BOD Estimate (S.E.)	SUMMER COD Estimate (S.E.)	SUMMER BOD Estimate (S.E.
TAMPA BAY				
Control Site	3.87 (0.32)	0.38 (0.03)	6.82 (0.35)	0.43 (0.07)
Sewage Site	3.93 (0.77)	0.35 (0.04)	4.54 (0.85)	0.31 (0.07)
Stress Site	5.62 (0.38)	0.41 (0.03)	6.94 (0.89)	0.33 (0.07)
INDIAN RIVER				
Boat Ramp Site	8.61 (1.46)	0.28 (0.08)	13.14 (0.77)	0.18 (0.03)
Jim Island	7.70 (0.98)	0.33 (0.06)	11.74 (1.13)	0.25 (0.06)
Round Island	5.42 (0.58)	0.35 (0.05)	9.42 (0.90)	0.26 (0.15)
CHARLOTTE HARBOR				
Catfish Creek	5.43 (0.40)	0.38 (0.04)	7.30 (0.57)	0.39 (0.07)
Cape Haze	5.19 (0.92)	0.39 (0.06)	6.02 (1.13)	0.42 (0.07)
Sandfly Key	4.54 (0.54)	0.35 (0.07)	7.39 (0.53)	0.35 (0.04)
FLORIDA BAY				
Healthy Site	—	—	1.31 (0.65)	0.22 (0.03)
Die-Back Site	—	—	2.28 (0.53)	0.23 (0.02)

TABLE 6. DIMENSIONS OF THALASSIA BLADES AT SEAGRASS STRESS STUDY SITES. Data are mean values (standard deviation) calculated from 20 to 100 observations. Mean and maximum blade length values are expressed on a per shoot basis.

SITE	MEAN BLADE WIDTH (mm) SPRING	MEAN BLADE WIDTH (mm) SUMMER	MEAN BLADE LENGTH (cm) SPRING	MEAN BLADE LENGTH (cm) SUMMER	MAXIMUM BLADE LENGTH (cm) SPRING	MAXIMUM BLADE LENGTH (cm) SUMMER
Tampa Bay						
Control Site	----	8.4(1.6)	----	31.6(21.3)	----	51.7(16.7)
Sewage Site	7.7(1.2)	7.8(1.5)	31.5(17.9)	35.3(22.2)	45.8(12.1)	54.1(14.5)
Stress Site	8.1(2.4)	8.0(1.6)	29.7(14.6)	38.3(22.5)	41.4(10.2)	57.9(14.9)
Indian River						
Boat Ramp	7.1(0.4)	6.5(0.3)	15.5(8.7)	16.6(7.7)	23.6(6.4)	24.1(5.1)
Jim Island	7.5(0.6)	6.0(1.1)	28.4(18.2)	9.9(3.5)	44.3(11.0)	12.7(3.2)
Round Island	7.1(0.8)	6.9(1.0)	17.5(9.1)	19.5(10.5)	30.7(6.0)	30.7(4.8)
Charlotte Harbor						
Catfish Creek	7.2(0.9)	6.9(1.3)	18.5(7.5)	20.1(9.3)	26.3(4.6)	29.1(3.4)
Cape Haze In	4.9(0.7)	5.5(0.7)	14.3(7.5)	20.8(10.5)	21.5(4.5)	29.4(7.2)
Cape Haze Out	3.9(0.7)	5.1(0.7)	16.0(6.9)	27.8(15.2)	23.5(4.5)	43.5(9.6)
Sandfly Key	8.6(0.9)	8.2(1.1)	23.1(10.2)	26.5(15.4)	32.3(6.9)	41.9(8.4)

TABLE 7. THALASSIA SHOOT AND BLADE CHARACTERISTICS AT SEAGRASS STRESS STUDY SITES. Data are means (standard deviation).

SITE	GREEN AND EPIPHYTIZED AREA (%) SPRING GREEN	SPRING EPIPHYTES	SUMMER GREEN	SUMMER EPIPHYTES	SHOOT DENSITY (M^{-2}) SPRING	SUMMER
Tampa Bay						
Control Site	---	---	50(6)	36(29)	---	44
Sewage Site	59(15)	24(14)	50(6)	17(10)	44	48
Stress Site	56(15)	34(22)	49(14)	17(20)	92	68
Indian River						
Boat Ramp	35(8)	24(14)	53(11)	32(13)	60	48
Jim Island	43(10)	26(14)	43(12)	18(23)	32	72
Round Island	38(14)	23(19)	48(9)	14(13)	34	76
Charlotte Harbor						
Catfish Creek	39(13)	27(11)	46(11)	21(9)	176	136
Cape Haze In	56(13)	14(13)	52(10)	1(4)	140	104
Cape Haze Out	48(13)	31(11)	60(11)	41(9)	88	60
Sandfly Key	43(12)	25(11)	43(9)	22(14)	124	84

TABLE 8. TOTAL AND GREEN LEAF AREA OF <u>THALASSIA</u> <u>TESTUDINUM</u> AT SEAGRASS STRESS STUDY SITES. Leaf area index (cm^2 blade area per m^2 bottom is based on measurement of only one side of a blade. Data are means (standard deviation).

	BLADE AREA PER SHOOT (cm^2)				LEAF AREA INDEX (one-sided)			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	GREEN	TOTAL	GREEN	TOTAL	GREEN	TOTAL	GREEN	TOTAL
<u>Tampa Bay</u>								
Control Site	---	---	175(105)	296(153)			3.27(1.49)	5.54(2.09)
Sewage Site	199(102)	287(150)	255(93)	398(137)	3.24(0.46)	4.66(0.59)	4.14(0.48)	6.46(0.024)
Stress Site	241(116)	390(166)	127(51)	221(68)	14.4	23.4	5.72	9.96
<u>Indian River</u>								
Boat Ramp	86(39)	207(63)	45(12)	79(17)	1.72(0.26)	4.14(0.28)	1.35	2.37
Jim Island	413(155	751(228)	17(8)	39(14)	8.77(6.14)	16.0(11.7)	0.81	1.84
Round Island	224(86)	611(730)	67(16)	118(28)	10.1	27.5	3.36	5.92
<u>Charlotte Harbor</u>								
Catfish Creek	46(17)	109(27)	63(18)	127(42)	5.08	12.0	5.54	11.1
Cape Haze In	40(16)	67(42)	83(39)	144(72)	3.57	6.02	3.20(0.085)	5.57(0.34)
Cape Haze Out	34(18)	67(37)	116(52)	183(102)	1.96	3.85	2.75(0.84)	4.34(1.03)
Sandfly Key	79(32)	164(54)	179(50)	364(128)	6.30	13.1	5.16(0.55)	10.5(2.86)

TABLE 9. GROWTH RATES OF THE NEWEST BLADES IN EACH <u>THALASSIA</u> SHORTSHOOT. Data are means (std. dev.) in millimeters per day.

SITE	SPRING MEAN GROWTH RATE	SPRING MAXIMUM GROWTH RATE	SUMMER MEAN GROWTH RATE	SUMMER MAXIMUM GROWTH RATE
<u>TAMPA BAY</u>				
Control Site	---	---	225.3(48.1)	289.1
Stress Site	77.2(52.9)	177.8	132.0(54.8)	204.7
Sewage Site	---	---	173.5(98.2)	460.1
<u>INDIAN RIVER</u>				
Jim Island	119.0(75.2)	225.1	---	---
Boat Ramp	92.3(32.8)	147.0	54.3(23.1)	87.4
Round Island	123.0(49.0)	211.8	88.1(13.4)	108.1
<u>CHARLOTTE HARBOR</u>				
Catfish Creek	53.8(24.1)	113.3	85.8(28.7)	169.5
Sandfly Key	88.7(56.2)	291.5	146.6(38.0)	288.0
Cape Haze	50.4(33.5)	125.0	60.6(27.0)	112.5

TABLE 10. GROWTH RATES OF THALASSIA SHORT SHOOTS. Data are means (std. dev.) expressed as the sum, in millimeters per day, of all the blades in a short shoot.

SITE	SPRING MEAN GROWTH RATE	SPRING MAXIMUM GROWTH RATE	SUMMER MEAN GROWTH RATE	SUMMER MAXIMUM GROWTH RATE
TAMPA BAY				
Control Site	---	---	269.8(126.8)	598.0
Stress Site	76.4(114.7)	290.2	156.6(90.0)	263.5
Sewage Site	---	---	203.5(188.4)	769.1
INDIAN RIVER				
Jim Island	144.4(348.7)	1102.0	---	---
Boat Ramp	141.5(78.5)	252.0	71.0(71.2)	172.6
Round Island	498.9(259.9)	855.6	125.3(33.6)	174.8
CHARLOTTE HARBOR				
Catfish Creek	81.0(64.2)	219.9	108.2(64.5)	306.0
Sandfly Key	136.3(102.8)	478.1	184.8(116.7)	603.0
Cape Haze	61.5(43.7)	141.7	68.9(54.2)	202.5

TABLE 11. SEASONAL AND DIURNAL VARIATION IN RHIZOME OXYGEN CONTENT IN FOUR ESTUARIES. Data are percent of total gas volume.

SITE	SPRING DAY	SPRING NIGHT	SUMMER DAY	SUMMER NIGHT
Charlotte Harbor				
Catfish Creek	36.6 (1.7)	5.8 (1.3)	32.2 (1.6)	4.3 (1.9)
Sandfly Key	40.1 (7.5)	11.4 (0.6)	38.1 (3.8)	26.5 (49.0)
Cape Haze	38.5 (1.4)	3.2 (1.0)	27.1 (22.0)	6.2 (4.5)
Indian River				
Round Island	27.5 (1.8)	1.6 (0.5)	16.1 (2.1)	4.1 (2.4)
Boat Ramp	42.3 (4.3)	2.6 (0.4)	37.8 (4.4)	9.3 (4.5)
Jim Island	34.3 (6.6)	5.3 (0.8)	15.8 (1.8)	4.1 (0.8)
Tampa Bay				
Control Site	31.4 (4.6)	13.7 (3.6)	37.7 (2.1)	2.0 (4.2)
Sewage Site	38.7 (2.5)	7.1 (4.1)	37.5 (1.6)	-0.9 (0.7)
Stress Site	35.6 (4.3)	5.1 (1.7)	33.4 (12.5)	-0.7 (1.9)
Florida Bay				
Dieback			32.1 (9.3)	16.3 (10.5)
Healthy			26.5 (3.5)	10.6 (5.0)

TABLE 12. SEASONAL AND DIURNAL VARIATION IN THE RHIZOME OXYGEN CONTENT OF <u>THALASSIA TESTUDINUM</u> AT THREE SITES IN TAMPA BAY. Data are volume percent oxygen (x= mean, s= std. dev.) in gas spaces of rhizome tissue. N for most data is 3 in March samples, and 6 for others.

Site		Noon	3pm	6pm	9pm	Midnight	3am	6am	9am	Noon
					A. MARCH 2, 1988					
Control	x	22.2	23.4	18.9	20.6	17.5	20.1	13.2	14.9	18.3
	s	1.0	2.2	0.7	1.1	3.6	8.6	0.8	1.9	3.0
Sewage	x	18.9	26.7	25.3	23.5	17.7	14.7	15.3	16.5	20.1
	s	7.6	3.2	2.3	2.8	2.4	2.2	1.4	1.4	4.1
Stress	x	30.2	28.7	27.1	24.2	21.1	17.9	*	20.8	20.8
	s	3.4	2.4	2.8	1.2	1.8	1.4		1.6	0.4
					B. APRIL 20, 1988					
Control	x	24.4	31.4	30.1	24.7	9.8	11.0	13.7	15.8	19.4
	s	3.0	4.6	2.6	0.5	3.0	1.6	3.6	1.5	4.0
Sewage	x	29.0	38.7	39.1	31.5	19.2	12.6	7.1	14.1	33.0
	s	2.4	2.52	4.4	2.1	2.7	2.7	4.1	4.8	1.5
Stress	x	28.9	35.6	32.3	*	*	8.2	5.1	10.0	27.1
	s	1.9	4.3	2.4			3.5	1.7	8.2	1.1
					C. JUNE 9, 1988					
Control	x	18.4	30.3	25.1	13.5	10.8	6.3	7.6	14.3	22.4
	s	1.2	1.4	2.9	2.3	1.7	0.8	3.1	0.8	3.6
Sewage	x	8.8	28.5	35.1	16.3	11.5	5.1	4.3	10.8	17.7
	s	2.3	2.9	2.8	3.0	2.6	1.1	1.1	4.4	2.5
Stress	x	18.1	31.2	33.1	26.1	15.7	7.7	6.7	13.9	21.5
	s	1.2	1.7	2.2	2.2	1.7	1.3	0.7	2.9	1.4
					D. AUGUST 29, 1988					
Control	x	31.6	37.7	29.7	NS	5.8	6.9	2.0	6.5	27.9
	s	2.6	2.1	1.0		0.8	0.8	4.2	2.3	7.9
Sewage	x	31.1	37.5	37.6	NS	20.1	4.7	-0.9	7.4	33.0
	s	1.1	1.6	6.2		1.8	4.3	0.7	1.2	3.4
Stress	x	27.7	33.4	40.3	NS	19.6	11.7	-0.7	10.7	25.7
	s	3.6	12.5	1.4		0.6	1.3	1.9	1.6	0.3

* site inaccessible at low-tide.

TABLE 13 a. VARIATION OF GLUTAMIC ACID AND GLUTAMINE CONCENTRA-
TIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	GLUTAMIC ACID				GLUTAMINE			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
Tampa Bay								
Control Site	7.32	16.11	27.22	8.29	17.54	52.65	38.75	5.24
Stress Site	7.39	14.39	6.09	17.57	18.54	13.29	3.81	21.48
Sewage Site	5.03	8.66	25.85	7.85	18.27	13.74	36.17	7.08
Indian River								
Jim Island			6.19	13.13			6.87	22.01
Boat Ramp			19.73	20.27			22.68	40.86
Round Island			12.16	9.92			22.18	6.78
Charlotte Harbor								
Catfish Creek	4.71	6.64	14.60	6.26	4.51	16.16	24.73	4.53
Cape Haze	3.90	5.55	13.90	14.58	2.51	5.45	7.44	16.33
Haze Bar		8.22	7.45			8.96	5.17	
Sandfly Key	10.13	5.22	8.83	5.31	12.81	4.13	11.78	2.89
Florida Bay								
Healthy Site			5.91	5.90			4.41	4.34
Die Back Site			11.23	5.53			10.59	4.87

TABLE 13 b. VARIATION OF ALANINE AND G-AMINO BUTYRIC ACID CONCENTRATIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	ALANINE				G-AMINO BUTYRIC ACID			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
Tampa Bay								
Control Site	8.79	13.55	31.52	12.28	3.96	9.61	23.99	9.58
Stress Site	9.68	15.34	7.16	22.13	10.86	13.64	10.97	31.03
Sewage Site	11.03	2.61	49.94	22.25	13.50	19.11	31.92	15.59
Indian River								
Jim Island			20.80	42.58			9.52	26.19
Boat Ramp			47.09	56.05			20.32	33.78
Round Island			23.09	23.00			30.97	10.12
Charlotte Harbor								
Catfish Creek	5.40	11.89	16.16	9.46	8.92	20.57	44.06	9.62
Cape Haze	3.81	12.59	18.90	33.86	6.42	12.91	7.78	48.49
Haze Bar		7.13	3.04			7.62	7.86	
Sandfly Key	20.03	8.10	14.91	8.71	27.29	15.65	23.52	6.12
Florida Bay								
Healthy Site			5.30	7.51			9.17	9.46
Die Back Site			15.86	9.53			19.03	15.76

TABLE 13 c. VARIATION OF TAURINE AND ASPARTIC ACID CONCENTRATIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	TAURINE				ASPARTIC ACID			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
Tampa Bay								
Control Site	0.75	0.85	2.86	1.29	4.03	6.27	7.43	5.02
Stress Site	0.84	0.76	1.00	0.80	4.60	5.05	5.72	8.02
Sewage Site	1.12	4.08	3.25	1.83	3.92	5.99	9.19	13.37
Indian River								
Jim Island			1.46	1.94			10.38	7.74
Boat Ramp			6.53	4.31			13.49	12.21
Round Island			5.24	3.37			10.13	6.09
Charlotte Harbor								
Catfish Creek	1.61	1.09	2.26	2.62	5.06	6.85	12.21	6.09
Cape Haze	0.99	1.10	2.74	1.15	4.96	3.79	9.76	9.08
Haze Bar		1.44	2.13			4.94	7.52	
Sandfly Key	1.46	1.10	1.34	0.88	7.08	5.52	7.11	2.79
Florida Bay								
Healthy Site			0.46	0.19			7.23	5.93
Die Back Site			0.05	0.00			7.83	4.37

TABLE 13 d. VARIATION OF ISOLEUCINE ACID AND LEUCINE CONCENTRATIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	ISOLEUCINE				LEUCINE			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
Tampa Bay								
Control Site	0.90	1.38	3.32	0.72	0.34	0.63	2.11	0.78
Stress Site	0.70	3.86	3.53	4.70	0.52	1.51	0.83	8.50
Sewage Site	0.70	3.86	3.53	4.70	0.52	1.52	0.83	8.50
Indian River								
Jim Island			1.19	2.74			0.81	1.65
Boat Ramp			4.14	6.07			0.92	1.21
Round Island			3.20	1.59			1.04	0.52
Charlotte Harbor								
Catfish Creek	0.00	0.09	3.51	1.82	2.28	2.43	0.78	0.00
Cape Haze	0.00	0.00	0.15	4.55	2.23	1.68	0.51	1.90
Haze Bar		0.00	0.00			2.61	0.00	
Sandfly Key	0.00	0.00	1.49	0.00	0.27	0.00	1.14	0.00
Florida Bay								
Healthy Site			2.00	2.36			0.63	0.70
Die Back Site			3.08	2.39			1.58	0.94

TABLE 13 e. VARIATION OF CITRULLINE AND VALINE CONCENTRATIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	CITRINE				VALINE			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
<u>Tampa Bay</u>								
Control Site	0.00	0.00	2.47	0.47	2.95	2.93	9.15	1.61
Stress Site	0.00	0.00	0.79	2.27	2.34	6.90	2.38	6.15
Sewage Site	0.00	0.00	3.12	1.32	2.05	4.67	6.18	2.97
<u>Indian River</u>								
Jim Island			0.55	1.26			2.00	4.08
Boat Ramp			1.19	2.46			4.53	7.24
Round Island			2.25	0.76			3.98	1.69
<u>Charlotte Harbor</u>								
Catfish Creek	0.00	0.00	2.26	0.00	2.41	3.08	3.95	1.88
Cape Haze	0.00	0.00	0.00	2.32	2.17	1.62	2.83	5.72
Haze Bar		0.00	0.00			2.47	0.55	
Sandfly Key	0.00	0.00	0.86	0.35	4.11	1.54	3.14	0.84
<u>Florida Bay</u>								
Healthy Site			0.00	0.00			1.60	2.07
Die Back Site			0.76	0.00			6.49	4.19

TABLE 13 f. VARIATION OF PHENYLALANINE AND B-ALANINE CONCENTRATIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	PHENYLALANINE				B-ALANINE			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
Tampa Bay								
Control Site	0.21	0.32	1.32	0.42	0.68	1.19	1.99	1.09
Stress Site	0.37	0.67	0.35	1.31	1.01	1.42	0.75	1.82
Sewage Site	0.22	0.60	1.51	0.63	1.92	2.03	2.46	1.44
Indian River								
Jim Island			0.55	0.90			1.19	1.76
Boat Ramp			0.18	0.17			2.40	1.60
Round Island			0.46	0.23			2.35	1.45
Charlotte Harbor								
Catfish Creek	0.00	0.00	0.31	0.00	0.86	1.91	1.78	0.51
Cape Haze	0.00	0.00	0.45	0.63	0.52	0.65	2.22	2.29
Haze Bar		0.00	0.00			0.65	1.14	
Sandfly Key	0.46	0.00	0.50	0.06	3.59	1.18	1.55	0.67
Florida Bay								
Healthy Site			0.38	0.59			0.00	0.00
Die Back Site			0.96	0.38			0.00	0.00

TABLE 13 g. VARIATION OF THREONINE AND SERINE CONCENTRATIONS (ug/GDW) IN _THALASSIA_ RHIZOMES.

	THREONINE				SERINE			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
<u>Tampa Bay</u>								
Control Site	1.91	3.76	5.07	1.72	3.42	5.70	5.68	2.41
Stress Site	2.47	14.39	6.09	17.57	18.54	13.29	3.81	21.48
Sewage Site	2.24	4.05	5.56	6.74	3.88	6.21	7.81	8.69
<u>Indian River</u>								
Jim Island			2.33	4.28			2.71	5.21
Boat Ramp			5.49	6.87			6.77	8.99
Round Island			7.00	2.73			5.59	2.77
<u>Charlotte Harbor</u>								
Catfish Creek	2.16	3.52	4.00	1.22	2.58	3.51	4.91	2.18
Cape Haze	1.32	1.83	3.89	5.78	1.36	2.18	4.65	6.41
Haze Bar		2.76	0.92			2.64	1.22	
Sandfly Key	4.35	1.42	2.79	0.73	10.34	3.26	3.72	1.36
<u>Florida Bay</u>								
Healthy Site			1.07	1.30			1.01	1.29
Die Back Site			3.50	2.25			3.99	2.38

TABLE 13 h. VARIATION OF ORNITHINE AND ARGININE CONCENTRATIONS (ug/GDW) IN *THALASSIA* RHIZOMES.

	ORNITHINE				ARGININE			
	SPRING		SUMMER		SPRING		SUMMER	
SITE	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
Tampa Bay								
Control Site	0.00	0.19	3.81	5.80	10.70	11.08	74.38	4.27
Stress Site	0.40	0.00	10.49	9.08	8.73	13.98	11.28	57.85
Sewage Site	0.18	0.42	6.22	8.20	3.55	6.24	68.11	41.93
Indian River								
Jim Island			0.00	0.00			6.12	31.43
Boat Ramp			4.96	10.00			27.60	52.79
Round Island			0.00	0.00			6.12	31.43
Charlotte Harbor								
Catfish Creek	0.00	0.00	10.00	11.56	14.67	53.47	58.94	4.40
Cape Haze	0.00	1.08	7.39	4.40	1.78	11.58	31.70	57.26
Haze Bar		0.00	3.78			6.91	7.49	
Sandfly Key	0.00	0.00	0.00	0.49	86.69	8.07	20.20	0.86
Florida Bay								
Healthy Site			3.13	2.66			1.44	0.55
Die Back Site			2.20	2.68			28.25	22.96

TABLE 14: ANALYSIS OF VARIATION IN THALASSIA RHIZOME AMINO ACID POOLS.

A. Variations in Amino Acid Concentrations Among Estuaries. Data are ug amino acid per gram dry weight rhizome tissue. Numbers with the same letter subscript are not significantly different.

ESTUARY	Glutamic Acid	Glutamine	Alanine	GABA	Total Amino Acid
Tampa Bay	15.8 a	19.2 a b	24.5 b	19.7 a	166 a
Indian River	13.2 a	20.0 a	34.3 a	21.6 a	162 a
Charlotte Harbor	8.3 b	9.3 b c	12.6 c	18.0 a	100 b
Florida Bay	7.1 b	6.1 c	9.6 c	13.3 a	73 b

B. Results of Analyses of Variance for <u>Thalassia testudinum</u> Rhizome Amino Acid Pools. Values are F-Ratios based on Type I Sums of squares for one-way analysis of variance.

Independent Variable	Glutamic Acid	Glutamine	Alanine	GABA	Total Amino Acid
Estuary	6.75***	3.95**	19.23***	0.66	4.98**
Location	1.15	0.96	4.78***	0.73	1.34
Season	3.36**	1.33	8.64***	1.24	1.23
Time	5.99**	3.20*	0.46	0.21	2.77*

*P < 0.10 **P < 0.05 ***P < 0.01

TABLE 15: SEASONAL VARIATIONS OF AMINO ACIDS IN THALASSIA RHIZOMES AT THREE TAMPA BAY SAMPLING SITES. Data are micrograms amino acid per gram dry weight of rhizome tissue.

Amino	Control Site				Sewage Site				Stress Site		
Acid	February	April	June	August	February	April	June	August	February	April	June
Taurine	2.21	0.80	1.10	3.05	0.97	2.60	2.32	2.98	0.00	0.80	0.90
Aspartic Acid	6.69	5.15	5.39	7.06	4.95	4.95	12.29	8.75	7.69	4.83	6.87
Threonine	4.00	2.84	3.01	3.79	2.67	3.15	6.75	4.35	5.32	3.69	3.50
Serine	6.63	4.56	3.31	4.78	4.12	5.04	8.97	5.98	5.79	4.11	3.56
Glutamic Acid	19.57	11.76	12.01	23.50	11.39	6.84	16.18	14.71	18.43	10.89	11.83
Glutamine	58.23	35.10	12.21	31.78	40.26	16.00	21.12	16.11	58.65	15.91	12.65
Alanine	24.82	11.17	12.67	31.13	11.91	6.82	29.21	53.26	17.70	12.51	14.65
Citrulline	0.00	0.00	1.06	1.88	0.00	0.00	2.17	1.94	0.00	0.00	1.53
Valine	6.27	2.94	6.15	4.62	2.62	3.36	4.73	3.25	4.79	4.67	4.26
Isoleucine	2.31	1.14	1.93	2.11	1.25	1.14	3.29	2.22	2.16	2.28	4.11
Leucine	1.70	0.48	1.77	1.12	0.80	0.93	1.96	1.17	1.40	1.01	4.66
Tyrosine	0.92	0.31	0.50	0.65	0.58	0.38	0.86	1.07	1.01	0.42	0.58
Phenylalanine	1.01	0.27	1.14	0.51	0.81	0.41	1.08	0.82	1.05	0.52	0.83
B-Alanine	1.94	0.933	1.40	1.68	1.77	1.97	1.99	1.57	2.34	1.22	1.28
B-AI-Butyric Acid	0.56	0.00	0.00	0.00	0.51	0.00	0.00	0.00	0.56	0.00	0.00
G-A-Butyric Acid	18.97	6.78	11.79	21.78	15.90	16.31	25.32	14.21	20.29	12.25	21.00
Orinithine	1.77	0.09	9.61	NS	2.40	0.31	9.41	NS	2.21	0.20	9.79
Lysine	1.59	0.24	1.07	NS	1.56	1.75	1.49	NS	1.36	1.52	1.19
Histidine	2.24	0.11	2.02	NS	2.42	0.57	1.89	NS	2.98	0.55	1.55
Arginine	64.82	10.89	31.70	49.96	67.01	4.89	50.83	63.14	82.69	11.36	34.57
TOTAL	226.3	95.6	119.8	189.4	173.9	77.42	201.9	195.6	236.4	88.8	139.3

TABLE 16. ACTIVITY (umol min^{-1} g fresh wt^{-1}) OF ADH IN <u>THALASSIA</u> RHIZOMES. Data are means (std. dev) of activities in three different rhizomes at a given site and time.

A. Tampa Bay

	Control	Stress	Sewage
23 May 1988			
Day	0.93(0.71)	0.12(0.06)	**
Night			
23 June 1988			
Day	0.99(0.59)	0.22	0.33(0.02)
Night	1.31	0.38(0.06)	0.36(0.17)
30 August 1988			
Day			**
Night			**

B. Charlotte Harbor

	Catfish	Sandfly	Cape Haze In	Cape Haze Out
10 August 1988				
Day	0.74(0.40)	0.79(0.22)	0.28(0.14)	0.87(0.93)
Night	1.33(0.80)	0.75(0.20)	0.37(0.22)	

C. Indian River

	Jim Is.	Round Is.	Boat Ramp
1 August 1988			
Day	2.09(0.96)	0.28(0.07)	0.44(0.13)
Night	1.00(0.75)	0.77(0.64)	0.37(0.18)

** inhibition of added standard

Task 2: Marine Resource Geographic Information System.

The primary objectives of this task were to begin development of a GIS layered database for the Little Manatee River (LMR) Watershed, implement increased disk storage and develop an organized data structure, interface to the Florida Natural Areas Inventory and continue to distribute MRGIS data.

Little Manatee River GIS

The development of the LMR GIS database has proven highly successful, but we have had to address issues in data development that were unforeseen. Preliminary data analyses have been completed. We are including, in the following text, a summary of the LMR GIS development which will be published in the fall 1989 proceedings of Coastal Zone '89.

INTRODUCTION

Historically, coastal resource management was inadequate or non-existent and generally was not considered important for the economic development of a region. Most failed to realize that degraded water quality, wetland loss, and other forms of coastal habitat alteration would have long-term negative impacts on desirable features of the coast such as production and harvest of fish and shellfish, and recreation.

As results of poorly managed coastal resources became evident to the public, and enough scientific data to support predictions for general long-term impact became available, increased attempts toward effective management have been supported. In the State of Florida this "awareness" translated into coastal resource management in the late 1960's and early 1970's which has continued to the present. Most management actions in Florida have been oriented toward specific habitats or species. With the tremendous growth Florida has been experiencing (1800 new residents/day with 900 residents leaving), it has become apparent that this targeted approach to resource management is inadequate. As more technical data on the status of our coastal resources have become available, it has become evident that without an understanding of habitats, communities, and species interactions, and the cumulative impacts of man on the environment, our management actions will often be reactive and not preventive. This realization has been stimulating the evolution of an ecosystem approach to resource management.

WATERSHED MANAGEMENT

An ecosystem is defined as a community of animals and plants and the environment with which it is interrelated. From a resource management perspective, an ecosystem should be defined within the context of a geographically manageable unit. Traditionally this was limited, for example, to an individual estuary. A more effective geographic approach to ecosystem management is based on watersheds, which include not only the estuary, but all of the land and waters which drain into that estuary.

Ecosystem management is very complex and requires data collection, environmental monitoring and ecosystem research that has not been accomplished. In addition, new techniques for data management, analyses and reporting are needed in order to fully benefit from this more holistic approach. We believe that one of the more promising analytical tools for this approach is the Geographic Information System (GIS). Johnston et al. (1988) and others have also suggested the potential of GIS for measuring cumulative impacts and conducting regional watershed analyses. A GIS, by hardware and software design, is able to accept large volumes of spatial data from a variety of sources and to manipulate, retrieve, analyze, and display the data efficiently according to user defined specifications (Marble and Peuquet, 1983). Although computer hardware and software are the technological vehicles for a proper GIS, the data utilized in a GIS constitute the analytical power of a GIS.

We will describe initial efforts in developing a GIS database for a small watershed in the Tampa Bay, Florida drainage-basin.

LITTLE MANATEE RIVER WATERSHED

The Little Manatee River (LMR) drains a 570 km^2 watershed on the eastern side of Tampa Bay (Fig. 1). The Tampa Bay area is one of the fastest growing regions in the state and impacts of this growth on the bay have been the subject of numerous investigations. Concern for the health of the bay has focused on problems of habitat loss and degraded water quality that in turn effect the recreational and commercial users of the bay. It has become apparent that if efforts to ameliorate some of these problems are to be successful they must be highly coordinated and conducted with a watershed management perspective. Major obstacles confronting watershed management in the area include the size and complexity of drainage areas around the bay, a lack of detailed information (hydrological, biological, chemical, and physical) to develop comprehensive management plans, and rapid development in critical watersheds.

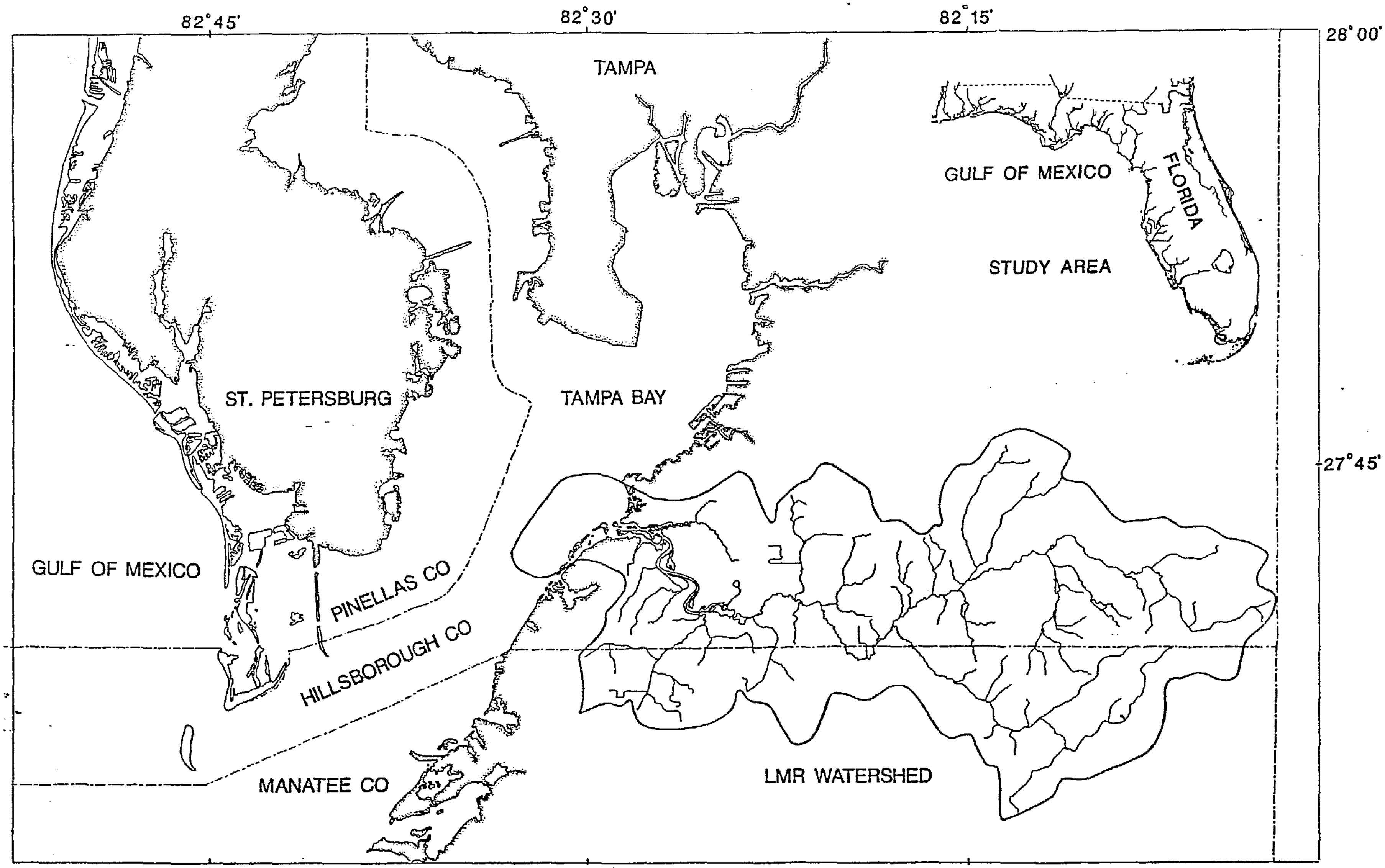


Figure 1. Little Manatee River (LMR) watershed in the Tampa Bay region of Florida.

The LMR watershed has been selected for a pilot program to focus on research, data collection, GIS development, and ultimately watershed oriented resource management. The LMR is the last major river of the Tampa Bay system remaining in a relatively natural condition. Mangrove swamp, tidal marshes, marine grassbeds, oyster bars, and other marine habitats characterize the estuarine portions of the watershed. Headwaters of the system contain bottomland hardwoods, cypress swamps, freshwater marshes and other wetland habitats. Land-use in the watershed is predominantly rural and agricultural, and while present uses probably contribute pollutants to the system, the primary concern is that the area lies directly in the path of urban development. The recently completed Interstate-75 highway will provide a major corridor for growth, and a large portion of the LMR watershed will be impacted.

GIS DEVELOPMENT

GIS technologies are recognized, in Florida, as powerful tools for resource and growth management. Consequently, private and governmental entities at federal, state, regional, and local levels, are exploring or developing GIS technologies and databases. A positive outcome of this surge in GIS development is a realization that effective GIS capabilities must be built with data from a multitude of different private and government entities. In governmental agencies, particularly, this has encouraged a level of interagency communication that has rarely been seen in Florida and which can be expected to increase as GIS technologies become operational. The LMR project is based on this philosophy and will not succeed without substantial commitments by the participating agencies. The LMR estuarine program has many participants with specific tasks and more participants are expected to become involved as the program matures. We will only discuss the GIS component of the program.

The LMR GIS is being developed for two broad uses; watershed resource management, and fisheries and ecosystem research. Many of the same data layers are needed for research and management and, from a research perspective, much needed data has yet to be identified or collected. However, we realize that management decisions must continue to be made and utilization of available GIS data will enhance those decisions. Thus, our short-term goal is to provide a base for more effective management, while our long-term goal is to be able to monitor and predict impacts to the estuary based on changes in the system.

The NOAA Office of Ocean and Coastal Resource Management, USDA Soil Conservation Service, Fl. Department of Natural Resources, Fl. Department of Environmental Regulation, Office of the Governor, Southwest Florida Water Management District, Tampa Bay Regional Planning Council, University of South Florida Department of Marine Science, and Hillsborough and Manatee Counties are all contributing data or other assistance in developing the GIS database for the LMR. In some cases data have been transferred and in others the research and data collection phases are still ongoing. Data are being housed and analyzed on the Florida Department of Natural Resources Marine Resource Geographic Information System (MRGIS). The MRGIS applications software include the commercially available ERDAS, Inc. raster-based (uses images) package and ESRI's ARC/INFO vector-based package. The MRGIS also uses NASA's non-proprietary ELAS, a raster-based image processing and data manipulation software. The MRGIS was developed in the early 1980s to map and monitor marine fisheries habitat and has evolved from a remote sensing and raster-based image processing operation into an integrated GIS (Haddad and Hoffman, 1987).

DATABASE DEVELOPMENT

The development of a GIS database is complex and dynamic and we have only begun to assemble meaningful data layers. Figure 2 depicts some of the layers of data being implemented on the MRGIS. These layers represent data we have accessed, identified as available in map form, or can be generated from aerial photography or satellite imagery. Figure 3 shows a simplified (for presentation purposes) flood zone data layer for a large portion of the watershed that has been digitized into the MRGIS.

Remote Sensing

Remote sensing plays a major role in the creation of many of the data layers being developed (see Figure 2). The base map (data layer to which all other layers are rectified) consists of an April, 1988 SPOT satellite panchromatic image geo-referenced to 7.5 minute U. S. G. S. quadrangles in a Universal Transverse Mercator projection. The MRGIS data layers are currently in raster format although we can accept vector data or convert raster data to vector for various analyses or data distribution.

We are using April 1988 SPOT satellite spectral data as a base for a detailed land-cover map for the watershed. These data are being supplemented with NHAP 1984 color infra-red aerial photography and LANDSAT Thematic Mapper (TM) satellite data to enhance the delineation of various land-cover categories.

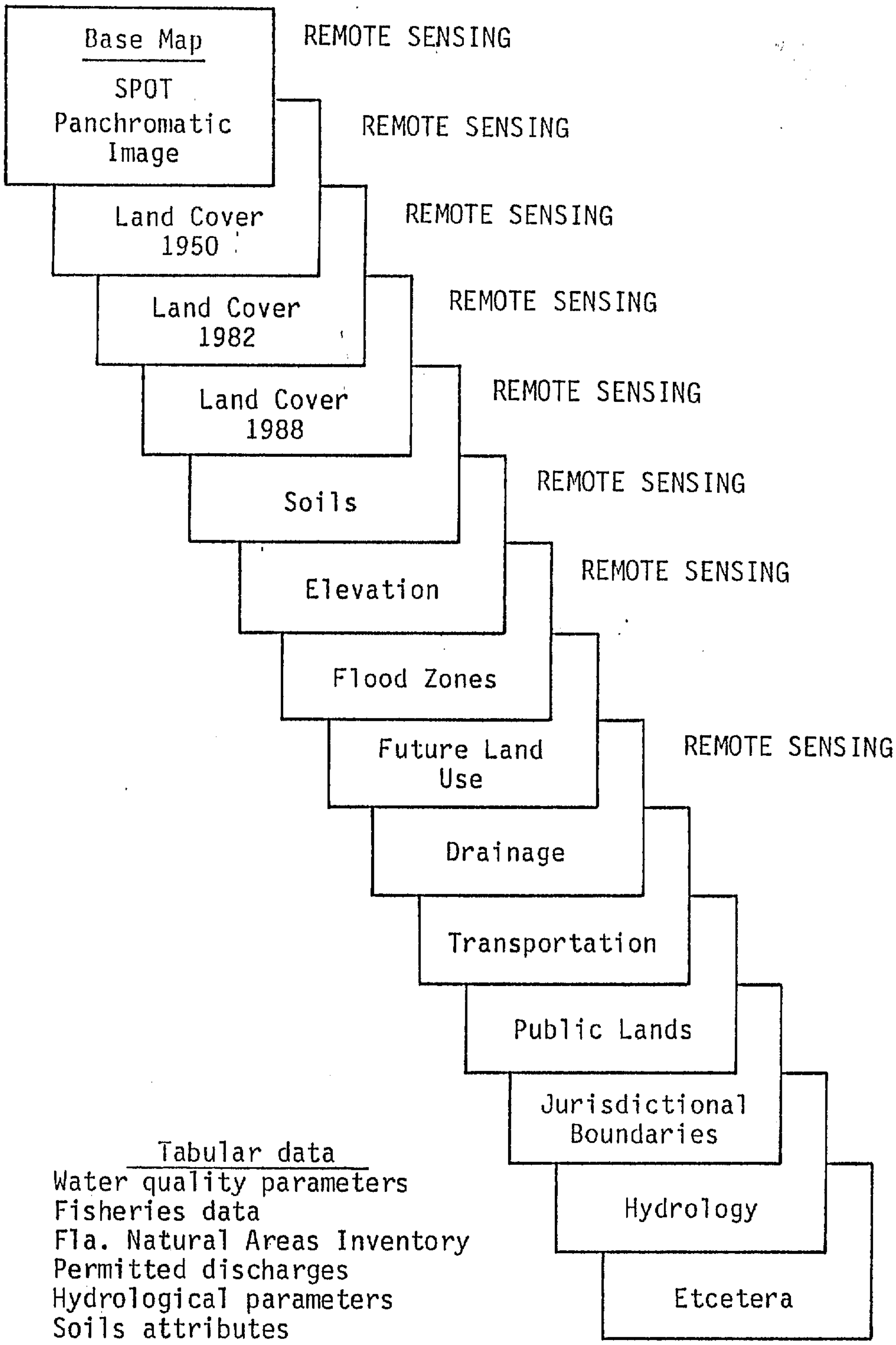


Figure 2. Some of the data layers being implemented on the MRGIS for the LMR watershed. Those layers dependent on remote sensing are noted. Tabular data to be linked to the data layers are also noted.

Using the SPOT panchromatic data, we have been able to take advantage of 10m spatial resolution by using a technique to enhance 20 meter SPOT spectral data to 10 m (10m x 10m = .01 ha or .025 ac.), while maintaining the spatial and spectral quality of the data (Seyfarth and Haddad, in prep). This technique can also be used on TM data to bring the superior spectral qualities of that data into the image analyses process for the LMR land-cover analyses. The Florida Dept. of Transportation land-cover classification system (modified from the Anderson classification system) is being used at levels II-IV depending on the ability to accurately map a given category.

Remote sensing will have a primary role in updating land-cover and land-use data on a routine basis and will provide a monitoring capability for the watershed. Full utilization of remote sensing techniques is a necessity in our program to develop watershed management capabilities.

Data Layers

Numerous problems have been encountered generating appropriate overlays. Some data sources, problems, and solutions are depicted in Table 1. It should be understood that many of these databases were not created with GIS entry in mind and do not have the cartographic integrity of a photogrammetrically developed map. Problems were compounded by the fact that the rectified SPOT data were more spatially resolved than National Map Accuracy Standards for 1:24,000 maps making geo-referencing difficult thus creating overlay problems at common borders. Furthermore, many data are in scales smaller than 1:24,000 compounding overlay difficulties. This does not present a problem

Data Type	Source	Problems	Solutions
Base Map	SPOT Pancromatic satellite data	Geo-referencing to 1:24,000 USGS Quads.	Careful selection of control points to reduce spatial errors found on USGS quads
1950/1980 Land cover	FDNR & USFWS aerial photography	30 meter data	resampled to 10 meter data
1988 Land cover	SPOT Multi-spectral satellite imagery.	Statistical analyses difficult at 10 meter spatial resolution	Incorporate TM satellite data in both the statistical analyses phase and interpretation phase. Use NHAP color-IR aerial photography.
Soils	Soil Conservation Service & Manatee County, Fl.	Soils delineated on photo-based separates are not cartographically accurate.	Soils scientist re-compile soils maps onto 1:24,000 USGS Quads. Scan digitize for digital access
Elevation	USGS Quads and Southwest Fla. Water Managment District (SWFWMD)	5 ft. contours from USGS Quads are not adequate in a low relief watershed. SWFWMD has undigitized 1 & 2 ft. contours	Accept resolution of USGS data or digitize SWFWMD maps
Flood Maps	Federal Emergency Management Agency	Cartographically inaccurate and very general spatially	Use 3 point triangulation to digitize.
Future land-use plans	Hillsborough and Manatee Counties	Cartographically inaccurate and different classification schemes	Use 3 point triangulation. Cross-reference classification system
Drainage	Aerial photography	Time consuming interpretation	None

Table 1. Sources, problems, and solutions for some of the data layers being entered on the MRGIS for the LMR.

if the limitations of the analyses are understood and not misused. For example, the future land-use data, if originally developed by the county at 1:100,000, cannot be applied to individual zoning issues at a parcel level but can be used to project land-use changes over large portions of the watershed.

Tabular Data

Tabular data, such as soils definitions, bald eagle nesting locations, fish distributions, permitted effluent discharges, and other digital data that represent a singular geographic location are also required for analyses. These data can be associated with the map base by their unique location and can be analyzed with the layered data. Figure 2 lists some of the general tabular data interfaces being developed. We currently access these tabular data through a dBase III interface to the GIS data layers.

Database development is difficult and time consuming. We have only cursorily presented some of the problems encountered. Not discussed are the lack of data necessary for layers such as river bathymetry and sediment distributions, and basic tabular data needs such as physical, chemical and biological parameters. These types of data issues will continually surface as we begin to understand the functioning of the ecosystem.

DATA ANALYSES

Although we do not have a fully functional database implemented, we can conduct some simple analyses and make some general observations for portions of the watershed.

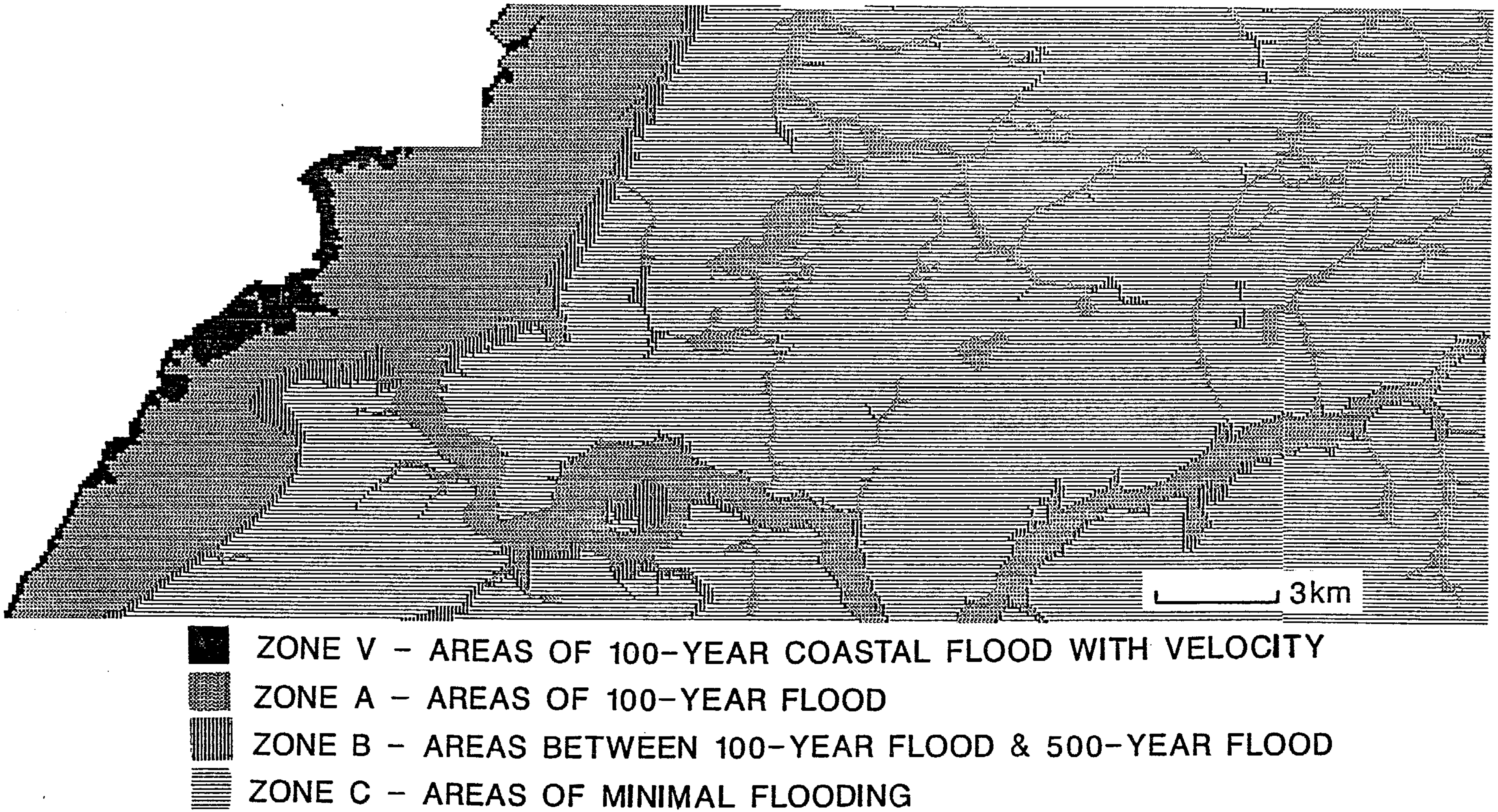


Figure 3. Flood zone data layer. Generalized from 34 categories for visual presentation.

Land-cover

Land-cover and land-cover changes can give us a perspective on factors influencing the watershed. Analyses on the estuarine portion of the watershed show tremendous increases in agriculture and urban coverage with concurrent losses of undeveloped uplands (Table 2). In 1982, 46% of the watershed was either agriculture or urban. Changes can be depicted graphically to observe the geographic distribution of the land-cover, and the data queried to depict, for example, what the 1982 urban and agriculture areas were in 1950 (Figure 4). The acreage results of the query show that major impacts were on the undeveloped uplands but all coverage types were impacted. A more detailed land-cover layer for 1988 is still being developed.

CATEGORY	1950 (HA)	1982 (HA)	CHANGE (%)
Seagrass	709	464	-35
Mangrove/marsh	785	728	- 7
Water	2,988	3,467	+16
Fresh wetlands	1,493	1,509	+ 1
Agricultural	1,448	7,529	+420
Urban	255	1,125	+341
Upland/undeveloped	10,849	3,709	-66

Table 2. Changes in generalized land cover from 1950 to 1982 for the estuarine portion of the LMR watershed.

Agriculture

Agriculture is a dominant land-cover in the estuarine portion of the watershed. We analyzed a 26 km^2 area (Figure 5) to determine

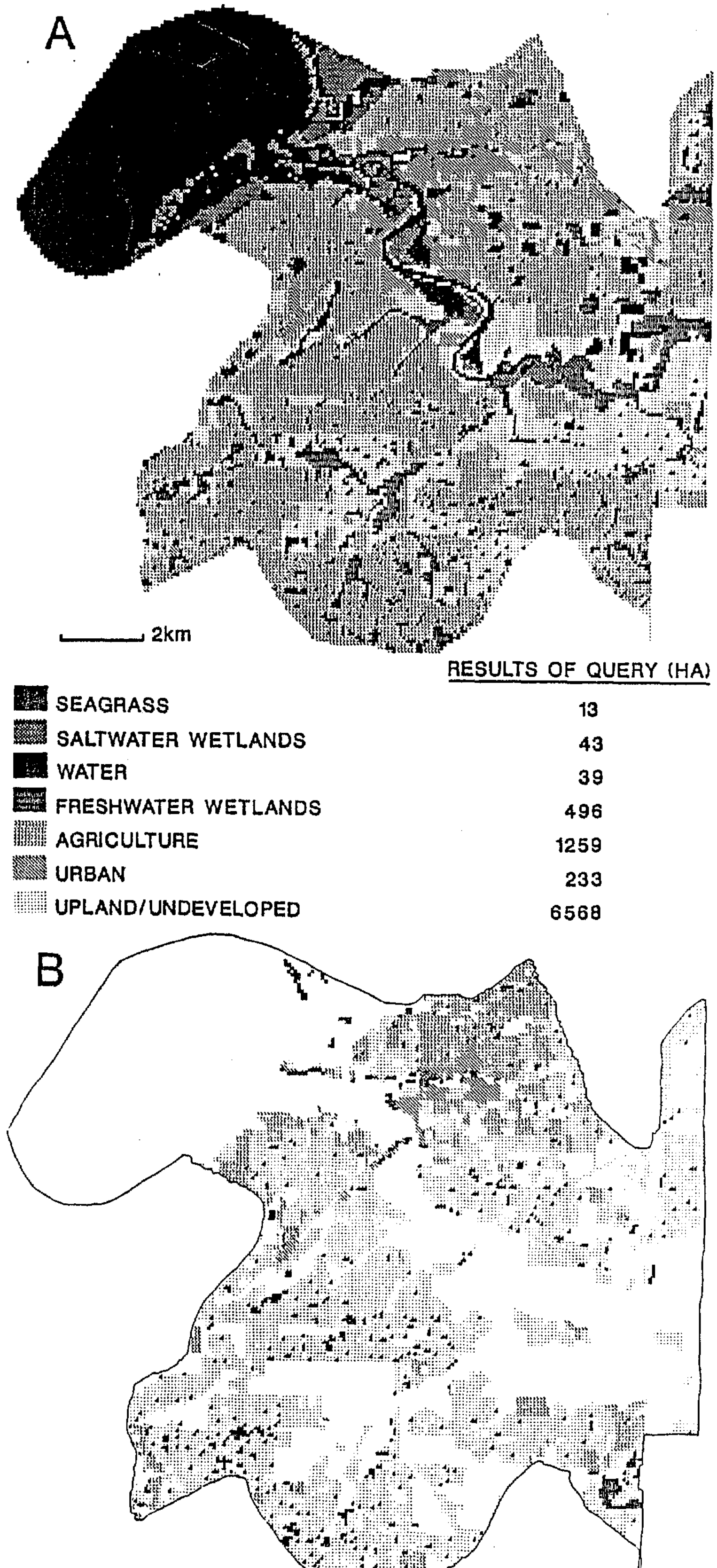


Figure 4. (A) Generalized land-cover for 1982 for the estuarine portion of the watershed. (B) Results of a query to determine the 1950 land-cover categories that were converted to agriculture by 1982. The agriculture category in the query represents those areas that have remained agriculture since 1950.

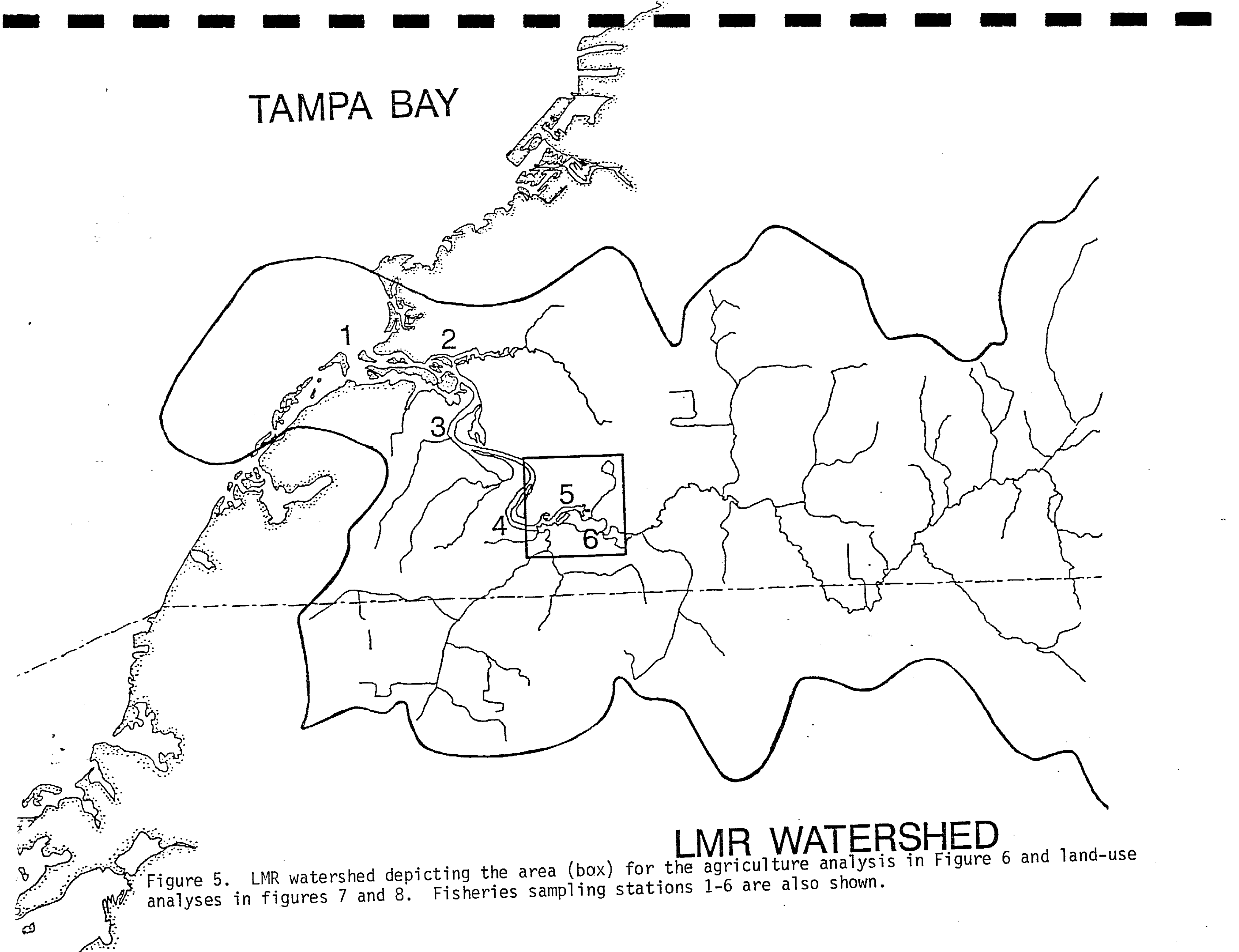


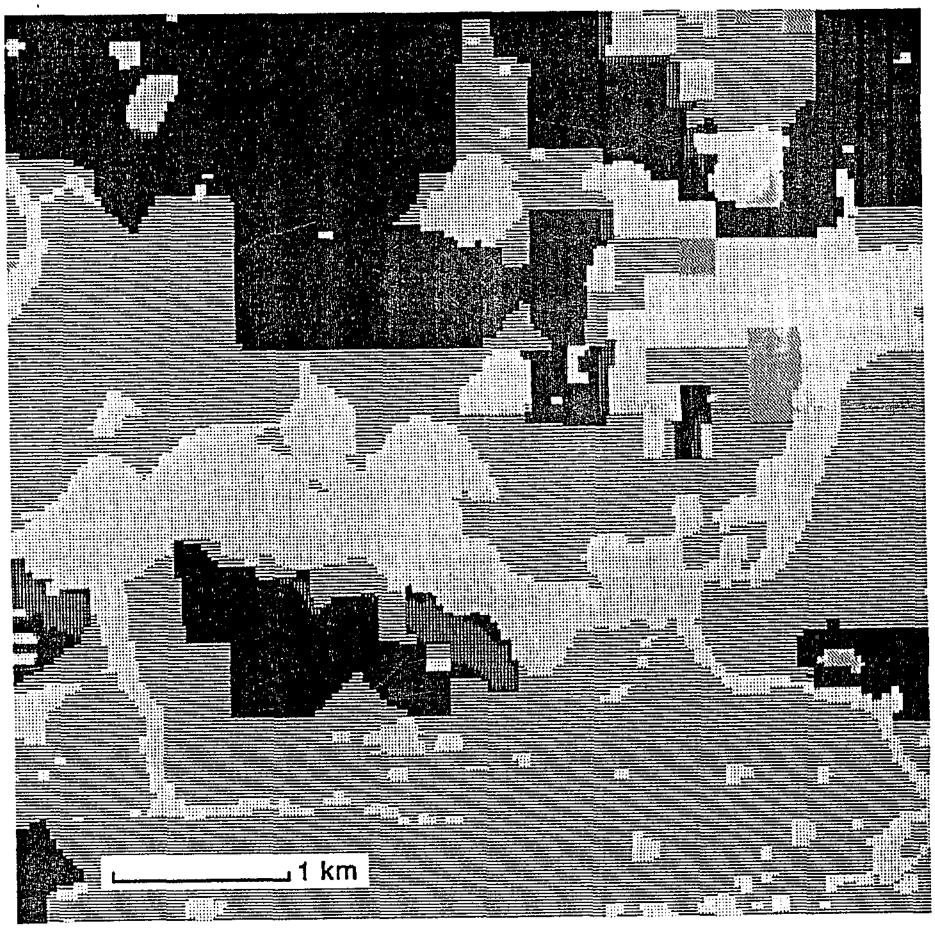
Figure 5. LMR watershed depicting the area (box) for the agriculture analysis in Figure 6 and land-use analyses in figures 7 and 8. Fisheries sampling stations 1-6 are also shown.

potential influences of agricultural runoff. The Soil Conservation Service (1987) defines soils by Hydrologic Group for runoff potential: Groups A and B, low potential; Groups C and D moderate to high potential. Group B/D represents soils with high runoff potential that have undergone drainage improvements. Total agricultural coverage for the area (1982) was 733 ha of which 94% ranked moderate to high for runoff potential as defined by Hydrologic Groups C, D, and B/D (Figure 6).

Future Land-Use

Counties in Florida are required to produce future land-use maps as part of the state growth management planning process. These maps can be used to project maximum planned growth in the watershed. We analysed a 26 km^2 area (see Figure 5) in the watershed, using 1982 land-cover, Hillsborough County preliminary future land-use, and Federal Emergency Management Agency (FEMA) flood zones, to determine future development potential in the FEMA designated 100-year flood zone. The 100-year flood zone areas require federal flood insurance and we hypothesize that this determination also reflects a potential for negative environmental impacts on the LMR.

Since our interest was future development, we eliminated existing urban areas by using the 1982 urban category to selectively filter the data during the analyses. Future land-use categories in the 100-yr flood zone were used to create a new data overlay. Figure 7 depicts the results of this analysis and suggests the potential for environmental impact. We used the coverage results for each future land-use category to calculate maximum numbers of single family dwellings allowed in the 100-yr flood



WETLANDS/WATER * 601 HA

UPLAND/UNDEVELOPED 1269 HA

URBAN 26 HA

AGRICULTURAL (LOW RUNOFF POTENTIAL) 40 HA

AGRICULTURAL (MODERATE-HIGH RUNOFF POTENTIAL) 693 HA

* Includes tropical fish ponds

Figure 6. 1982 land-cover analyzed with soils data to determine runoff potentials on agricultural lands.

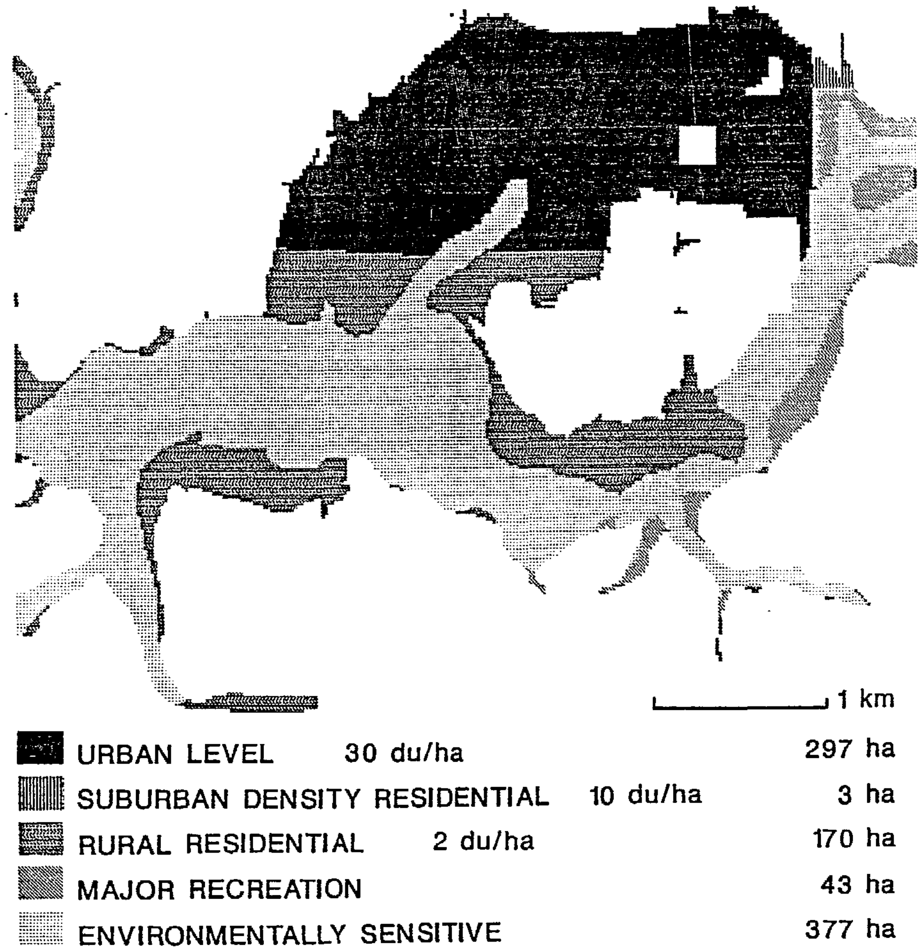


Figure 7. Results of query to determine future land-use designations in the 100 year flood zone.

zone (Table 3). Of the 890 ha comprising the 100-yr flood zone, 470 ha can be developed with a maximum 9,280 single family dwellings. Only 377 ha have been designated as environmentally sensitive.

Land-use Category	hectares	Dwellings/ha	Total dwellings
Urban Level 1	297	30	8,910
Rural Residential	170	2	340
Suburban Density Residential	3	10	30
Environmentally Sensitive	377	-	-
Major Recreation	43	-	-

Table 3. Future land-use categories in the 100-yr flood zone and projected development of single family dwellings for a representative area in the LMR watershed.

Further analyses were conducted on these data to determine whether the flood maps were accurate and the results meaningful for calculating the number of dwellings. Elevation data (Figure 8) were used to corroborate the 100-yr flood zone by checking for areas at elevations greater than 15 ft. mean sea level. A total of 9 ha, representing 277 dwellings, were above the 15 ft elevation yet in the 100-yr flood zone . This suggests a 3% error in the compilation of projected dwellings.

Fisheries

One of the long-term goals of the LMR program is to understand the habitat associations and environmental factors that influence various fish populations. An intensive multi-disciplinary field research effort has been initiated concurrent with

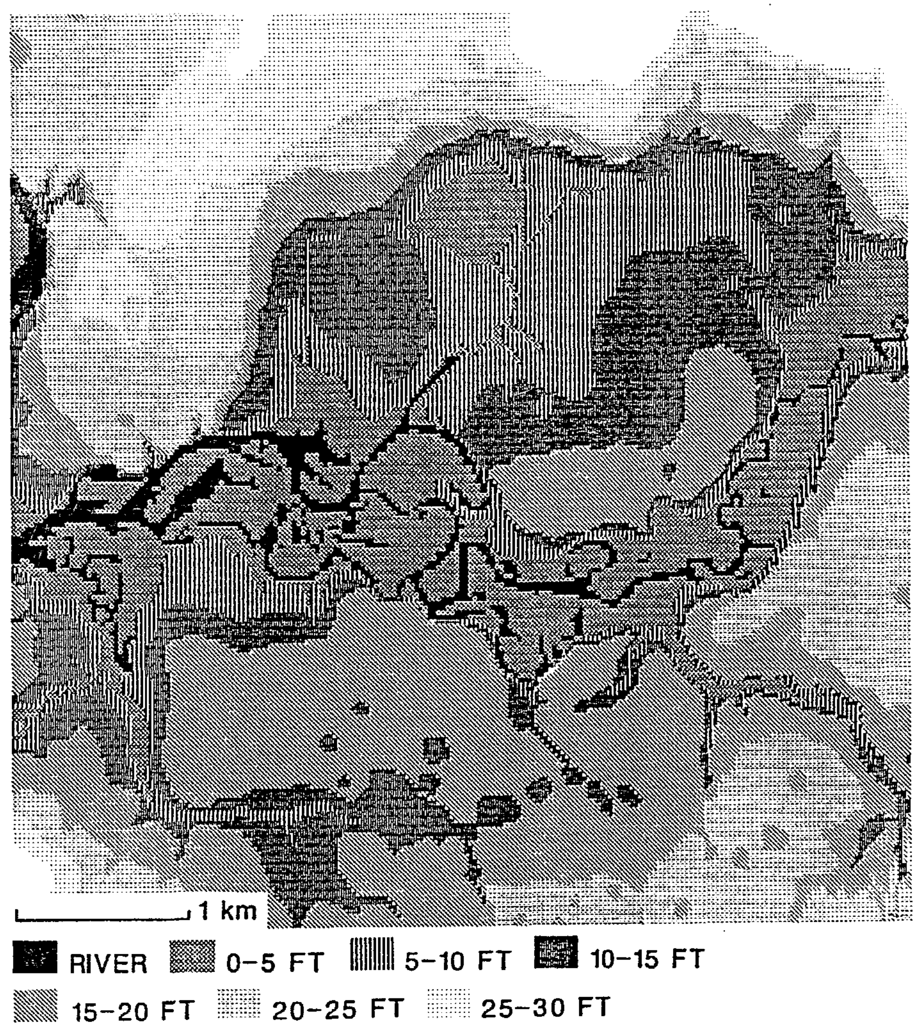


Figure 8. Elevation data layer used to validate the land-use analysis.

the GIS database development. One phase of the research, conducted by the Fl. Department of Natural Resources, is to determine the distribution and abundance of resident and juvenile fish species relative to habitat and other environmental parameters.

The LMR is thought to be a nursery ground for many of the commercial and recreational species caught in Tampa Bay and the Gulf of Mexico. Spotted seatrout are one of the more important species caught in the bay and previous research suggests that seagrass meadows are primary habitat for the juveniles (McMichael and Peters, in prep.). Our current research has begun to define distribution of juvenile spotted seatrout at 6 sampling stations located along the salinity gradient of the river (see Figure 5 for locations). By using the MRGIS land-cover data we can begin to look at general relationships and suggest management implications. Table 4 presents the abundance of juvenile spotted seatrout collected at the first 5 stations, from high to low salinities, and vegetated fisheries habitat coverage within a 1.5 km^2 area of the sampling stations.

Station #	1	2	3	4	5
Salinity	High				Low
Habitat Coverage (ha)					
Seagrass	63	--	--	--	--
Saltwater wetlands	32	70	50	30	54
Freshwater wetlands	--	1	--	--	38
Spotted seatrout (#s)	303	59	50	59	6

*Totals from 24 sampling trips in 1988

Table 4. Comparisons of salinity range, vegetated fisheries habitat coverage, and spotted seatrout abundance in the estuarine portion of the LMR.

We can suggest, from these data, that (1) low salinity and associated habitats do not support optimum spotted seatrout populations, (2) mid-range salinities (stations 2-4) support moderate populations regardless of the amount of saltwater wetlands present, and (3) the combination of higher salinities and the dominance of seagrass habitat at station 1, support greater than 82% more juvenile spotted seatrout than other stations.

Since the watershed has already lost 35% of its seagrass (see Table 2), and we have established an approximate relationship between seagrass and spotted seatrout abundance; management of the watershed can be demonstrated to be more than a one-dimensional issue with ramifications beyond habitat loss.

SUMMARY

A watershed (ecosystem) approach to coastal resource management is complex but necessary. GIS technologies provide a tool for both the ecosystem research and management analyses required to develop watershed management capabilities.

The Little Manatee River watershed, in the Tampa Bay region of Florida, has been selected for a multi-agency pilot program to focus on research, data collection, GIS development, and ultimately watershed-oriented research and management.

Database development and entry have, not unexpectedly, proven the most tedious and problematic phase of GIS development. Remote sensing is critical to database development and we have used SPOT and Landsat satellite imagery and aerial photography for data layer development. In addition, many of the other data we are using have been developed with remote sensing techniques. We are continuing to develop numerous data overlays and have performed some rudimentary analyses which demonstrate the potential power of the GIS for management and research. The overall effort is long-term and complex, but the goal of effective coastal resource management is attainable.

ACKNOWLEDGMENTS

Funds for this project were provided by the Department of Environmental Regulation, Office of Coastal Management using funds made available through the National Oceanic and Atmospheric Administration under the Coastal Zone Management Act of 1972, as amended. We expres our appreciation to George Henderson, Llyn French and Marjorie Myers for their assistance in editing and producing this manuscript.

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Implement increased data storage and an organized data structure

Increased mass storage has been added to the microcomputer component of the MRGIS. A total of 3 300mb disk drives and 1 800mb optical worm drive has been added. In addition, a 6250 BPI 9-track tape system has been added to facility data transfer and archiving. These data storage units are not all interfaced to the MRGIS but will be on-line in the near future. Additional software to drive these devices is also being interfaced to the MRGIS.

MRGIS data have been organized by geographic location and stored on 300mb disk packs. This has helped with data distribution.

Interface MRGIS with Florida Natural Areas Inventory

Software to link to the FNAI database was successfully implemented. Figure A is an example of portions of the Brevard County data pictorially linked to a MRGIS image. Table A is a printout from the FNAI accessed through the MRGIS for the Great Egret nesting site shown as a full gold rectangle in Figure A. This MRGIS module has full query capability by field and is a two way interface.

Data Distribution

We continue to receive numerous requests for data and data analyses. Table B lists some of those requests.

Figure B, Apalachicola Bay Aquatic Preserve, and Figure C, Lemon Bay Aquatic Preserve, are examples of Preserves that were completed during this grant period. Also attached are copies of manuscripts and a magazine article pertinent to this grant.

Table A. Printout of FNAI information for Great Egret nesting site.

```
RECORD:    70
 1. EOCODE        = ABNGA05010.002
 2. NAME          = CASMERODIUS ALBUS
 3. COMNAME       = GREAT EGRET
 4. MARGNUM       =         1.0000000
 5. TENTEN        =
 6. IDENT         =
 7. EORANK        =
 8. EORANKCOMM    =
 9. SURVEYDATE    =
10. LASTOBS       = 1976-07-06
11. FIRSTOBS      = 1975
12. GRANK         = G5
13. SRANK         = S4
14. STATE         = FL
15. COUNTYNAME    = FLBREV
16. QUADCODE      = 2808036
17. QUADNAME      = COCOA
18. PRECISION     = SC
19. LATITUDE      =         281740.00
20. LONGITUDE     =         803922.00
21. S             =         .00000000
22. N             =         .00000000
23. E             =         .00000000
24. W             =         .00000000
25. TOWNRANGE     =
26. SECTION       =
27. MERIDIAN      =
28. TRSCOMM       =
29. PHYSPROV      =
30. WATERSHED     = 03080202
31. DIRECTIONS    = BRADY AND GEORGE ISLANDS [JUST O
32. GENDESC       = ESTUARINE ISLANDS, MANGROVE USED
33. ELEV          =         3.0000000
34. SIZE          =         30.000000
35. EODATA        = POP ESTS BASED ON NEST COUNTS: 1
36. EODATA2       =
37. COMMENTS      = FWS COLONY 612002; SITE USED AS
38. MACODE1       =
39. CONTAINED1    =
40. MACODE2       =
41. CONTAINED2    =
42. MACODE3       =
43. CONTAINED3    =
44. ADDLMAS       =
45. MORELAND      =
46. MOREPROT      =
47. MOREMGMT      =
48. SITECODE      =
49. SITENAME      =
50. OWNER         =
51. OWNERCOMM     =
52. PROTCOMM      = PROTECTED?
53. MGMTCOMM      =
54. MONITOR       =
55. MONITORNUM    =
56. BESTSOURCE    = OSBORN & CUSTER. 197
57. SOURCECODE    = U78OSB01FL
58. DATASENS      =
59. BOUNDARIES    = Y
60. PHOTOS        =
61. OWNERINFO     =
62. TRANSCRIBR    = 82-03-29 DRJ
63. COREV         = Y
64. MAPPER        = 82-03-29 DRJ
65. QC            = Y
66. UPDATE        = 82-09-26 JWM
DBSD?
>
```

Table B . List of data requests.

1. Erdas Inc.
   Advanced Technology Development Center
2. Marine Environments Sciences Consortium
   Dauphin Island Sea Lab
3. DNR - Bureau of Sanctuaries & Research Reserves
   Rookery Bay National Estuarine Research Reserve
4. Planning Division
   City of Dunedin
5. DNR - Bureau of Marine Research
   Marathon Field Lab
6. DNR - Bureau of Land & Aquatic Resources Management
   Tallahassee
7. Collier County Government Center
   Naples
8. Planning & Community Development
   City of Ormond Beach
9. Greiner Inc.
   Tampa
10. U.S. Army Corps of Engineers
    Tampa
11. Dept. Environmental Regulation
    Tallahassee
12. Board of County Commissioners
    Citrus County
13. Snyder Oceanography Services, Inc.
    Jupiter, FL
14. Dept. Geology & Physics
    Georgia Southwestern
15. Alvarez, Lehman & Assoc., Inc.
    Gainesville
16. Mangrove Systems, Inc.
    Tampa
17. Engineering Dept.
    St. Johns County
18. Planning Dept.
    St. Petersburg
19. Natural Systems Analysts, Inc.
    Winter Park
20. DNR - Terra Ceia Aquatic Preserve
    Ellenton
21. Planning & Development
    City of Clearwater
22. University of North Florida
    Coastal Fisheries Laboratory
    Jacksonville
23. Enviro Sciences, Inc.
    Mt. Arlington, NJ
24. Office of Coastal Planning
    Sarasota
25. Consultant Engineering & Sciences
    Miami
26. CZR, Inc.
    Jupiter, FL
27. CARP
    Riverview

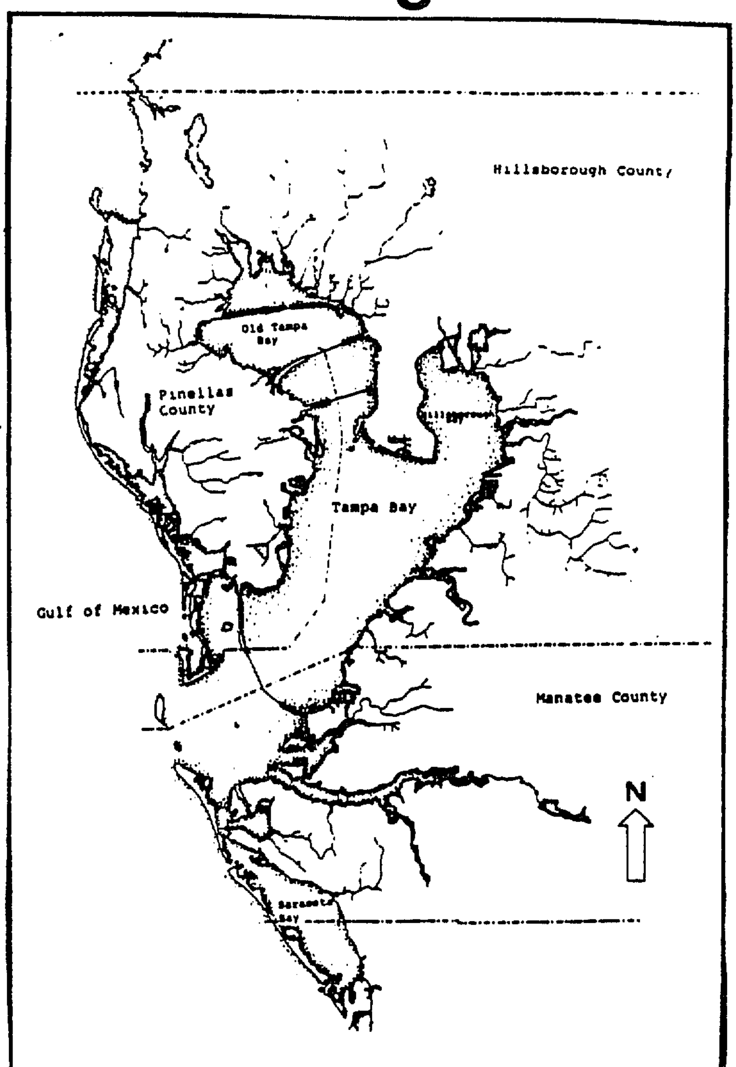
28. Consulting, Engineering, and Science
    South Miami
29. Water Pollution Control
    Palm Beach County Health Dept.
30. Tampa Bay Regional Planning Council
    St. Petersburg
31. Executive Management & Engineering Consultants, Inc.
    Lake Worth
32. The Trust For Public Land
    Tallahassee
33. Biological Research Associates, Inc.
34. Kevin L. Erwin Consulting Ecologists Inc.
    Fort Myers
35. Post, Buckley, Schuh & Jernigan
    Orlando
36. Hillsborough County Public Schools
    Tampa
37. DNR - Bureau of Historical & Environmental Land Management
38. Suncoast Business Journal
    St. Petersburg
39. U.S. Fish & Wildlife Service
    Dept. of Interior
    Washington, DC
40. Board of County Commissioners
    Pinellas County
41. T.A. Herbert Assoc.
    Tallahassee
42. Suwannee River Water Management District
    Live Oak
43. USAE District Vicksburg
    Vicksburg, MS
44. Hatfield Marine Science Center
    Newport, Oregon
45. Flagler County Planning Dept.
    Bunnell, FL
46. Volusia County Planning & Zoning Dept.
    Daytona Beach
47. Environmental Services & Permitting, Inc.
    Gainesville
48. National Wildlife Federation
    Washington, DC
49. NUS Corp.
    Tucker, GA
50. North East Florida Regional Planning Council
    Jacksonville
51. Syracuse University
    Syracuse, NY
52. Marine Resources Council
    Melbourne
53. East Central Florida Regional Planning Council
    Winter Park

NOAA Estuary-of-the-Month

Seminar Series NO. 11

Tampa and Sarasota Bays: Issues, Resources, Status, and Management

February 1989



U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA Estuarine Programs Office

HABITAT TRENDS AND FISHERIES IN TAMPA AND SARASOTA BAYS

Ken Haddad
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Fisheries are an important result of the complex biological web of Tampa and Sarasota Bays. Habitat plays an important critical role in defining the success of any given species within a system. Habitat refers to the specific structural, physical, and chemical environment in which an organism lives. This paper will focus on several components of the estuary considered important to the juvenile populations of commercial and recreational fishery species in Tampa and Sarasota Bays. The discussion on fisheries will provide only an overview of the actual industry and highlight some relatively new programs that will have a long-term influence on fisheries management in the bays. General references to Tampa Bay imply the inclusion of Sarasota Bay unless otherwise stated.

HABITAT TRENDS

Fisheries habitat includes mangrove, saltmarsh, seagrass meadow, intertidal mudflat, and unvegetated subtidal bottom communities. An integral and encompassing habitat component that influences the distribution of other components is the water column. Other less extensive, specific habitats of the Tampa Bay system contribute to the fishery, but they will not be detailed here. Figure 1 defines the boundaries of the quantitative analyses for habitat distribution and trends. The total estuarine area for this region is 124,155 hectares (ha, 1 ha=2.47 acres).

Mangroves cover approximately 8,036 ha, or 7% of the bay estuarine environment. Although Tampa Bay is near the northern limit of their distribution, mangroves remain an important component of the intertidal system. The aerial root systems provide a substratum for algal and invertebrate attachment and serve as a structural and protective habitat for juvenile fish, crustaceans, and shellfish. Leaf litter can also be important, forming the basis of a mangrove-detritus food web and providing a food supply to many organisms and ultimately the fishery. Mangroves also stabilize sediment and can be a nutrient and sediment trap for upland runoff.

Saltmarshes cover approximately 1,432 ha, or 1% of the bay estuarine environment. In Tampa Bay they generally serve as intertidal transition zones between mangroves and the freshwater marsh systems. Marshes also grow in mangrove areas damaged by occasional freezes (Lewis, this report). Like mangroves, saltmarshes provide a concentration of high-quality food for estuarine animals in addition to a protective

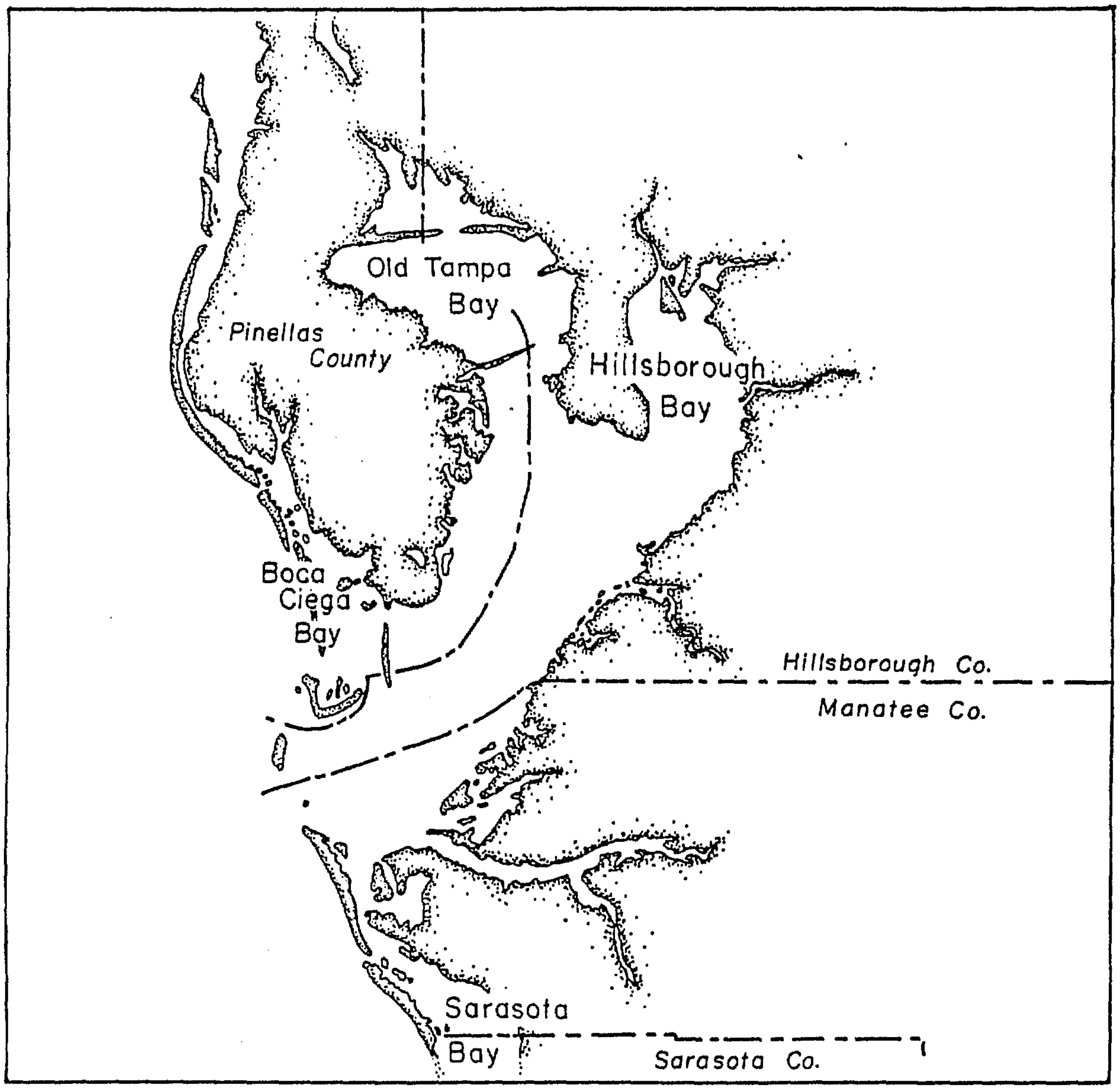

Figure 1. Boundaries for the quantitative analysis of habitat distribution and trends in the Tampa Bay Region.

environment for early life stages. Saltmarshes are also a fundamental part of nutrient cycles, long-term accumulators of pollution, short-term pollution buffers, and inhibitors of erosion.

Seagrass Meadows cover approximately 12,968 ha, or 10% of the bay system. They are the dominant vegetative cover in the bay and are critically important to productivity of the bay system. Seagrass meadows provide a direct food source to herbivores, such as sea turtles and manatees, and to numerous detritivores. Because this habitat is subtidal and extensive in distribution, it provides a constant and expansive structural shelter for fish, shellfish, and crustaceans important to the fishery. In addition, the complex food web and tremendous organism diversity and quantity provide a major food source to all stages of fishery species in the bay. Seagrass meadows also stabilize sediments and prevent erosion. They improve water quality by removing nutrients and by providing a baffle effect on waves and currents, which causes settling of suspended particulates in the water column. Macroalgae, in either drift or attached forms, are often associated with seagrass meadows and other communities of the estuary. The algae are a more readily digestible food source than seagrass and appear to be important to the ecology of the estuary.

Mudflats (sandbars, sandflats, flats) cover approximately 9,389 ha, or 8% of the bay bottom. They are "unvegetated" sites that become exposed at low tide. During the day they serve as primary feeding grounds for wading and shore birds. At night, fish, crabs, and shrimp become major consumers. Production in a mudflat is driven by smaller algae, such as dinoflagellates, diatoms, and blue-greens; macrophytic algae have a lesser role. Flats do not provide a protective structural component except to burrowers. A special type of flat found in Tampa Bay is the saltbarren (saltern), a transitional area between mangrove-saltmarsh and uplands. Although a harsh habitat, saltbarrens are important for bird populations, and growing evidence exists that they support fisheries species during irregular flooding. Saltbarrens host a variety of vegetation from stressed mangroves to lush succulents.

Unvegetated subtidal bottom comprises 92,334 ha, or 74% of the estuary. For this discussion, this area also includes artificial reefs, natural rock reefs, algal communities, sand, mud, and others. This habitat type is a major component of the system, as in most estuaries, and although extremely important for overall bay production, its extent serves to emphasize the importance of the relatively lesser amounts of structural, vegetative cover on the periphery of the bay.

Depending on the tides, the water column, overlies part or all of the estuarine habitat. The chemical, physical, and biological composition of the water column influences all aspects of the estuary. Phytoplankton are the primary producers and not limited to shallow areas or shorelines (as are seagrasses, mangroves, and saltmarshes). Phytoplankton exist as readily digestible food for consumers and are essential components in the food chain that supports larval stages of the fishery. An abnormal abundance of phytoplankton occurs in the Tampa Bay region as a result of an overabundance of dissolved nutrients. This process of eutrophication can have serious implications for the quality of production in the bay.

Through a cooperative study, the U.S. Fish and Wildlife Service (USFWS) and the Florida Department of Natural Resources (FDNR) estimated habitat changes in the Tampa Bay area from the 1950's to 1982. The data, housed in digital form on the DNR Marine Resource Geographic Information System (MRGIS) are photo-interpreted aerial photographs that have been computer digitized in a 1:24000 scale using the National Wetlands Inventory standard classification system. Over 600 separate categories are detailed in this hierarchical classification for the Tampa Bay region. Two 7.5-minute USGS topographic quadrangles (approximately 36,000 ha, northwest and southwest portion of Figure 1) have been interpreted and digitized into the MRGIS in addition to the data developed in conjunction with USFWS. The data have been synthesized on the MRGIS into general categories for ease of discussion (Table 1).

Table 1. Summary of major habitat trends, in hectares, for the Tampa Bay region.

Habitat	1950	1982	Percent Change
Mangrove	8,629	8,032	- 7
Saltmarsh	2,063	1,432	- 30
Seagrass	25,801	12,968	- 50
Mudflats	6,812	9,389	+ 37
Freshwater wetland	18,335	14,440	- 21
Agriculture	25,347	45,193	+ 78
Range/forest	124,630	42,997	- 65
Urban	32,730	95,586	+192

Lewis et al. (1985) estimated that 44% of the saltmarsh and mangrove and 81% of the seagrass meadows have been lost in Tampa Bay since the late 1800's. The recent calculations (Table 1) are not readily comparable because of differences in time, methodology, vegetation classification, and aerial coverage. However, the results confirm that significant losses of habitat have occurred. Perhaps the most significant deviation from other published results is the seemingly small loss of mangroves (7%) in the bay. This is an artifact of the USFWS classification system which underestimates change for this particular category and is being addressed in the MRGIS database.

Significant loss of fishery habitat has occurred in the Tampa Bay area. Loss of marsh and mangrove has been the result of dredge and fill activities. Dredge and fill has caused direct loss of seagrasses and indirect impacts have been hypothesized, primarily from changes in water quality which preclude seagrass growth. Dredge and fill activities are now under strict control; although permitted dredging continues, protective measures exist to minimize loss that is not "for public benefit". Water quality is considered the primary and continuing limit to seagrass distribution in the bay. Loss of seagrass has generally occurred throughout the bay, but the most significant losses have occurred in Boca Ciega Bay and the upper portion of Tampa Bay. In Boca Ciega Bay, shallow seagrass meadows were dredged into massive fill areas for residential and commercial development. Simon (1974), citing other researchers, indicates that loss of Boca Ciega Bay bottom destroyed a standing crop of 1,133 metric tons of seagrass and in annual production; 25,841 metric tons of seagrass; 73 metric tons of fisheries products; and 1,091 metric tons of associated infauna. In 1968, this translated to an estimated value of $160/hectare/year loss, or $1.4 million, annually. Simon (1974) estimated a loss in natural investment by 1974, if capitalized at 6%, of $23 million. Although these values are opinionated estimates, the point to understand is that these are substantial economic losses.

Loss of seagrass in upper Tampa Bay has been caused partially by dredge and fill, but the majority has not been due to direct mechanical destruction. Figure 2 depicts seagrass loss since 1950. In Hillsborough Bay (eastern extension of the upper bay), the loss is 90%. Changes in water quality suspected as the causative factors can be attributed to: 1) loss of range/forest and freshwater and saltwater wetlands,which act as filtering systems for runoff; 2) increases in agricultural area, which may increase sedimentation and suspended particles in the water; 3) intense urbanization and industrialization, which generate wastewater and stormwater disposal problems; and 4) dredging, which causes long-term release of fine sediments into the bay environment. With such large increases in urban and agricultural development (see Table 1) and decreases in those habitats that cleanse and buffer the bay, we can expect imbalances and changes to occur within the system as a whole.

The overall importance of the seagrass community to the region cannot be overstated. For perspective, the Chesapeake Bay estuary encompasses 3,237 sq. mi. and has 75 sq. mi. of seagrass (2% coverage), whereas the Tampa Bay region encompasses 479 sq. mi. and has 50 sq. mi. of seagrass (10% coverage). A major issue in Chesapeake Bay has been the importance of the seagrass meadows to the overall production in the bay. It is readily apparent that this should be a major issue for Tampa Bay.

FISHERIES

The Tampa Bay region has historically been a highly productive source of consumable fish and shellfish. Indian populations used the bay for food and tools. During the 19th century, the bay was a commercial fishing area for boats from as far away as New England (Pizzo, 1968; cf. Lombardo and Lewis, 1985). The first known fishery lost in the bay was the Atlantic sturgeon, with 5,000 lb. landed in 1867 and 6,500 lbs landed in 1868. Sturgeon all but disappeared in 1869, probably due to fishing

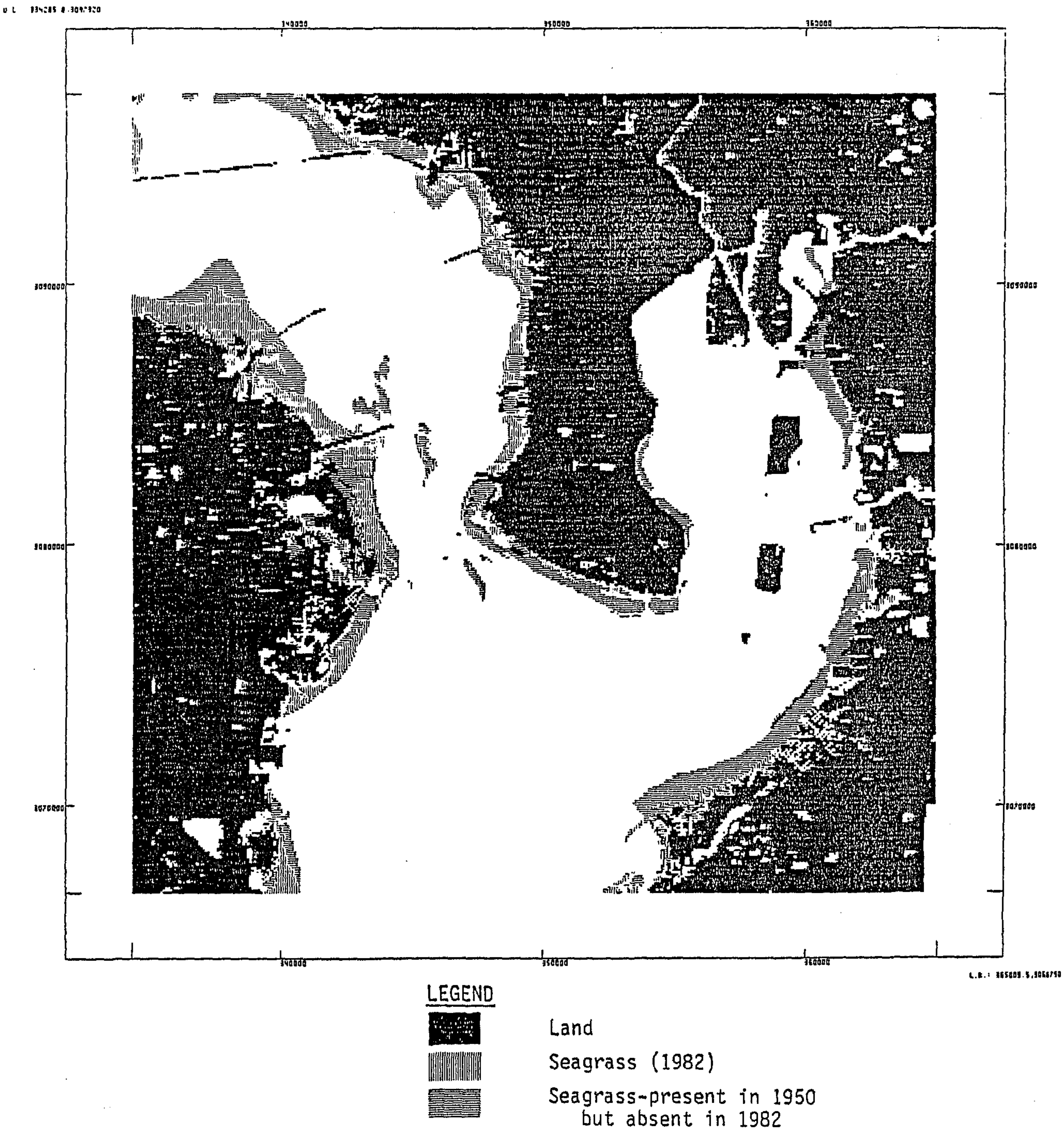

Figure 2. Seagrass loss in upper Tampa Bay and Hillsborough Bay.

pressure and poor recruitment; they no longer inhabit the bay. The area remains a fishing center, but fishing is not the primary water-dependent industry. Two counties in the Tampa Bay region --Pinellas and Hillsborough-- ranked 2nd and 6th, respectively, in value of Florida landings in 1976 (Mathis et al., 1979), confirming the importance of the industry even to the present. The 1986 dockside value of the fishery to the region is presented in Table 2 as estimates; the prices used to calculate the values are based on statewide averages and do not reflect local variations.

Table 2. 1986 fisheries landing for the Tampa Bay region including the number of trips made by the fishermen, pounds landed, and value of the fishery at dockside (Kennedy, pers. comm.).

County Landed	Trips	Pounds	Dockside Value $
Pinellas	32,549	10,658,222	$14,275,594
Hillsborough	8,463	8,662,909	5,293,494
Manatee	28,412	15,395,044	4,938,522
Sarasota	5,799	659,400	356,228
TOTAL:	75,223	35,375,575	$24,863,838

Commercial landings have traditionally been used to monitor trends in the fishing industry and economic value. Commercial landings data have historically been collected by the National Marine Fisheries Service (NMFS) and were originally designed to monitor the value of the fishery on a national scale. Landings data have little additional validity other than to observe possible trends in the fishery. NMFS landings data cannot provide the number of man-hours to catch a fish (catch per unit effort), the recreational catch, or where the fish were caught. These put severe limitations on the interpretation of the data, i.e., whether a decline is due to fewer fish, fewer fishermen, low dockside prices, or inclement weather.

Enhanced approaches to fisheries management have been instituted at the state level which will have a positive impact on fisheries management in Tampa Bay. The 1983 Florida Legislature created the Marine Fisheries Information System to gather the types of fisheries data necessary for management and research. FDNR expanded the NMFS commercial landing data collection to create a marine fisheries trip ticket. Florida law requires that anyone wishing to sell their catch of saltwater products must have a valid Saltwater Product License and that licensed wholesale seafood dealers must maintain records of each sale on a coded trip ticket. The data collected are both mandatory and voluntary. The mandatory information includes time fished, county landed, species sold, and number of pounds of each species caught. The voluntary information requested includes area fished, depth where caught, number of traps pulled/days since last pulled, and price per pound. Voluntary reporting has been used for the latter information, because it was felt that these specific types of information would be more reliably reported. Voluntary information has been used to estimate total landing for an area by statistically extrapolating the percent of voluntary "area fished" reports to the landings that did not have this information. Catch per unit effort by area can be determined by comparing the number of trips reported and the time fished with the pounds of each species caught.

The estuarine species listed in Table 3 are indicative of those produced and caught in Tampa Bay. By using the trip ticket information, we can specifically target the bay landings. For example, bait shrimp landings in pounds can be extrapolated to 31,619,800 live individuals. By using "area caught" information (not shown), we can estimate that only about 5,000,000 of those shrimp were caught in Tampa and Sarasota Bays; the remainder were caught north and south of the bay. Eight hundred trips were needed to catch the 5,000,000 shrimp, or 6,250 shrimp/trip worth about 150 dollars to the shrimper.

Table 3. Some typical species caught in the Tampa Bay region in 1986.

Species	Trips	Pounds	Dockside Value $
Bait shrimp	4,341	316,198	$ 692,473
Blue crabs	1,852	198,025	74,690
Clams	54	5,219	24,894
Menhaden	328	5,106,083	255,304
Mullet	12,748	6,842,456	2,253,528
Sheepshead	4,101	100,193	33,063
Spotted seatrout	7,037	175,432	171,923
Oysters	1	103	31

The majority of the remaining species in Table 3 were caught in the bay region. The major fishery in pounds and value is mullet. An Asian market for mullet roe (up to $30/lb retail) was developed in the 1970's and has influenced the value of this fishery tremendously (Figure 3). Fishing pressure has also increased, and research is currently being conducted on mullet populations.

Clam and oyster landings are very low in this area, primarily because only 15-20% of the potential shellfish areas are approved for harvest. The Department of Natural Resources has been systematically closing portions of the bay to shellfishing, because these areas do not meet state and federal water quality standards for shellfishing. Old Tampa Bay was permanently closed in 1979, and portions of the lower bay system have been temporarily closed in the 1980's. Permanent closures are expected to increase with continued urban growth around the bay. Scallops, which require good water quality, disappeared from the bay by

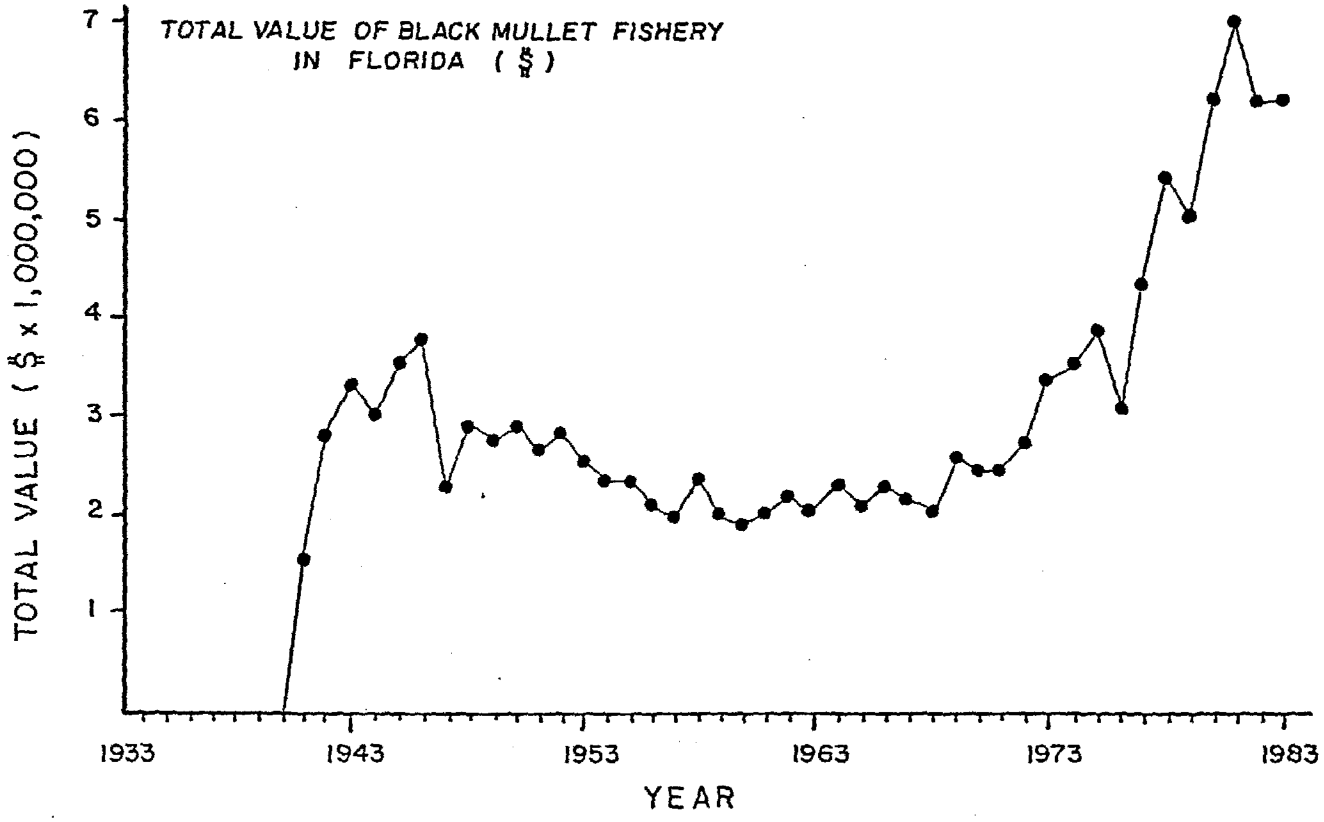

Figure 3. Black mullet fishery value in Tampa Bay, 1940-1983.

1963 (in commercially or recreationally viable numbers) and are only occasionally found today.

Menhaden are another species actively sought in the bay. The catch was minimal until 1985, when a controversial fishery suddenly developed. The recreational fishermen targeting tarpon have complained that tarpon no longer feed in the bay as they have in the past, because commercial fishermen are catching all of the baitfish, such as menhaden. Some research is currently funded to address the baitfish problem, which in reality can be accomplished only by understanding the entire ecosystem.

Spotted seatrout landings further demonstrate the utility of the marine fisheries trip ticket information. Of the 175,000 lbs landed, 157,000 lbs were from the bay system. Of the 7,655 trips reporting trout, only 278 landed more than 100 lbs, suggesting that trout are an incidental catch. In fact, the primary catch is mullet. Of the 278 trips that apparently targeted seatrout, 111 trips were in January when trout can be concentrated in schools.

The value of this type of information cannot be overstated. It provides a tool for management that has never before been available and does not exist elsewhere in the southeastern region of the country. Recreational catch records are also critically important in complementing the commercial fisheries statistics now being collected. Recreational data are currently collected by NMFS, but they do not have enough regional and local statistical validity to correlate with the trip ticket data. Unfortunately, these data remain a much needed informational component in the Tampa Bay region.

Historical NMFS commercial landings can be compiled to observe potential trends in individual fisheries. Keeping the limitations of the NMFS data in mind, landings for spotted seatrout, Cynoscion nebulosus, and bait shrimp, Panaeus duorarum, are presented in Figure 4. Declines in catch are consistent and significant and should be cause for alarm.

Spotted seatrout have historically comprised an important recreational and commercial fishery in the Tampa Bay region. Scientific data documenting the reasons for decline in this species do not exist, but we can speculate based on existing knowledge of the juveniles and adults in the Tampa Bay system. McMichael and Peters (in preparation) found that seagrass meadows in Tampa Bay appear to be the primary nursery ground for juvenile seatrout. Seventy-eight percent of 1,379 juveniles collected were found in seagrass, though less than 40% of the collections were made in this habitat. Furthermore, commercial and recreational fishermen target seagrass meadows as the most likely source of adult spotted seatrout. Seatrout are non-migratory, spending their entire life cycle in a given estuary, and thus the Tampa Bay region can be assumed to produce and support its own population with minimal external influences. Although numerous factors control the spotted seatrout population, a loss of 50-80% of the seagrasses in Tampa Bay should affect landings. We may also assume that with the loss of seagrasses, the actual production

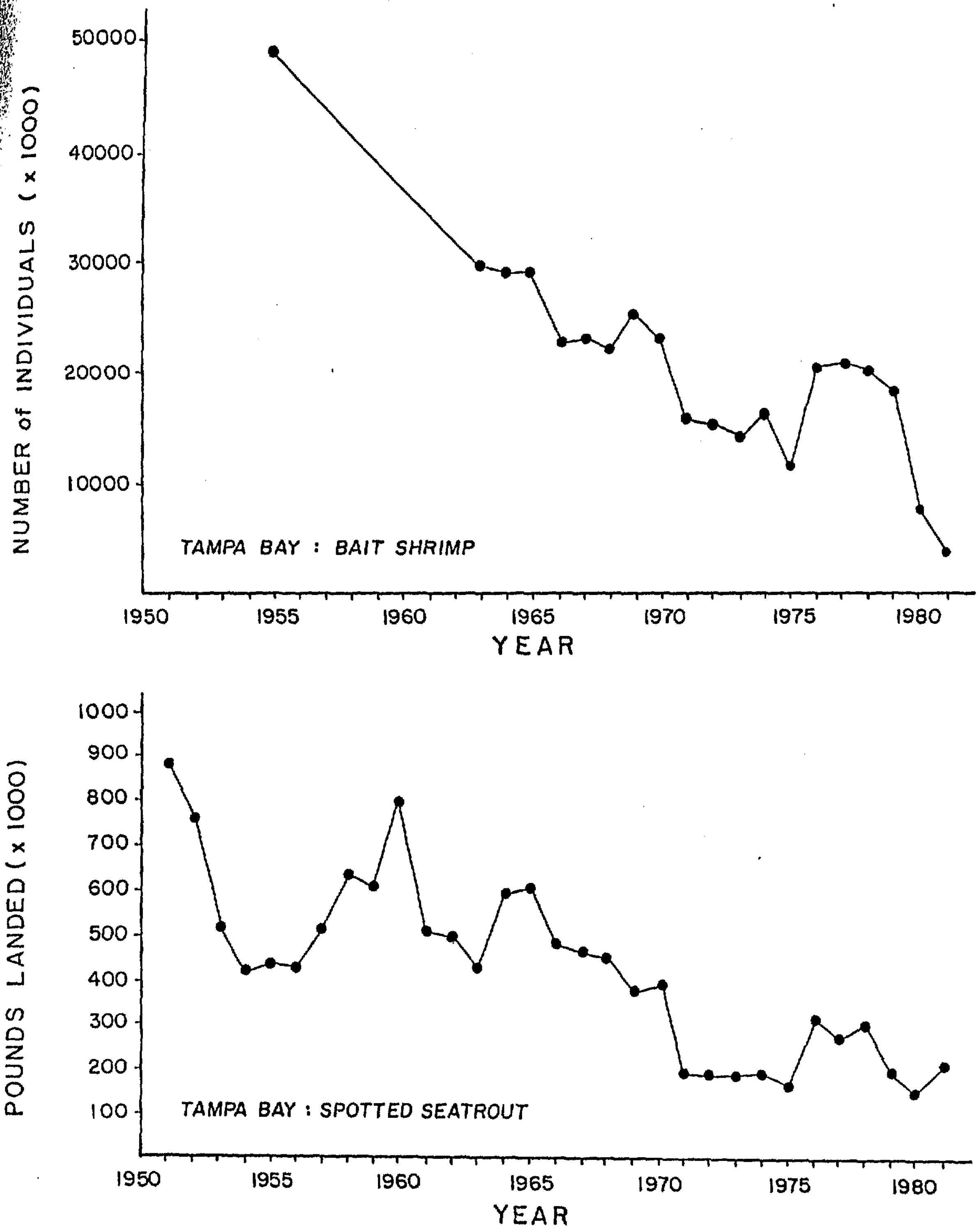

Figure 4. Landings of bait shrimp (top) and spotted seatrout (bottom) in Tampa Bay.

potential (carrying capacity) of this species would be reduced in the bay, and the seatrout population could not recover to historical levels, even if all fishing pressures were eliminated.

The bait shrimp industry also relies heavily on production in seagrass meadows. Bait shrimp are kept alive and sold in the retail market to recreational fishermen. The shrimp are captured by roller-trawls specifically designed to work efficiently in seagrass meadow target areas. Unlike seatrout, adult shrimp migrate offshore to spawn, and the juveniles return to use the seagrasses, marshes, and mangroves as nursery grounds. Again, the loss of seagrass can be expected to influence the catch of bait shrimp and their population potential.

The two species just described are representative of many commercial and recreational species caught in Tampa and Sarasota Bays. Over 70% of the commercial and recreational species caught in Florida utilize the estuaries during some portion of their lifecycles, suggesting that we must understand the estuary as a system in order to manage the fishery. Each estuary has unique characteristics that separate it from others that may be reflected in the fishery. For example, biologists have found that the primary nursery ground for red drum (redfish, <u>Sciaenops ocellatus</u>) in some Texas estuaries appears to be seagrass meadows (Holt et al., 1983), whereas Peters and McMichael (1987) determined that primary nursery areas in Tampa Bay are quiet backwaters with freshwater influences. The red drum in Texas spawn offshore; the Tampa Bay red drum spawn at or near the entrance to the bay. These findings suggest that specific studies in individual estuaries may not apply uniformly to other estuaries which have different physical, chemical, and biological characteristics. We must understand Tampa Bay as a system and conduct appropriate, systematic research to elucidate the information required for effective fisheries management.

The landings data report only adult populations. Juvenile populations can be assumed to have a great influence on the size of the adult populations. Influences on the juvenile populations, such as habitat availability, climatic cycles, spawning success, species competition, and a myriad of other factors, should translate into the potential production of a fishery. Unfortunately, most fisheries research has not concentrated on understanding the quantifiable relationships within an ecosystem. Years of catch-up research must be conducted in order to develop population projection capabilities that can be effectively used in fisheries management.

Research is being conducted in Tampa Bay to develop techniques for assessing juvenile populations of commercially and recreationally important species prior to their entry into the fishery. We expect that relationships between relative abundance of a juvenile population and commercial and recreational landings of adults will provide a tool for projecting the fishery in advance. The fishery can then be managed according to the resource available. This long-term program is linked with research to determine habitat carrying capacities and production potential. The research is being carried out with funding or cooperation from the National Oceanic and Atmospheric Administration Office of Ocean and Coastal Resource Management, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Florida Department of Environmental Regulation, and the Florida Department of Natural Resources.

Only through cooperative federal, state, and local programs and research can the fishery in Tampa and Sarasota Bays be understood and managed effectively. For further information on fisheries programs, contact Frank S. Kennedy, FDNR Bureau of Marine Research, 100 8th Ave. SE, St. Petersburg, FL 33701.

RESTORATION

One logical approach to revitalizing the bay and ultimately the fishery is to enhance the existing habitat. Restoration projects are not new to the Tampa Bay region. They have generally been coupled with mitigation of permitted habitat destruction or small independently sponsored projects. No overall systematic approach has been taken to monitor and evaluate the results of restoration.

In 1985, the Department of Natural Resources developed a legislatively-mandated Marine Habitat Restoration and Research Program, focusing on the restoration of natural vegetative components of marine fisheries habitat (saltmarsh, mangrove, and seagrass). The program was facilitated by commercial mullet fishermen who sponsored legislation requiring a $300 per annum County Gill-Net License. The legislation targeted the Tampa Bay region and overcame the major obstacle to implementing a marine habitat restoration program -- lack of funding. To date, four counties in Florida have adopted this legislation, providing the local initiative critical to the recovery of the bay: Pinellas (1983); Manatee (1984); Hillsborough (1987); and Pasco (1984). All of these counties are in the Tampa Bay region, and the first three encompass Tampa and Sarasota Bays. Revenues over $100,000 per year are administered by the Florida Department of Natural Resources and are legislatively mandated to be used for "marine habitat restoration and research". In addition, local state legislators have provided seed money for specific restoration research on seagrasses, but these funds are not on a continuing basis, such as the county net bill funds.

The Tampa Bay restoration projects have been designed to facilitate significant contributions toward understanding the dynamics of habitat restoration and resource recovery. Without valid project design, results from one project cannot be transferred to another, a factor often overlooked by those seeking comprehensive planning solutions to complex environmental problems.

Activities in 1986-87 have involved transplanting of saltmarsh, mangroves, and seagrass at several sites in the bay. Some experimental plots have been monitored only for survival and growth, whereas other experiment sites are intensively monitored for planting unit survival and spread, water column chemistry (seagrass), and faunal utilization. Monitoring will continue at experimental sites for a minimum of three years while site selection continues for future saltmarsh and seagrass plantings.

Success is not guaranteed in restoring natural vegetation. Factors controlling planting success may be site specific and vary with planting stock sources and handling. Survival of planting units thus far have ranged from zero to 100%. Seagrass restoration is proving to be the most difficult to accomplish, as losses have been extensive and appear to be related to changes in water quality. Until basic water quality relationships with seagrass are understood and addressed, large scale restoration cannot be accomplished. Unfortunately, funds are more easily made available for replanting, and the needed basic research is often overlooked.

The principal interest of this program is in restoration of the complex functions of marine fisheries habitat, which presumably begins with revegetation. Utilization of those habitats created by fisheries organisms, although costly to assess, will provide a perspective on the value of created vs. natural environs. Before large-scale restoration of the Tampa Bay area can begin, planting techniques, survival of plantings, and habitat contributions must be understood. This information is essential to the long-term management of our coastal resources and marine fisheries. The FDNR is being assisted in this work by the NMFS; Mote Marine Laboratory; Pinellas, Hillsborough, Manatee, and Pasco Counties; Pinellas Marine Institute; Mangrove Systems, Inc.; and other contracted and volunteer organizations. The Tampa Bay region has provided the initiative and funding for this effort and demonstrates that difficult tasks may be accomplished by local, state, and federal interactions. For more information on restoration research, contact Alan Huff, FDNR Bureau of Marine Research, 100 8th Avenue SE, St. Petersburg, FL 33701.

STOCK ENHANCEMENT

Stock enhancement is another approach to fisheries restoration. The practice entails hatching, rearing, and releasing fish into the natural environment to augment or enhance target species populations. Stocking of freshwater fishes into lakes, reservoirs, and streams for a management tool and/or for a put-and-take fishery is common. Stocking of fingerling marine fish into estuaries is a relatively untried concept. Stock enhancement in Florida is currently in pilot stages without production hatcheries. The principal hatchery research participants are the University of Miami Experimental Fish Hatchery, Miami; Mote Marine Laboratory, Sarasota; Harbor Branch Foundation, Indrio; and FDNR Bureau of Marine Research, St. Petersburg. The state is constructing an experimental hatchery in Manatee County adjacent to Tampa Bay, on property provided by the Manatee Port Authority. This facility will be the center for research on hatching, rearing, and stocking of red drum, snook, and other species.

Success in stocking marine fishes depends on species chosen, size of fish released (smaller sizes are more susceptible to predation and environmental stress), and habitat carrying capacity (how many juveniles or adults can be supported per acre regardless of the number of fish released). Also, from a hatchery perspective, bio-energenics, growth, metabolism, osmotic/ionic systems, reproductive physiology, feeding dynamics, behavior, and genetics have not been thoroughly investigated (if at all) for most estuarine species.

There are many questions that need to be answered before full-scale stocking, if feasible, can be accomplished. The problems are multi-disciplinary and will require a myriad of information to accomplish an environmentally sound enhancement program. The fisheries and habitat research already discussed will greatly enhance the information base of the stock enhancement program. The Tampa Bay region is fortunate to have this program centered here because of the existing related programs and the demonstrated ability of the scientific and management community to work together. For further information on stock enhancement research, contact Daniel Roberts, FDNR Bureau of Marine Research, 100 8th Avenue SE, St. Petersburg, FL 33701.

SUMMARY

I have briefly addressed fisheries habitat concerns and trends, fisheries management and research needs, habitat restoration, and stock enhancement in Tampa and Sarasota Bays. The complexities of the research have been presented only as an overview. It is important to recognize the cooperative spirit demonstrated by researchers and managers in addressing the problems within this estuary.

Much of the habitat necessary for the maintenance of quality biological production in the bay has been altered. New approaches to fisheries management are being implemented, which should provide enhanced techniques for quantitatively understanding the fishery populations in the bay. Restoration and stock enhancement programs may help to increase the quality of production in the bay. Funding continues to be a prime concern for research and management, but, because of the spirit of cooperation in the bay area, much has been accomplished with minimal dollars. Most programs are minimally funded and need to be put on accelerated schedules. Unless long-term committed sources of funding are directed to the bay area, little improvement in the bay system can be expected in the next decade.

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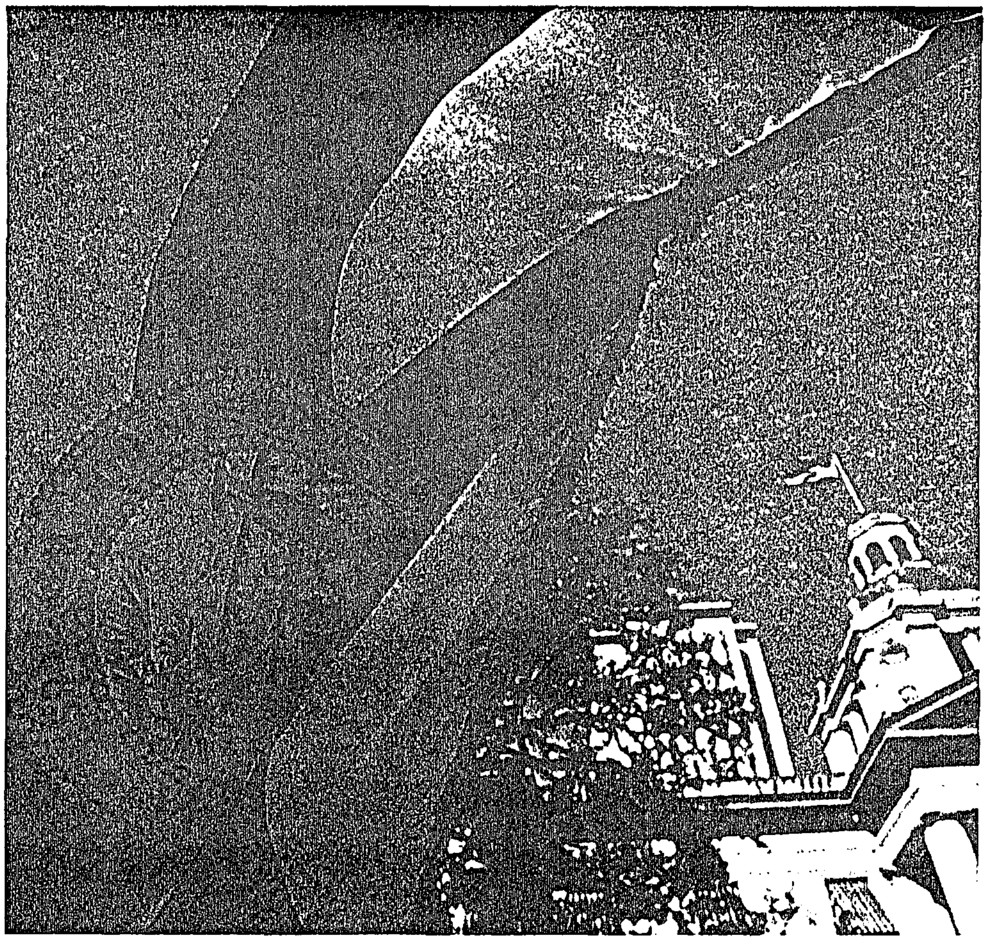

Florida's people and their government

Allen Morris

Florida's Marine Resources

Kenneth D. Haddad

The beauty, diversity, and abundance of Florida's marine resources are major lures for visitors and new residents to the State. Consequently 80% of Florida's population lives near the coast. From sunning on the beach and watching dolphins frolic in the nearshore waters, to catching the fish of your life, the pleasures are many. Along with these pleasures come associated industries and jobs.

The rich diversity of Florida's marine environment has evolved as a result of its unique geography. There are over 8,000 coastline miles of marine waters (1,300 linear miles) extending 3 miles offshore into the Atlantic Ocean on the east coast and 9 miles into the Gulf of Mexico on the west coast and covering more than 9,800 square miles. Jutting south into a Caribbean-like environment, the coastline from Cape Canaveral on the east coast and Tampa Bay on the west coast is considered tropical to sub-tropical and a wide range of marine fauna and flora exist, in abundance, that cannot be found anywhere else in the United States. A major influence on the stability of the tropical marine resources of the area is the warm ocean currents that flow from the Caribbean and bathe the coastline. The northern half of the state is considered warm-temperate and the marine flora and fauna are more typical of those found in the remainder of the eastern U.S.

Plants, Animals, and the Environment

Thousands of species of plants and animals comprise the marine environment in Florida. They range from marine mammals, such as manatees and dolphins, to coral reefs and their associated fishes. All of the marine plants and animals we see in Florida are the result of the numerous and complex habitats in which they live.

Reefs

Living coral reefs and rocky limestone outcroppings are the two major types of natural reefs found in Florida. The coral reefs off the Florida Keys are spectacular and rival the Caribbean areas to the south. Rocky outcroppings are found all along the Florida coastline and are important to the productivity of our offshore waters. Both types of reefs are complex habitats for fishes and other plants and animals providing food and cover in an otherwise inhospitable environment.

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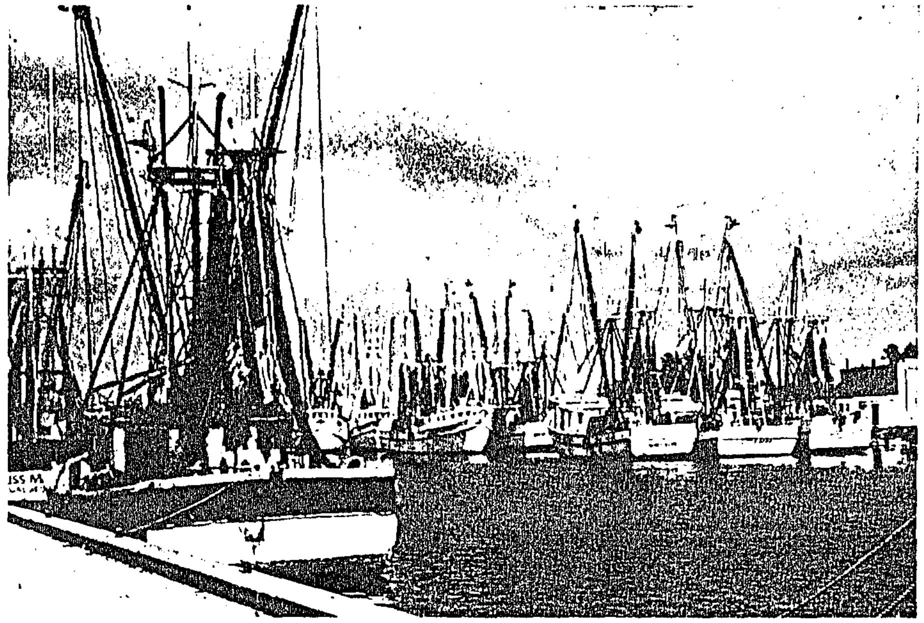


These shrimp boats are clustered at Tarpon Springs. Department of Natural Resources

Artificial reefs, constructed of rubble and other man-made materials and structures, are becoming important habitats and fish attractors in the marine environment. Programs at the state, county, and local government level encourage artificial reef development in a coordinated and environmentally sound manner.

Estuaries

The estuarine environment is the most productive marine ecosystem in Florida and one of the most productive environments on Earth. Estuaries occur where freshwater meets and mixes with salty ocean waters and include bays, lagoons and shallow, low energy areas such as the Big Bend portion of the west coast. Important wetland habitats in the estuaries are mangroves, saltmarshes, and seagrasses. Mangroves are sub-tropical trees that have adapted to grow in saltwater and cover over 500,000 acres of southern Florida. Saltmarshes are coastal wetlands rich in marine life that grow in low energy areas in the zone between low and high tide. They are found throughout Florida, often mixed with mangroves, and cover over 450,000 acres. Seagrasses are saltwater-adapted, flowering plants that grow below the tidal zone and cover between 600,000 and 900,000 acres of submerged bottom. Seagrasses are probably the single most important marine habitat in Florida and one undergoing serious stress from man's development of the coastline.

The estuary is the sink for the majority of man's activities in Florida, including sewage waste, stormwater runoff and the myriad of associated pollutants. The vegetated portions of the estuary serve to filter and clean the waters in the estuary and their loss through various types of development can lead to serious and compounding problems for our marine resources.

Natural Events

When man alters the natural marine environment it is often permanent and a loss to the marine system is incurred. Natural events can have the same type of impact but often the resources recover or, in some manner, remain a functioning part of the marine ecosystem. Hurricanes and storms can destroy mangroves, saltmarshes, seagrasses, coral reefs, and oyster reefs through uprooting or burial but recolonization is rapid. Winter freezes can kill thousands of acres of sub-tropical mangroves, but new plants germinate as soon as the weather warms. Sea level rise has been occurring and is projected to increase due to the greenhouse effect. This could impact the distribution of many of our marine resources that are tidally and water depth dependent, and consequently impact entire ecosystems.

Florida's red tide is a natural phenomenon resulting from dense concentrations, called blooms, of a microscopic, plant-like organism. The toxins produced by these tiny cells can kill fish, that may wash ashore, and also can cause human illness if ingested through clams, oysters and other bivalves that concentrate the toxins. A local shellfish harvesting ban is announced whenever red tide is imminent inshore.

The Marine Fisheries

Fishing and seafood immediately come to mind when the State of Florida is mentioned in any conversation. The State has large and viable commercial and recreational industries and both are growing. Florida ranks third in the nation in resident anglers (greater than 2,100,000) while over 1,200,000 tourist anglers annually fish in Florida waters. Many of these are saltwater anglers with an economic impact of more than $2 billion. The commercial industry is also significant with the dockside value of landing reaching $210,000,000 in 1987. This is an 18% increase over the 1981 landings and is the 6th highest state value in the nation. Florida ranks 2nd nationally in processed fish products. If the commercial fisheries values are economically scaled to retail and combined with the recreational values it is apparent that the industries are worth billions to the states economy.

It is important to realize that these industries depend on the abundance and health of the species sought. To this end, the estuaries are major producers of fisheries products and serve as the nursery grounds for many of our fishery species. In fact, over 70% of the commercially and recreationally caught species in Florida utilize the estuaries during some portion of their life cycle. Estuaries provide juvenile fish with an abundant food supply and, just as importantly, protective cover in the various mangrove, seagrass, saltmarsh, and other structural habitats found in the estuaries. Many of these fish grow up in the estuary but spend their adult life in our coastal oceans. Shrimp, baitfish, red drum, mullet, and grouper are examples. Others, such as spotted seatrout, spend their entire life in the estuary. Those species which do not directly use the estuary, such as sailfish and swordfish, depend on the estuaries for producing their food.

Commercial Florida Landings of Major Species for 1987

Species	Catch (lbs.)	*Value ($)
Grouper, Combined	12,546,121	18,966,748
Mullet, Black	22,688,527	8,682,334
Swordfish	2,586,234	8,669,025
Tuna, Yellowfin	3,233,479	5,949,601
Mackerel, King	3,110,404	3,404,950
Snapper, Yellowtail	1,353,607	2,448,571
Shark	4,607,508	2,395,904
Pompano	778,434	2,324,029
Mackerel, Spanish	6,267,993	2,142,203
Snapper, Red	841,107	1,972,997
Seatrout, Spotted	1,659,866	1,749,649
Total Fish (all species)	123,831,536	76,579,226
Shrimp	25,546,009	65,769,138
Lobster, Spiny	6,075,026	14,397,812
Crabs, Stone	4,744,912	11,779,729
Oysters	3,784,914	7,078,327
Clams, Hard	1,192,705	6,004,337
Crabs, Blue	18,386,671	5,782,721
Total Shellfish (all species)	70,987,314	133,594,849
Total Landings (all species)	194,818,850	210,174,075

*Value refers to the amount received for the catch delivered to the dock

Fisheries Management

Marine fishery resources are renewable, yet finite. When finite resources are shared among increasingly larger user groups, each individual must settle for a smaller share. Accordingly, many questions arise regarding government's ability to adequately protect and manage this common property resource. Currently, effective management techniques are based on open and closed seasons, minimum and maximum size limits, bag limits, and other regulations that restrict the users access to the resource and cap allowable harvest. Maintaining the information base to regulate in this manner is especially difficult in Florida because of the number of species sought and the fact that open marine systems have so many factors that influence a population; unlike that in freshwater systems.

Florida's fisheries are managed by the Marine Fisheries Commission. Established in 1983, the seven member Commission evaluates the need and effectiveness of marine resource regulations and proposes new rules. Any new rules or changes to existing laws must be approved by the Governor and Cabinet. Since regulations change and there are special local regulations in some areas, it is advisable to contact the Marine Patrol District Office nearest the location where harvest activities are planned.

Ecosystem Management

With such a diverse richness of our marine resources and a resultant diverse group of users, management of the resources is not an easy task. This is compounded by the rapid growth occurring in the State and its unquantifiable impact on our marine resources. Realizing that preservation and protection of the resources are paramount to a healthy ecosystem, the State has developed numerous programs within different agencies to purchase and manage resources, protect them through regulations, and manage growth that is seriously impinging on health of the natural resources. Currently the state has designated 41 Aquatic Preserves, 37 that are marine or estuarine, covering 3.1 million acres. The Florida Aquatic Preserve Act of 1975 has as its goal the protection of these sensitive areas from over-use by man. Florida also has two National Estuarine Research Reserves—Rookery Bay and Apalachicola River and Bay. Key Largo Coral Reef and Looe Key are designated as protected National Marine Sanctuaries. Other areas within the marine environment are currently being considered for special management.

If the state's Constitutional policy requiring the conservation and protection of its natural resource is to be followed, much work must be accomplished to retain or restore elements of Florida's natural system and preserve our marine resources. The signs are evident that we are seriously stressing our marine resources. We have lost much of the natural habitat and we are using the resources more than ever before. Our marine resources are part of our State's heritage and it is up to us to ensure them a place in Florida's future.

Early Punishments

Pillory, branding iron, the post of nailing ears, and whip were instruments of justice as Florida became a state in 1845.

Nothing so illustrates the change in regard to human life and feelings during a century than the laws which sheriffs enforced as the territory progressed into statehood.

A gambler or vagrant might, for example, be punished:

". . . by a fine not exceeding $500, and imprisonment for a term not exceeding 12 months, or by being sold for 12 months to the highest bidder, or whipping not exceeding 39 stripes . . ."

Inspection of the Acts of 1846 shows these fees for sheriffs:

"Whipping a person under sentence of the Court, two dollars.

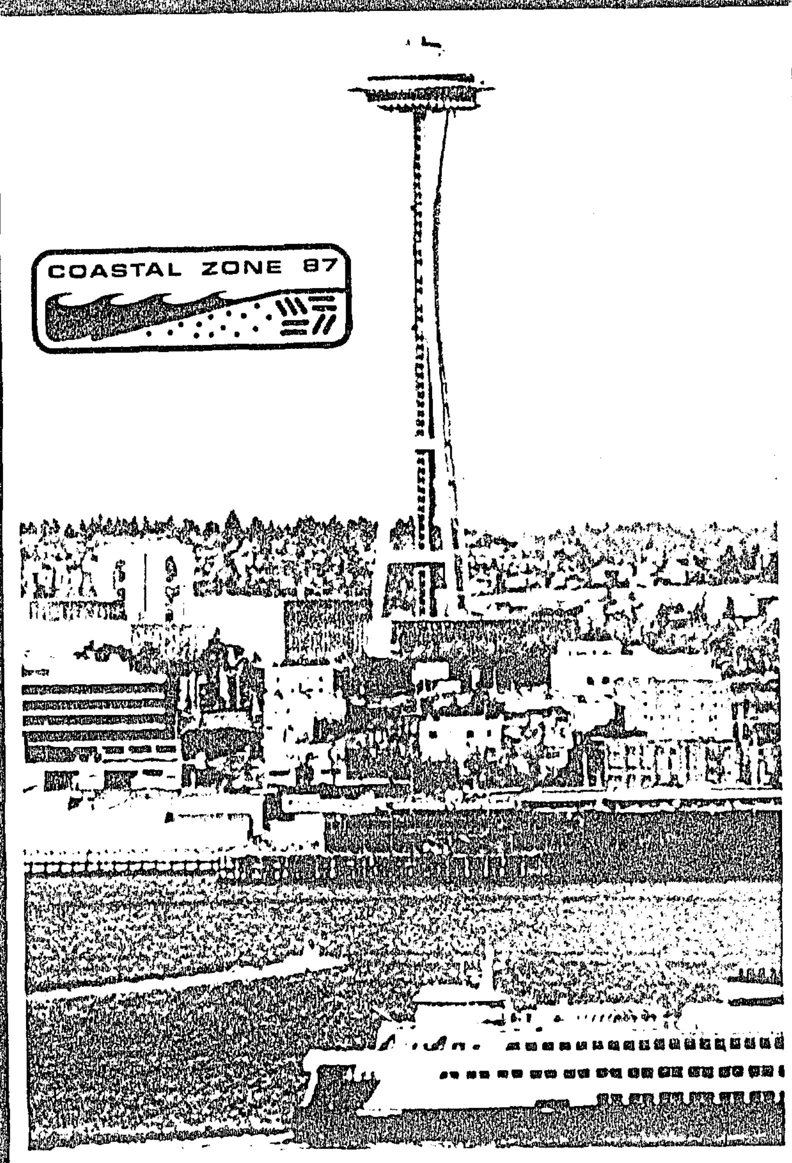
"Confining person in pillory, under sentence of Court, three dollars.

"Branding prisoner, five dollars.

"Nailing ears of prisoners to posts, under sentence of Court, three dollars.

"Hanging a prisoner under judgment and sentence of Court, ten dollars."

In addition, a sheriff might be allowed up to $10 for erecting a gallows and up to $3 for placing the stocks to embrace a person sentenced to stand in pillory—target for the town's gibes and occasional rotten eggs.



Coastal Zone '87

Volume 5

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POTENTIAL OF LANDSAT TM IMAGERY FOR ASSESSING THE NATIONAL STATUS AND TRENDS OF COASTAL WETLANDS

Kenneth D. Haddad* & Donald R. Ekberg**

The management of wetlands resources requires detailed information on the amount and type of wetlands and how these change with time. Since wetland alterations directly or indirectly affect fisheries, the fishery manager must also be cognizant of wetland status.

Considerable literature has accumulated on wetland loss, particularly in the southeast which contains over 80% of the coastal wetlands in the contiguous United States. Loss of wetlands from natural causes, e.g., subsidence, rising sea levels, and erosion, cannot be regulated; however, losses occurring from human activities can and should be controlled. During 1985, the National Marine Fisheries Service (NMFS) reviewed approximately 4,400 applications submitted to the Corps of Engineers (COE) in the southeast requesting permission to alter wetlands. About 1,800 of the applicants proposed to dredge, fill, drain, and impound more than 65,000 acres of fisheries habitat. Most of these requests were from Louisiana (666) follwed by Florida (343), Texas (317), North Carolina (209), South Carolina (140), and the rest in Mississippi, Alabama, Puerto Rico and the U.S. Virgin Islands (Mager and Hardy, in press).

A wetlands resource manager who attempts to follow the alterations in his district should have an accounting of acreages lost and gained. Monitoring COE permits can only approximate loss or gain of wetland vegetation. Illegal practices by persons who alter wetlands without permits or do not adhere to permit limitations are not readily apparent. Direct wetland assessments must be made and are essential to monitor both natural and human-induced alterations.

Direct assessment can be accomplished by on-site measurement or remote sensing. Both are required if detailed data are necessary. Field measurements, though labor intensive, may suffice for small areal studies of

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less than 100 ha. However, studies of thousands or millions of hectares require remote sensing as the primary investigative method and, in addition, the resultant geographic database should be in a digital format. The most common tool for remote sensing is aerial photography, but this, too, becomes labor intensive as the area under investigation increases, particularly if the photographs are to be reduced to a digital format. Satellite imagery data from the LANDSAT Thematic Mapper (TM) and the French SPOT now have spatial resolutions of 30 and 10-20 m and seven and four spectral bands.

Database Development

Techniques for developing geographic, digital databases are numerous and they often dictate the database format. The two primary data formats are (1) vector, in which the data are composed of x,y coordinates to form lines and arcs, and (2) rastor, in which the data are composed of cells in a grid with each cell represented by a numerical value (Haddad and Hoffman, these proceedings). In general, digital vector data are created through manual interpretation of aerial photography and subsequent manual digitization into a computer database. The output products are map-like. Rastor data are received in digital format from a variety of satellite and aircraft sensors and the output products are pictoral.

Historically, the only approach to wetland assessment and monitoring was through standard photographic techniques; this remains the standard today. An alternative to this technique became available through advancements in satellite sensors, computer hardware, and image processing software. The Florida Department of Natural Resources (FDNR) investigated the potential for using LANDSAT TM data as the primary data source for mapping and monitoring the status and trends of coastal wetlands. Haddad and Harris (1985) determined that the only economically feasible method of developing a statewide digital database for FDNR was to use TM data. They found a 69-72% cost reduction and an 83% time reduction when they compared the use of TM data to standard photogrammetric techniques. The primary reductions occurred during the photointerpretation and digitization processes.

LANDSAT Thematic Mapper Data

The use of satellite imagery for resource mapping and monitoring has generated much criticism in the past as to accuracy and information content. These criticisms were often well founded and, unfortunately, engendered a general skepticism of this technology which remains despite recent advancements. TM data from LANDSAT satellite has only been available since 1982-83 and advanced preprocessed data became available in 1984. TM data are far more resolved than Multispectral Scanner data, the primary satellite data available from LANDSAT in the past. The 1/4 acre spatial resolution and 7 spectral bands provide tremendous potential for wetlands mapping and monitoring. Unfortunately, this potential is overlooked because of past biases and the incorrect perception that TM data will not interface with past mapping efforts or provide reliable resource data.

The results of studies that evaluated the potential of this technology are only now becoming available. Welch et al. (1985) determined that TM data, geodetically rectified to the standard UTM map coordinate system, can meet National Map Accuracy Standards (residual means) for 1:24,000 scale maps and overall accuracy standards for 1:50,000 maps. This confirms the potential of using TM data as the primary map coordinate system in a geographic database. Assessments of TM data for accurate resource mapping and monitoring suggests that the processing techniques are ready for implementation (Lauer, 1986; Smith, 1986; Haddad and Harris, 1986; Fox et al., 1985). Specific investigations also show that TM data can be used in wetland resource mapping with existing processing capabilities (Dottavio and Dottavio, 1984; Jenson and Davis, 1986; Leipner and Myers, 1986; Welch et al. 1985).

Utilization of TM Data by Florida DNR

The FDNR has an active program utilizing TM data as the map coordinate system and the primary data for coastal wetland resource mapping and monitoring. A key to the success of this program has been the ability and flexibility in using multiple sources of data to produce resource maps which can be compared with existing and future resource maps. This approach relies on the use of multiple image processing techniques, digitization of photointerpreted aerial photography, and integration of vector data that has been converted to rastor format.

The above approach has been applied successfully to many areas and wetland types. An example focuses on a 10,000 ha area in lower Tampa Bay, Florida. Three images have been compared for both trend analyses and conflicts in map conventions for the years 1952 (Figure 1), 1982 (Figure 2), and 1984 (Figure 3). The 1952 and 1982 data are rastorized, vector data from the USFWS National Wetlands Research Center (Slidell, La.). The wetland categories in this database were based on the National Wetlands Inventory map convention but have been grouped into broad categories for presentation. The 1984 data set was produced from TM data using both parallel-piped and maximum-likelihood statistical classifiers. The statistical classes were grouped to distinguish mangroves as a single resource from

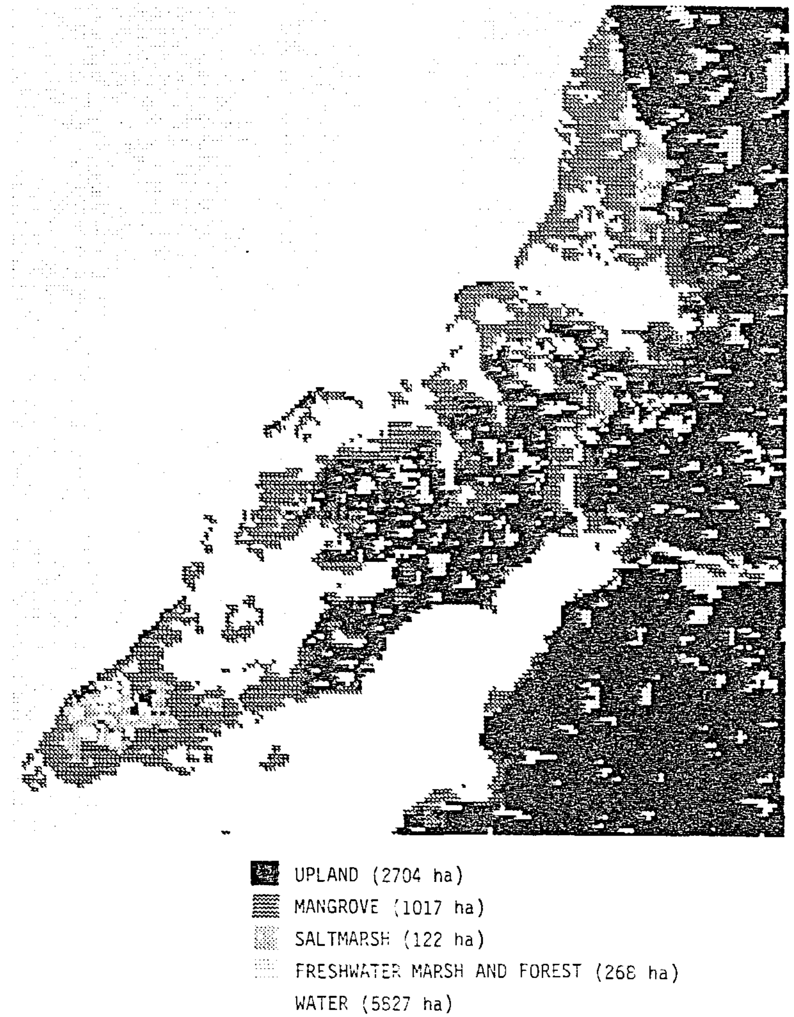
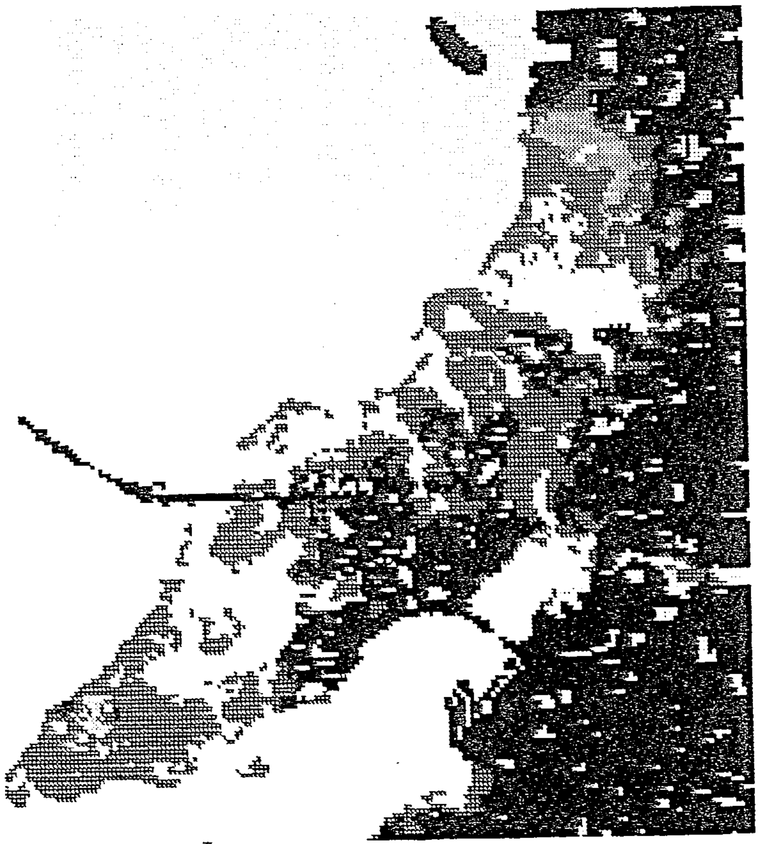
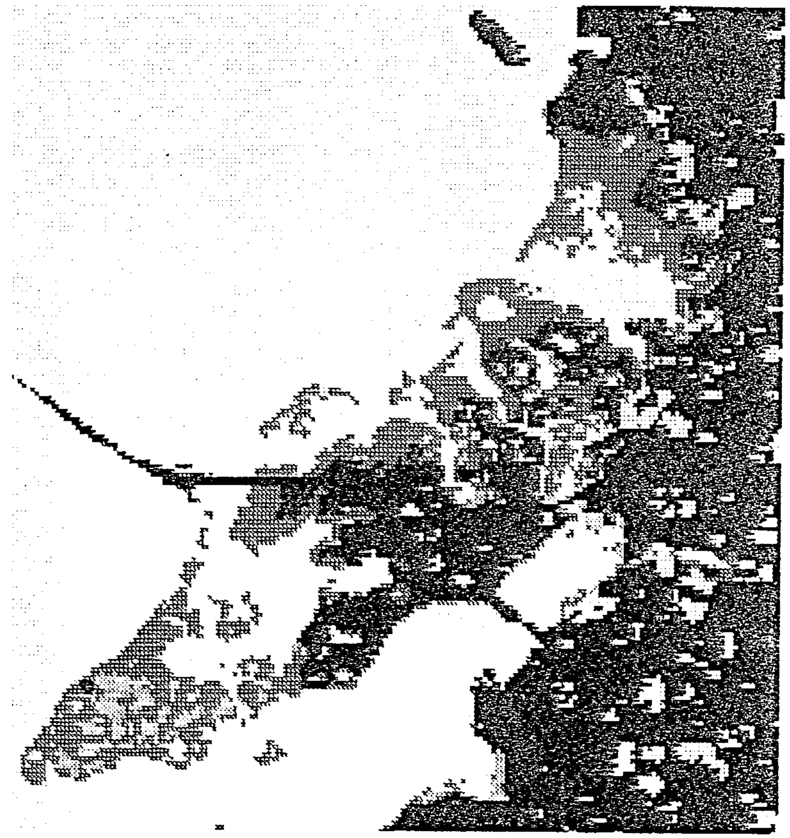


Figure 1. A section of Tampa Bay, Florida (scale 1:50000) in digital format based on interpretation of 1952 aerial photography.



UPLAND (2792 ha)
MANGROVE (1243 ha)
SALTMARSH (102 ha)
FRESHWATER MARSH AND FOREST (155 ha)
WATER (5646 ha)

Figure 2. A section of Tampa Bay, Florida (scale 1:50000) in digital format based on interpretation of 1982 aerial photography.



UPLAND (2949 ha)
MANGROVE (1004 ha)
SALTMARSH (135 ha)
FRESHWATER MARSH AND FOREST (252 ha)
WATER (5598 ha)

Figure 3. A section of Tampa Bay, Florida (scale 1:50000) in digital format based on interpretation of 1984 LANDSAT TM imagery.

saltmarsh while the remaining categories were grouped to show the differences in the ability of TM data to conform to standard map conventions and photointerpretations.

Because the 1952 and 1982 data were compiled from aerial photography, the differences in areal coverage should reflect only the changes in the resource and errors in the photointerpretation process. The 1984 data, when compared to the the 1982 data, show changes in the resource and differences in the interpretation of TM processing, photointerpretation, and map conventions. In general, the increase in uplands from 1982 to 1984 is due to (1) construction of an interstate highway, (2) variations in the defined border between uplands and other categories and (3) the interpretation of a wetland transition area as wetland in 1982 and upland in 1984. These same differences occur in the other categories; careful visual comparison of the figures will also reveal the similarities and differences.

A detailed study of mangrove distribution (Figure 4) provides a good example of the potential for data comparison and the utility of using TM for the mapping process. Mangroves show an increase in distribution from 1952 to 1982 but a decline between 1982 and 1984. The majority of that decline is the result of a winter freeze which caused mangrove defoliation in this area. As a result, the underlying marsh became the dominant signature in the TM data. If this marsh is included in the areal calculations for mangrove then mangrove area becomes 551 ha in 1982 and 541 ha in 1984. The 10 ha difference resulted from variation in the interpretation. If the mangrove area in the southern portions of the data (lower left sections of Figure 4) is only considered then the mangrove/marsh for 1982 is 313.9 ha and 314.9 ha for 1984. Only a minor portion of uplands are in this area, suggesting that the wetland/upland interface is interpreted differently when comparing TM analyses to photographic analyses. These differences can be reduced during photointerpretation or refined image processing. We emphasize that the differences depicted in these data represent only a small percentage of the total areal coverage being compared.

Conclusion

The potential for using TM data in assessing trends in wetland distribution have been briefly discussed. TM data can be used for general trend comparisons if conventional maps are digitized. However, a primary deterent to conducting such comparisons is that most existing wetland maps are not in a digital form and the expense of converting them insures that, in most cases, digitization will not occur. The resource manager must then determine what techniques to use to create a digital database capable of providing trend data for the resources. We suggest that

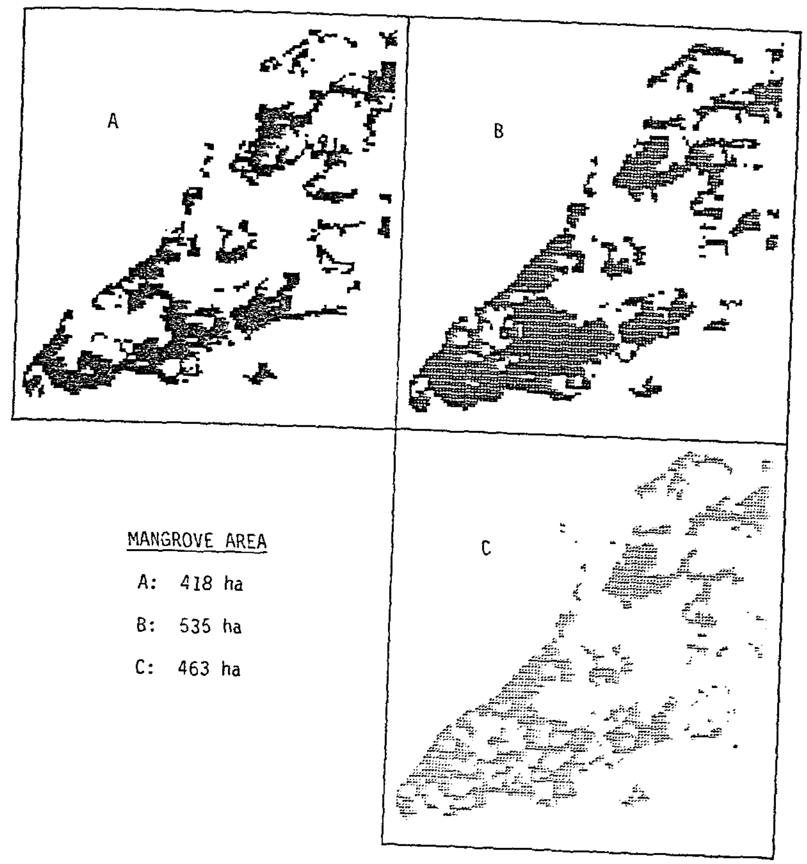


Figure 4. Mangrove coverage extracted from Figures 1, 2, and 3 based on interpretation of 1952 aerial photography (A), 1982 aerial photography (B), and 1984 LANDSAT TM imagery (C).

TM data can provide this capability and the techniques to use it should be explored, not ignored. We do not suggest that these data alone can be used to monitor small, permitted or illegal alterations of the wetland environment. Such detection requires a combination of techniques. However, by using TM data as the basis for resource assessment, compatible technological advances will provide finer spatial resolution (ie., new satellite sensors, video imaging, digital photography) and resource discrimination. The assessment of the status and trends of important wetlands must be accomplished at a national level. The tools are now available to accomplish this type of endeavor if the proper commitment and expertise are merged. Again, we are not advocating the use or exclusion of any given remote sensing technique, but an interaction of all the digital techniques now available. The inflexibility of many resource managers in accepting this concept will only serve to delay the creation of resource databases to encourage informed management.

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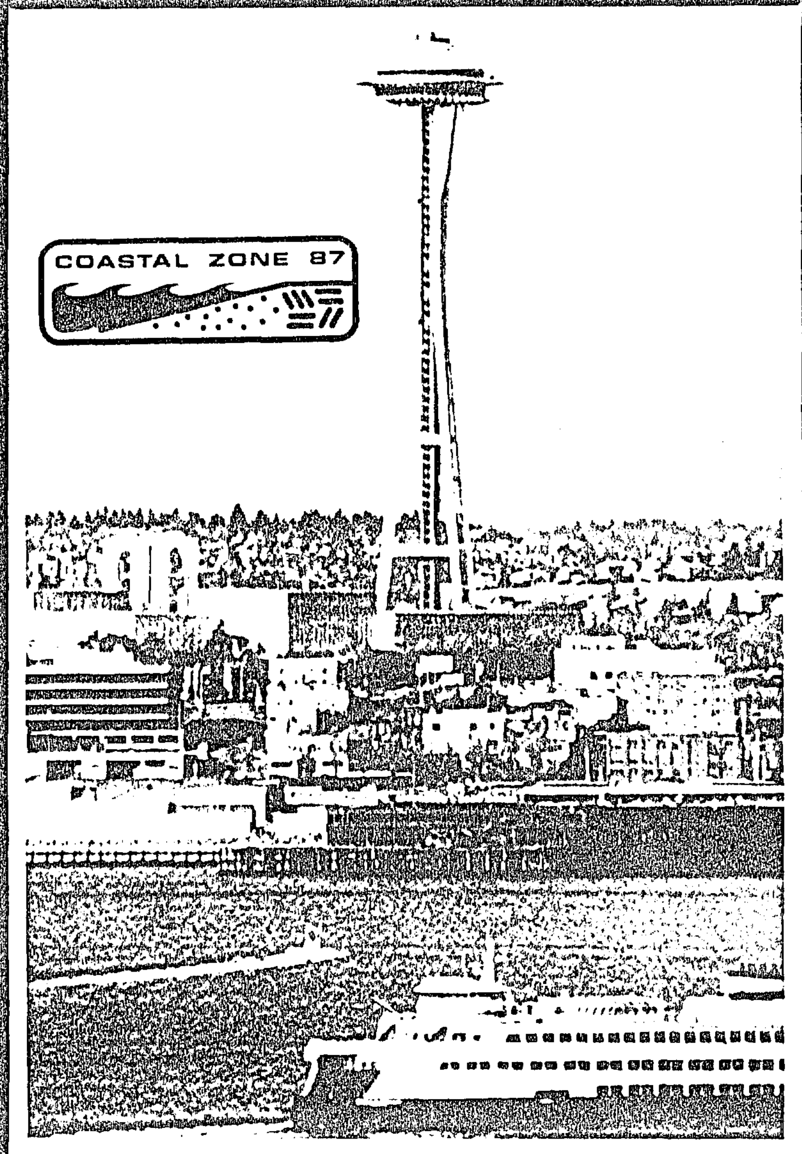

Coastal Zone '87

Volume 5

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THE ROLE OF GEOGRAPHIC INFORMATION SYSTEMS IN MANAGING FLORIDA'S COASTAL WETLAND RESOURCES

Kenneth D. Haddad* & Barbara A. Hoffman*

Florida is one of the fastest growing states in the nation and this trend is expected to continue into the twenty-first century. The impact of this growth on our wetland ecosystems is difficult to assess and monitor. To deal with the complex and often conflicting issues of growth versus environment, coastal resource managers require rapid access to a comprehensive coastal resource database from which they can extract and synthesize pertinent data to aid in their decision-making. Although the concept of using resource data to manage the resources is not new, the reality of such databases is that they have been limited because of the technical and organizational complexities associated with implementation. With rapid advances in computer and software technology, the creation of comprehensive resource databases is now possible at the state and local level. The data requirements of the resource manager are often geographical in character and much of the resource software technology is addressing this requirement.

Geographic Information Systems

"Geographic information system" (GIS) is a generic term and may be defined as a computer system or network that has as its primary function the analysis and handling of geographic (spatial) data. A GIS, by hardware and software design, is able to accept large volumes of spatial data from a variety of sources and to manipulate, retrieve, analyze, and display the data efficiently according to user-defined specifications (Marble and Peuquet, 1983). Any database that is geographically referenced has the potential for GIS entry and, certainly, many aspects of Florida's coastal wetland resources meet this criterion. Some GIS software designs incorporate capabilities to access attribute (tabular non-spatial) data associated with a geographic location. An example of this would be the ability to access, on a computer terminal, a permit application or tax record based on the location of a parcel of property displayed graphically in a map form. GIS applications are numerous but a clear understanding of the

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various types of GIS data and database development are required for successful implementation.

Two basic data structures are utilized in GIS systems: rastor and vector. GIS software packages, with many variations of these data structures, are becoming increasingly available within both the non-proprietary (tax-dollar developed) and commercial markets.

A rastor-based GIS is one in which the geographic data are presented as discriminate cells of a predetermined geographic size (i.e., 1/4 acre, 1/3 acre, etc.) with each cell having one data value commensurate with the type or layer of data being displayed (Figure 1). The user actually sees the specific numerical values as colors or gray shades on a computer screen. This type of GIS database is an extension of digital image processing of aircraft and satellite scanners and, more recently, digital photographs and video imaging.

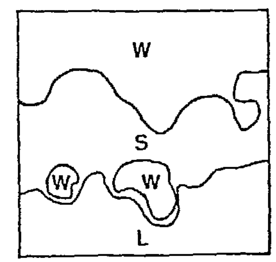
A vector-based GIS utilizes a map display in which a series of x,y points are connected by lines and arcs and are presented on a map or computer screen as polygon outlines (Figure 2). Vector-based GIS's generally are extensively modified Computer Aided Design (CAD) packages and are logical extensions of non-computerized map drawings.

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	2	2	1	1	1	1	2
2	2	2	2	1	2	2	1
2	2	2	2	2	2	2	2
2	1	3	1	1	2	3	3
3	3	3	3	1	3	3	3
3	3	3	3	3	3	3	3

LAND COVER, RASTOR

1 = water
2 = seagrass
3 = land

Figure 1



LAND COVER, VECTOR

W = water
S = seagrass
L = land

Figure 2

These two basic types of data are often interchangeable, but they also are substantially different in many aspects of data manipulation, geographic accuracy, overlay capabilities, attribute handling, and data entry. In addition, some GIS's give the user all possible options and benefits of both the rastor and vector types of data. These aspects will not be presented in detail, but one must fully explore the ranges of GIS capabilities prior to a database development initiative.

Marine Resource Geographic Information System

A program has been initiated at the Florida Department of Natural Resources (FDNR), with funding through the Florida Department of Environmental Regulation and the NOAA Office of Ocean and Coastal Resource Management, to develop a coastal wetland resources spatial database and incorporate these data into a computer-based information system. The initial phase of the FDNR program was to institute a Marine Resources Geographic Information System (MRGIS) and develop techniques in remote sensing and image analysis for mapping and monitoring marine wetlands in Florida's coastal zone. Haddad and Harris (1985a) concluded that the time constraints and enormous funding required for conventional photogrammetric mapping preclude standard approaches to mapping and monitoring a coastline of over 2,172 km. Thematic Mapper (TM) data from Landsat satellite (1/4 acres spatial resolution) was evaluated and chosen as the primary database in the mapping procedure. The TM data are not effective in all mapping requirements and are supplemented with aerial photography where necessary (Haddad and Harris, 1985b). The success of the MRGIS now depends on (1) transformation of the raw LANDSAT TM data into a wetlands/land-use map and (2) the use of geographically referenced TM data as the coordinate reference system for overlays of ancillary geographic data. We emphasize that the wetlands mapping effort provides just one of many layers of data required for the MRGIS.

Since TM data are in a rastor format, the MRGIS required a rastor-based GIS. ELAS, a non-proprietary software package developed by NASA Earth Resources Laboratory, was chosen as the primary tool for MRGIS development. ELAS is a modular FORTRAN overlay package that is machine independent (Junkin et al. 1981). ELAS, as described by Marble and Peuquet (1983), may be categorized as a rastor-based GIS. The exceptional flexibility of the ELAS software package makes it a powerful image processing/GIS tool. The ability to manipulate and sort layered data is not based on a "user friendly approach"; thus, ELAS is not recommended for direct infusion into a management situation. Our choice for this software was based on the variety of remotely sensed data interfaces and image processing capabilities, crucial elements for successful implementation of the MRGIS. The data created on the MRGIS can be manipulated by the GIS capabilities of ELAS or is easily compatible with any rastor-based GIS on the market (see Data Dissemination).

MRGIS Data Overlays

A major function of a GIS is to utilize compatible, multiple, co-referenced layers of geographic data (Figure 3) to create a new file containing the results (pictorially and numerically) of a user generated query. The ability to enter ancillary data (such as bathymetry, sediment and soil types, etc.) is the feature that gives the GIS such value as a tool in resource management. This approach has been applied to many different situations, such as forestry and fire control management (Root et al., 1986) and land use management (Nystrom et al., 1986). A comprehensive applications review of GIS technology is in Geographic Information Systems Workshop (1986). The MRGIS overlay database is being designed specifically to provide the Florida resource manager with the capability to assess and monitor submerged and emerged wetland environment. This is important for balanced and informed management of these sensitive lands for dependent fisheries, non-game wildlife, and burgeoning population growth in the coastal zone.

MRGIS data layers input for the Tampa Bay region of Florida include vegetation cover, waterbird nesting sites, sediment distribution, topography, open/closed shellfish areas, manatee sanctuaries, pertinent jurisdictional boundaries, water currents, and seasonal averages of salinity, temperture, and chlorophyll. Additional data layers can be added when necessary.

A typical query of this system could be based on the following hypothetical scenario. An Aquatic Preserve manager in the Tampa Bay region has determined that the wading bird populations are declining because the parent birds are unable to feed their young adequately during nesting season. These birds only range three kilometers from the nesting site during the active nesting season and feed only in shallow, vegetated wetland areas with sandy sediment. In order to grant special protective status on these feeding habitats, the manager needs to know all the areas within the Aquatic Preserve that meet these conditions (see Figure 3).

The results of such a GIS query are immediately available to the Aquatic Preserve manager (Figure 4). This is just one example of the many queries that could be imposed on the data. The queries are generally based on simple mathematical logic and can utilize various types of modelling (i.e., soil runoff coefficients, biological carrying capacities, etc.) to generate a final data set.

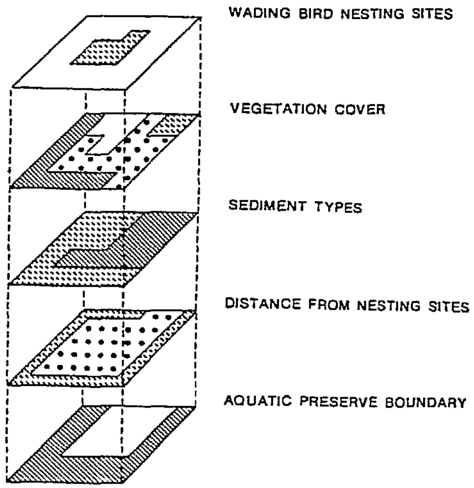


Figure 3

Data Dissemination

As the MRGIS database has been developed, demands to access that information have increased. Most resource managers deal with either hand-drafted maps or computer produced vector-type maps from line plotters. Since rastor data cannot easily be conveyed in these forms, two primary approaches to data dissemination have been taken with the MRGIS.

1. Rastor data are pictorial in character and are displayed in color on a computer screen. Each color has a specific meaning and the user can readily identify and visually extract the information subsets of an image. In the past, simple photographic techniques have been used in the past to present a hardcopy of the data, but this has proven expensive and impractical in many applications. An inkjet printer, which has the capability of reproducing 4,096 different colors in an image (photographic like output) format, has been interfaced to the MRGIS. Utilizing a combination of in-house and commercially available software, the ELAS data files can be reproduced on paper, at minimal cost, in any scale and in a variety of earth coordinate systems. Figure 4 is a black and white production from the inkjet

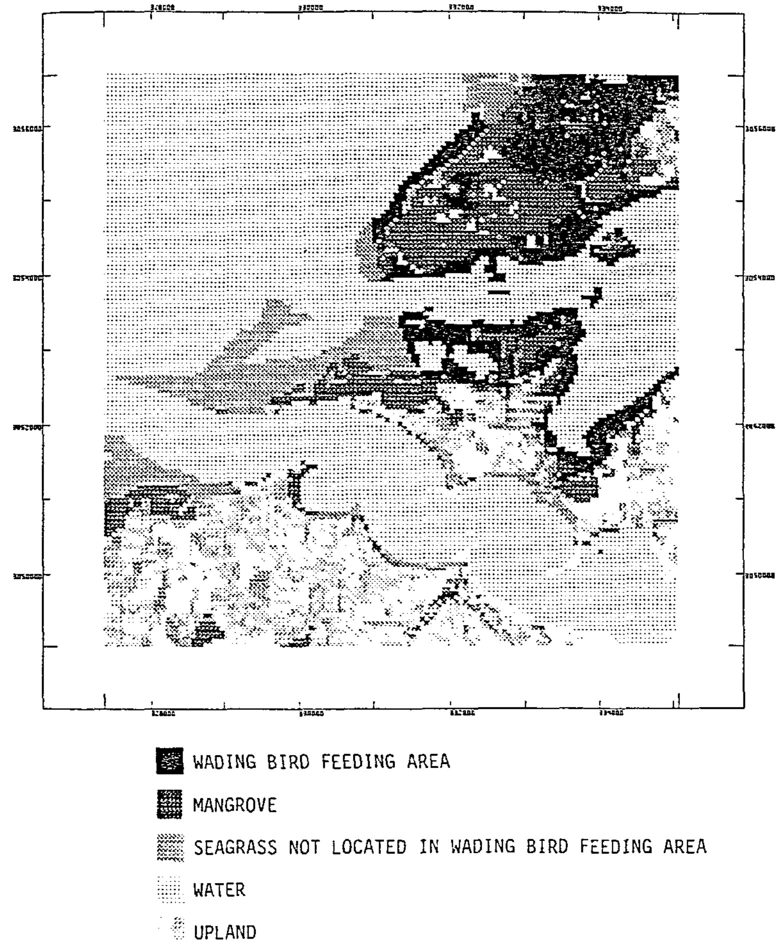


Figure 4. Inkjet printer output in a Universal Transverse Mercator map projection (tick marks = 1000 m). This print represents the results of a management query on a multilayered data set (see Figure 3). A standard inkjet print would be in color (256 shades) and more defined pictorally. The scale of the print is 1:67000. The scale of the data on the MRGIS is 1:24000; thus, this print does not present full resolution.

printer and represents the final data set created from a query based on Figure 3. Products from the inkjet printer for data dissemination have proven useful for many resource queries.

2. Hardcopy products are applicable in many situations, but the real value of working with digital data in a GIS is the ability to manipulate and query the data in a real-time management decision-making process. The only method for rapid access is direct computer access. Real-time access to a mainframe computer housing the data is technically and economically impractical bbecause many resource managers are in field situations and graphic data volumes are so large. An alternative approach is to make the data available on microcomputers with their own GIS capabilities.

A pilot program to evaluate the potential of downloading MRGIS data to a microcomputer for use in a management setting has been completed. Figure 5 schematically depicts the maximum microcomputer GIS configuration. The peripherals in the configuration can be added or deleted, depending on user needs and budgets. One major obstacle in

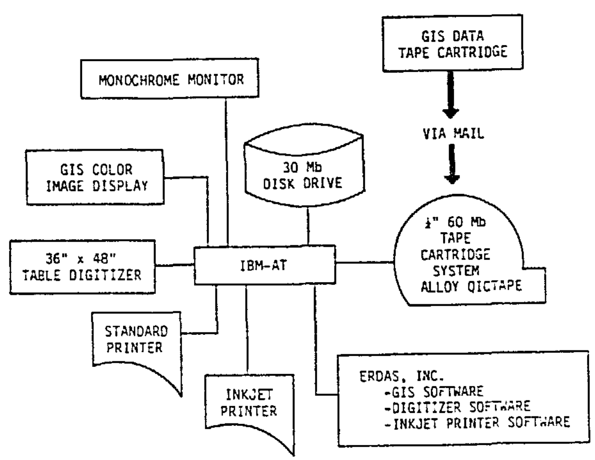


Figure 5

working with geographic data is the large data volume. A typical file exceeds 5 megabytes in storage space, precluding data transfer by floppy disk. Direct data

transfer to microcomputer by modem is currently not feasible due to expense and transfer times. Transfer through the mail on a medium was considered the most viable method. Nine track tapes are a standard data transfer method for mainframe computers and can be used in the microcomputer environment, but they are expensive and not used universally. Optical disks will eventually be the preferred method, but that technology has not advanced sufficiently. We are currently transferring data on 1/4 inch tape cartridges. The tape cartridge industry is not standardized, so transfer can only be accomplished on compatible tape drives. The system we chose was an file-oriented tape back-up unit. It can store up to 60 megabytes of data in separate files on standard tape cartridges. Data are transferred from the mainframe MRGIS via an RS232 serial interface to an IBM-AT. The data are reformatted during the transfer to conform to the GIS software used on the microcomputer. The data files are then transferred to the tape cartridges as DOS files and sent via mail to the field GIS.

As part of the pilot project, two commercially available, rastor-based micro-GIS's were installed, one at the East Central Florida Regional Planning Council and the other at an FDNR Aquatic Preserve in Naples, Florida. The ERDAS, Inc. GIS has a basic configuration that allows a color display of the data, various GIS manipulations, and data deletions and additions. Capabilities important to the basic system and available as separate additions are table digitizing and color inkjet printer hardcopy generation (see Figure 4). A commercial system was chosen because the careful software planning and design provide simple menu-driven access to the data. This puts the GIS within the realm of potential use by the resource manager.

The development of the MRGIS and the ability to transfer GIS data to microcomputers has been a technical success. Management utilization has not been fully assessed, but the initial results are encouraging. The East Central Florida Regional Planning Council (ECFRPC) used the micro-GIS to target wetlands requiring different levels of planning. Wetland cover for Brevard County, Florida, was developed on the MRGIS using LANDSAT TM data and downloaded to the ECFRPC. ECFRPC then used U.S. census tract populations and regionally developed population projections to create a data overlay of predicted changes in population densities throughout the county from the year 1985 to 2000. These projections were then weighted by density and analyzed with the wetland data in order to target wetlands of high to low potential for impact by population growth. This information can now be used in prioritizing wetland management in the growth management planning process. The FDNR micro-GIS in Naples, Florida, is being used to develop a comprehensive database on the Rookery Bay, Cape Romano, and Ten Thousand Islands Aquatic

Preserves. This database will be an extension of the type of overlays being developed for Tampa Bay. Again, the wetlands resources were developed on the MRGIS using TM data and downloaded to the Aquatic Preserve GIS. Additional resource data are being entered using a table digitizer capability. The micro-GIS will be the primary management tool for these Aquatic Preserves.

Conclusion: The Role of the MRGIS in Resource Management

MRGIS rastor database development and data dissemination by hardcopy and, more importantly, to microcomputer, have proven to be the techological success of the GIS concept. This strategy for data dissemination will also provide rapid access of large volumes of geographic data to the resource manager. The MRGIS, combined with microcomputer field systems, offers a desktop, user-friendly approach, with a color map-oriented display. This system allows resource managers to effectively utilize the best available data in resource planning and decision-making. We also plan to link geographically-oriented data with tabular data (such as fisheries statistics, boat licenses, and environmental permits) to provide state, regional, and local resource managers and planners with additional information regarding the use of natural resources.

Even though the MRGIS has been successfully tested in small scale management situations, the GIS concept may not be accepted or incorporated into management structure, primarily because upper level management lacks familiarity with GIS technology. Consequently, GIS development is not initiated at this level, but at the technical level, which often results in a minimal and inadequate commitment to develop a GIS.

The success of the MRGIS is attributed to definitive goals, established in its development, that were to (1) develop a spatial inventory of marine fisheries habitat using remote sensing technques, (2) determine and monitor trends in habitat change, (3) integrate ancillary data from a variety of sources as GIS overlays for fisheries management queries, and (4) demonstrate the potential of an image processing rastor-based GIS for research, management, and education. These goals currently govern the role of the MRGIS in management of Florida's coastal resources, but an interest in applying GIS techniques to many aspects of resource management is growing.

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Agenda for the 90's

ASPRS/ACSM 1989 AGENDA FOR THE 90'S
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TECHNICAL PAPERS

1989 ASPRS/ACSM ANNUAL CONVENTION

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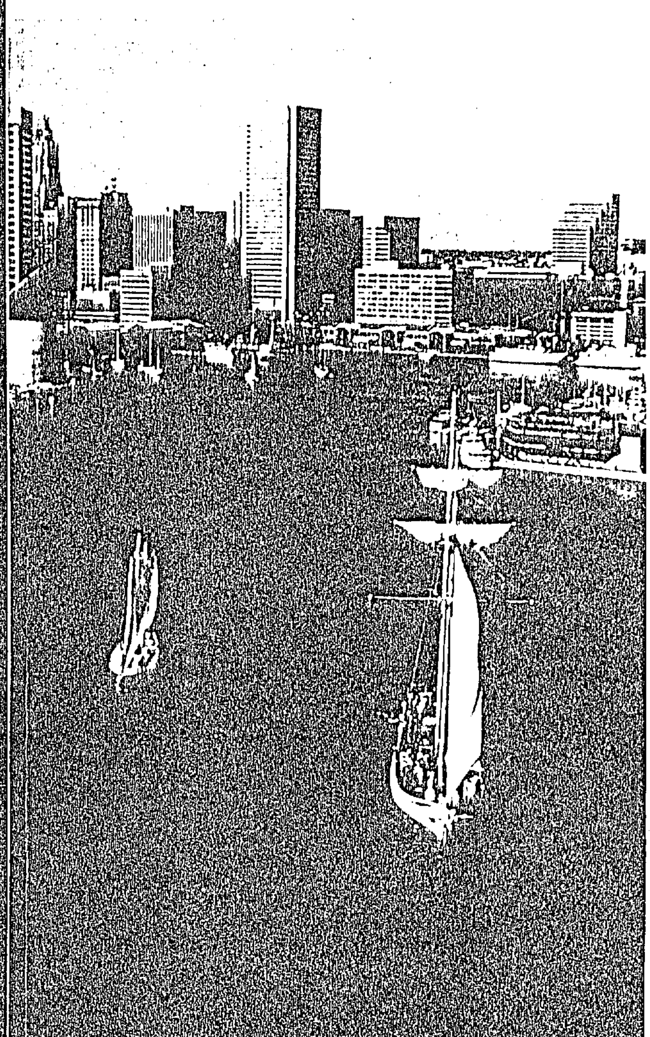

VOLUME 3

THE POTENTIAL USE OF SATELLITE IMAGERY FOR MONITORING COASTAL BEACH PROCESSES

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ABSTRACT

This study assessed the Tampa Bay and Panama City regions along Florida's Gulf coast, using multitemporal satellite imagery or a combination of satellite imagery and aerial photography, to determine the applications of digital image analyses in monitoring and quantifying changes in coastal geomorphology. Four Landsat Thematic Mapper (TM) images were compared for the Tampa Bay region (1982, 1984, 1985, and 1987). In the Panama City region, photointerpreted aerial photography from 1953, 1964 and 1980 were digitized and overlayed onto a 1986 geo-referenced TM base-map for comparisons. For all TM images, land/water interfaces were determined using TM Band 4 (0.76-0.90 um) geo-referenced data.

INTRODUCTION

Changes in beach morphology have long been used to aid in the understanding of beach processes. Numerous methods have been used to depict and quantify these changes. Beach profiling is the most conventional method and utilizes standard surveying techniques to provide highly resolved sets of transect data, such as beach width and topography. These data characterize the beach and provide erosion/accretion estimates (Fox, 1978). This time consuming method is not amenable to rapid, large area coverage and, depending on the spacing of surveyed areas, spatial resolution may not be adequate for mapping changes in morphology along a beach system.

Aerial photography also has been used as a tool for observing and quantifying changes in beach morphology (Williams and March, 1983; Leatherman, 1983). Aerial photography can be used both qualitatively from off-nadir photographs and quantitatively from flight controlled, vertical, cartographic-quality photographs. Although this approach does not achieve the accuracies of surveying, it allows repeated, spatially integrated, two-dimensional mapping.

McGarry and Doyle (1987) have used digital Landsat Thematic Mapper (TM) data to evaluate changes in coastal geomorphology for Pinellas County, FL, after the 1985 passage of Hurricanes Elena and Juan. Wells and Camp (1987) have used TM photographic products for monitoring inlet dynamics after a hurricane. In their study of Old Drum Inlet, NC, they determined that the spatial resolution and 16-day coverage cycle made TM data particularly useful in inaccessible areas or areas that had infrequent aerial photography coverage. They also suggested that an image processing approach to analyses may provide a better method for quantification of beach

processes.

With the current capabilities in image processing and the relative low cost of the necessary hardware and software, raster-based images have become an effective data source for many applications. Leatherman (1983) stated that satellites can provide repetitive synoptic information, but aircraft data remain the best tool for coastal studies because of the attainable spatial resolution. However, the improved spatial resolution of satellite imagery is increasing its potential use in coastal studies.

In this study, two areas on the Gulf coast of Florida (Figure 1) were assessed using satellite imagery or a combination of satellite imagery and aerial photography to determine the applications of image analyses in monitoring coastal geomorphology.

DATA ANALYSES

The Tampa Bay region on the central Gulf coast and the Panama City region on the northwestern Gulf coast of Florida were selectively analyzed for changes in beach morphology. Image analyses were conducted at the Florida Department of Natural Resources, Florida Marine Research Institute using the Earth Resources Laboratory Application Software (ELAS) developed by NASA (Graham et al., 1985).

Four Landsat TM images were compared for the Tampa Bay region and one TM image was compared to aerial photography for the Panama City region. A digital overlay process was used to place all of the corresponding images in a Universal Transverse Mercator (UTM)

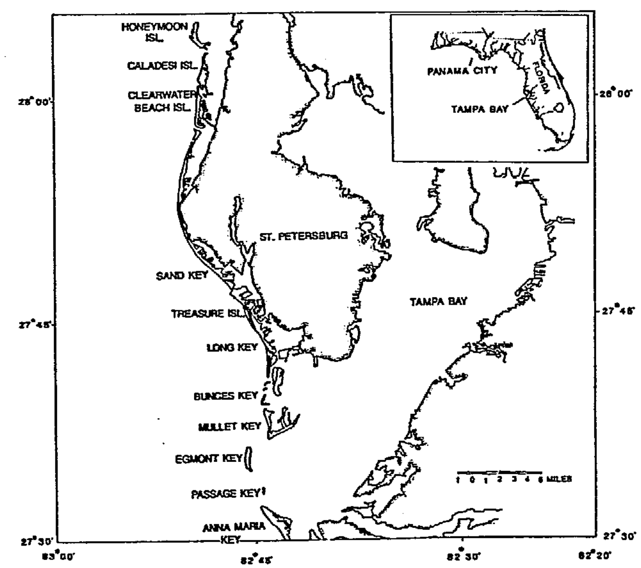

Figure 1. Gulf Coast of Florida study areas. See insert for location of Panama City.

projection relative to a TM base-map. Haddad and Harris (1986) have determined that Landsat TM images can be effectively used as base maps in a UTM projection with subpixel accuracies. Welch et al (1985) showed that properly rectified TM data can have residual errors that meet National Map Accuracy Standards (NMAS) at scales of 1:50,000 and smaller and can fall within NMAS for 1:24,000. For this study we used a TM image from each area as a 1:24,000 geo-referenced base-map each having subpixel residual errors. Control points were picked from U. S. G. S. 7. 5 minute quadrangles. A bilinear interpolation algorithm was used for the rectification process. The remaining Tampa Bay region TM images were then rectified to the base map also using a bilinear interpolation. For the Panama City area aerial photographs were photointerpreted and digitized as overlays to the TM base-map using a three control points scheme to develop a linear relationship for the table digitizing process. Acreage and distance calculations were from the UTM formatted overlays.

We made numerous attempts to develop an automated process for separating land and water (i. e. ratioing, cluster analyses, combinations of different spectral bands). Several techniques appeared promising, but the results always required subjective interpretation. We determined that a subjective land/water decision could be made by using the geo-referenced data in Band 4 (0. 76-0. 90 um). Band 2 (0. 52-0. 60 um) was used for submerged features and aided in the entire decision making process. By using Band 4, we took advantage of the high absorption of infra-red by water and the high reflectance of infra-red by beach sand. The land/water interface was chosen as the pixel value which appeared to contain a 50-50 split of land and water. It was assumed the high-water mark fell within those 30 x 30 meter pixels although this assumption would be less valid as beach slope decreased. Due to the high contrast between dry sand and water/wet sand, the cut-off points could be reasonably determined and provided a technique for comparing different images. This method was used only for high-contrasting beach interfaces and appeared to become less effective in lower reflectance (i.e. upland and wetland vegetation) water boundaries for some of the imagery. A weighted parallel-piped-like classifier applied to Bands 2 and 4 appeared to give the best over-all results for simultaneous high- and low-contrast analyses. Although not presented, ambient tide and weather conditions at the times of imagery collections were evaluated and considered not significant to the results of this particular study.

TAMPA BAY REGION

Four TM images were compared along a 70-km stretch of the Tampa Bay region coastline (Figure 1). Caladesi Island, Bunces Key and Passage Key are representative of measurable changes observed with the TM imagery.

Caladesi Island

Caladesi Island was formed when Hog Island was breached by a hurricane in 1921 to create two separate islands. Rosen (1976) illustrated historic changes of Caladesi Island (Figure 2) and concluded that (1) long-term spit accretion and progradation were the dominant processes controlling the northern terminus of the island, (2) the area immediately south of the prograding spit was continuing its eastern migration with net strandline retreat, and (3) low energy conditions produced no seasonal variation in beach morphology.

Examination of Landsat TM imagery from July 1982 (Figure 3) indicates that Caladesi Island had changed considerably from its 1975 position (Figure 2). In that seven-year period, beach ridge progradation had broadened the southern end of the island. Thinning of the island just south of the northern prograding spit, as described by Rosen (1976), had also continued. These trends continued, as evidenced by the 1984 imagery. Marked changes in Dunedin Pass, resulting from the northward extension of Clearwater Beach Island, were also visible.

In late August and late October 1985, Hurricanes Elena and Juan impacted the Tampa Bay region. During Elena, the peak significant wave height was recorded at +8. 2 feet with maximum storm surge estimated at +4. 6 feet mean sea level (Bodge and Kriebel, 1985). The northern spit of Caladesi was breached and a tidal inlet, known as Willy's Cut, was formed. In late October, Hurricane Juan minimally affected the Tampa Bay area with tides 1-3 feet above normal.

In the 1985 TM imagery, acquired ten weeks after the passage of Hurricane Elena and just two weeks after Hurricane Juan, Willy's Cut was not apparent although a resultant washover fan was clearly evident (Figure 3). A general thickening of the severed spit was also noted in the 1985 scene. The significant gain in area between 1984 and 1985 can be attributed to material deposited on the seaward portion of the tip (by longshore transport) and on the washover fan. By the April 1987 TM scene, Willy's Cut had widened and deepened, and a second breach had appeared just north of Willy's Cut. The net loss of acreage in the 1987 scene was from the widening of Willy's Cut, the creation of the second pass immediately to the north, and the loss of emergent sand built up by Hurricane Elena.

Bunces Key

Bunces Key is a narrow, linear, barrier island formed by vertical aggradation in 1961 (Crowe, 1983). Crowe depicted the dynamics of the area between 1957 and 1983 (Figure 4).

Bunces Key has continued to be a dynamic barrier island as seen in TM imagery from the 1980's (Figure 5). In the 1982 and 1984 images, the Key appeared similar to the March 1983 morphology described by Crowe (1983), including a breach that divided the island. In the 1984 image, a small island just landward of the barrier island was connected to the feature. The 1985 scene, however, was markedly different. Several new shoal islands were evident in the vicinity of the Bunces Key breach. The pass that had separated the north and south segments of Bunces Key appeared to have migrated to the north. This migration was at the expense of the lower tip of the northern segment. The northern spit of the southern section had been extended with accretion occurring along that segment.

By the spring of 1987, this dynamic barrier island had changed again (Figures 5 and 6). Shoal islands that had appeared after the 1985 hurricane season had been eroded. The northern segment of Bunces Key was eroded relative to its 1985 state, and breaching of the southern segment had also occurred, essentially dividing Bunces Key into northern, mid, and southern segments.

Passage Key

Passage Key, a National Wildlife Refuge at the mouth of Tampa Bay,

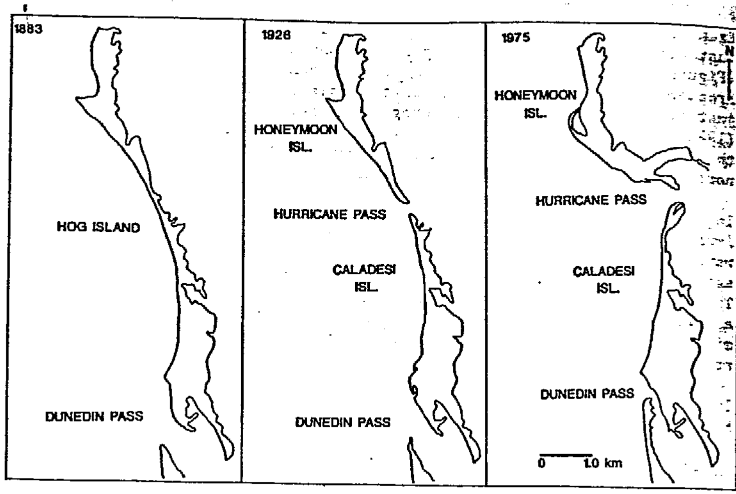

Figure 2. Historic changes of Caladesi Island, FL 1883-1975 after Rosen (1976).

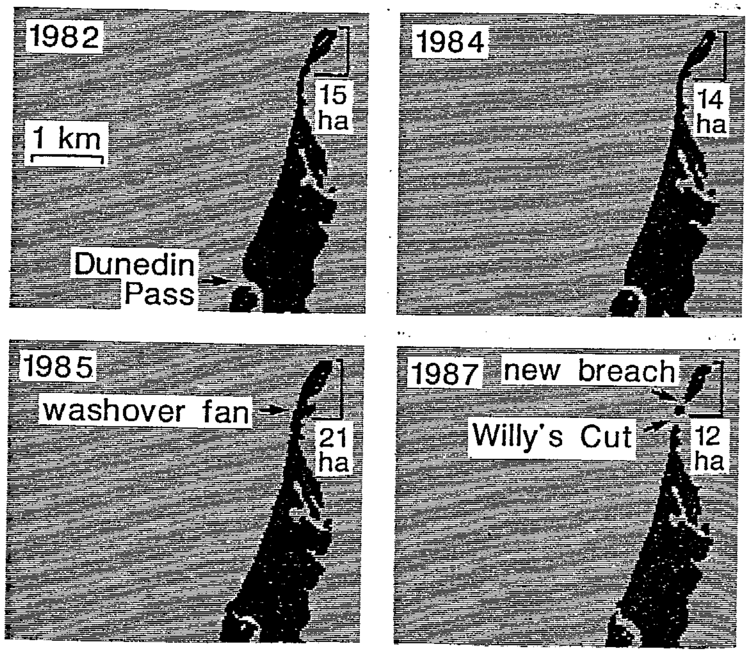

Figure 3. Morphological changes of Caladesi Island, FL determined from TM imagery.

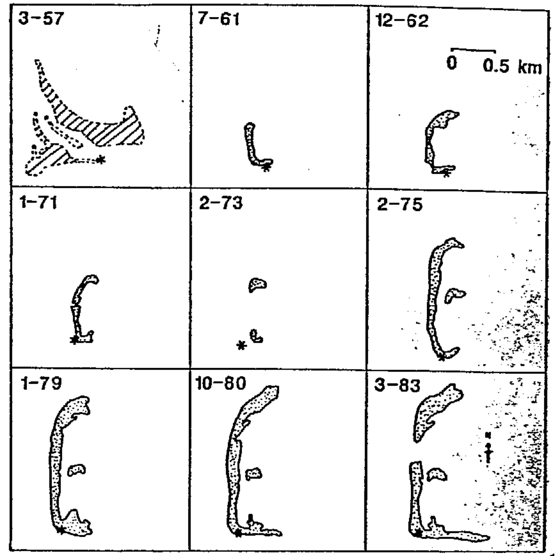

Figure 4. Historic changes of Bunces Key, FL 1957-1983 after Crowe (1983).

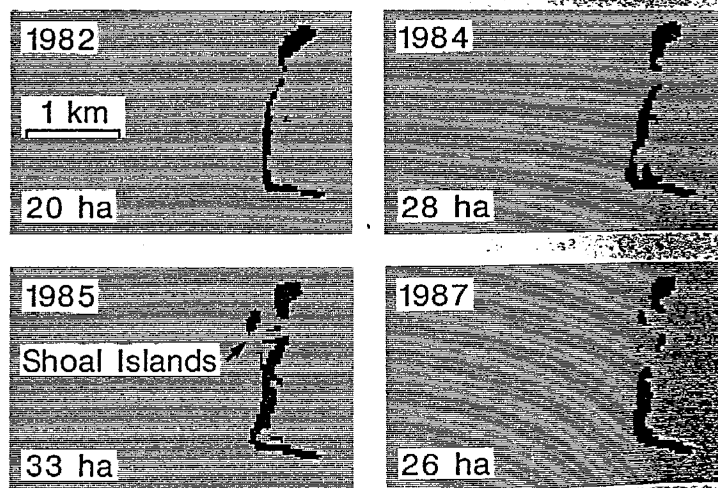

Figure 5. Morphological changes of Bunces Key, FL determined from TM imagery.

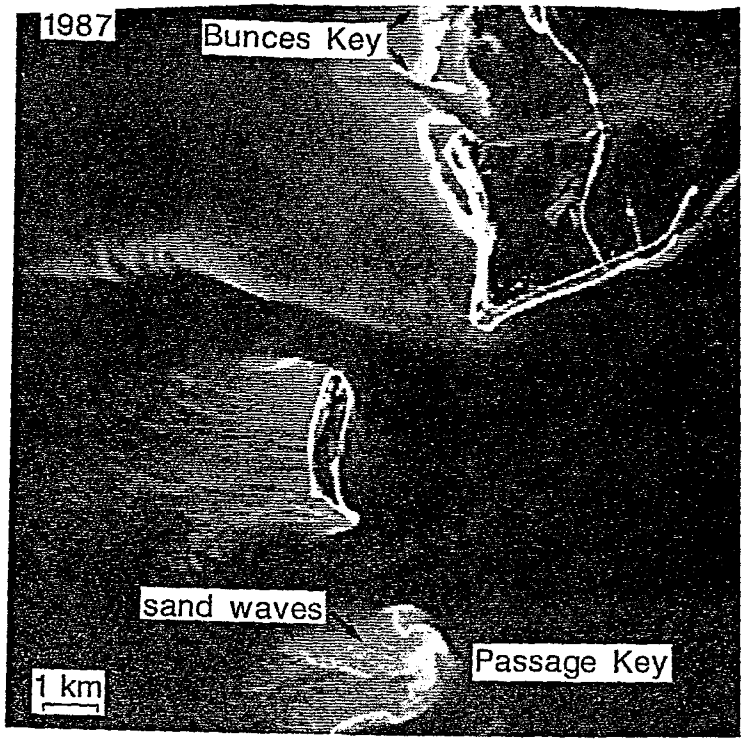

Figure 6. 1987 Landsat TM imagery (Band 2) Bunces Key to Passage Key, FL.

has received little morphological study. Hurricanes in 1848 and 1921 washed the small island away. In the 1980s, Passage Key exhibits sand wave features superimposed on the major tidal delta system (Figure 6). Sand fields are present on both the Gulf and Bay sides indicating the ebb and flood tidal nature of the area. Figure 7 depicts the morphological changes of Passage Key since 1982. The significant gain in area between 1984 and 1985 can be attributed to sand deposited by the hurricanes. By 1987, currents had eroded the north and south ends of the islands. Although emergent acreages for 1982, 1984, and 1987 were very similar, the island's morphologies were very different: the island shortened by approximately 600 meters. The results of an analysis of the overlayed imagery (see Figure 7) depict an area of Passage Key that has remained unchanged since 1982 and appears to be the pivot point for island migration.

PANAMA CITY REGION

Figure 8 depicts changes at the southern tip of Shell Island, at the mouth of St. Andrews Bay, near Panama City, Florida. The 1953, 1964, and 1980 aerial photographic data of Shell Island have been digitized as overlays to the 1986 TM data while the mainland area is 1986 data

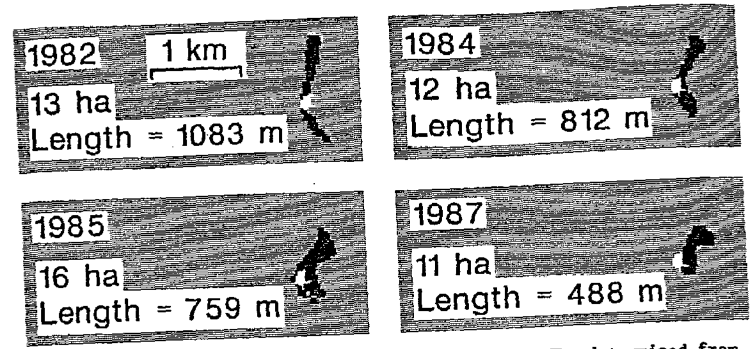

Figure 7. Morphological changes of Passage Key, FL determined from TM imagery. White = unchanged emergent area.

for all four time periods. By examining the morphology along the mainland side of the island, the preservation of unchanged features in the photography and the TM data are apparent. Shell Island lengthened by 1,374 meters and increased in area by 93 ha since 1953. Growth has been parallel to the mainland, toward an extension of the mainland at 68 m/yr and, at that rate, could be expected to connect to the mainland by the year 2001.

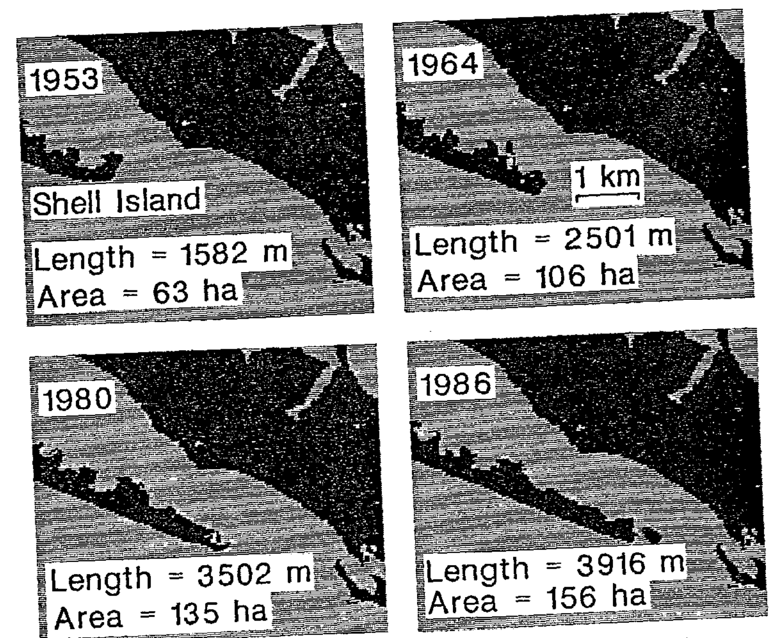

Figure 8. Morphological changes of the southern portion of Shell Island near Panama City, FL.

CONCLUSIONS

The ability to digitally enhance and overlay multitemporal satellite images and aerial photography has increased the potential for rapidly quantifying changes in both mesoscale and local beach morphologies. This was not practical until high resolution Landsat Thematic Mapper data were available. With the increasing resolution of satellite images (e. g., SPOT) and increasing coverage, the use of digital imagery will become more important. Cost of data will always be a factor in any type of routine monitoring, but the data content of the imagery can serve many other needs and multipurpose uses for the data are recommended.

We have successfully identified and quantified changes in beach morphology along selected portions of a 70-km stretch of the Tampa Bay region using Landsat TM data. The same success was evidenced in the Panama City region. Even though Florida's west coast is one of low to moderate energy, substantial changes do occur.

ACKNOWLEDGMENTS

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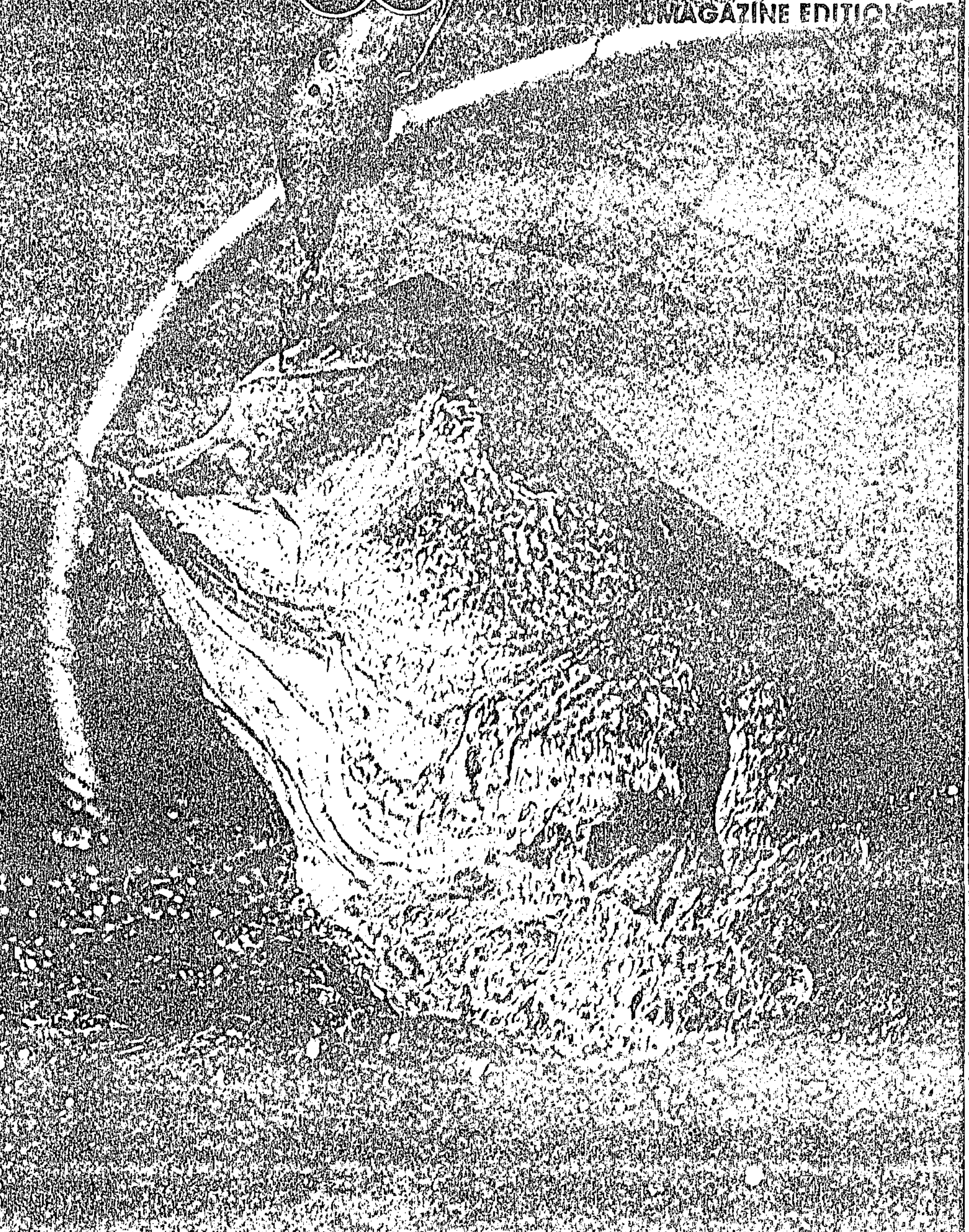

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TROPHY BUCKS IN THE 1990s

Rich Bay, Poor Bay

An exclusive profile of Tampa Bay: how rich in resources it is, and how richly it has been robbed.

by Beirne Keefer

(**Editor's Note:** This article is the first in a three-part series on the fishing resources of Tampa Bay.)

When Ponce De Leon "discovered" it in 1513, he learned that the Timucuan Indians called it Tampa Bay. Taking up 426 square miles smack in the middle of Florida's Suncoast, this bay contains the greatest diversity and abundance of marine life recorded for any bay between the Chesapeake in Maryland and the Laguna Madre in Texas.

The estuary system, forming a "Y"-shape about 35 miles long and 10 miles wide, didn't suddenly appear after crashing waves and windswept rain lashed the earth. Instead, it was gouged slowly during the Great Ice Age as the seas silently rose and fell and rose again.

About 10,000 years later, Tampa Bay is modest in appearance and quiet in demeanor.

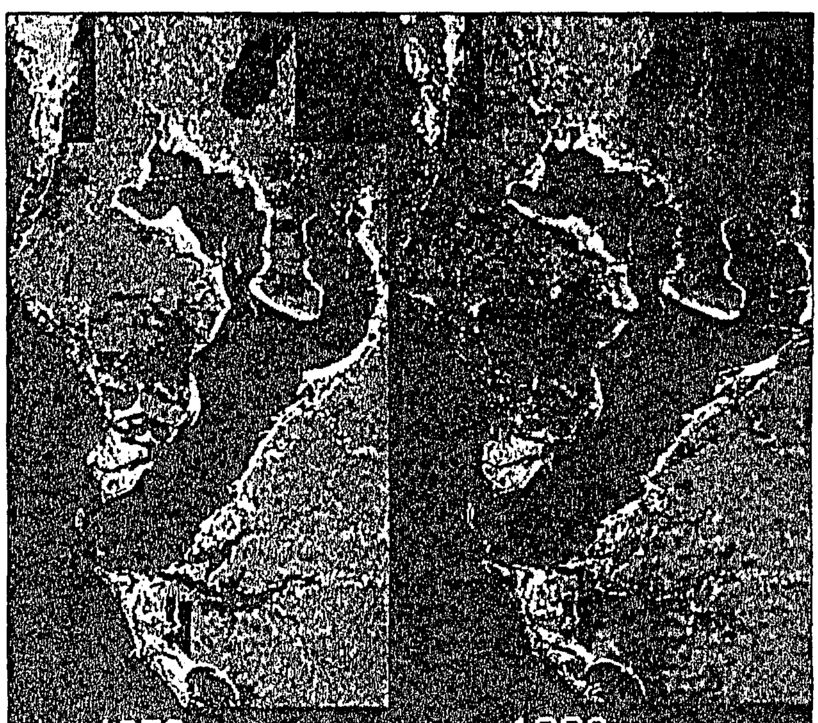
The estuary system is made up of five bays. Old Tampa Bay lies to the north, with Hillsborough-McKay Bay to the east. The broad valley forming the system's midsection is named Tampa Bay Proper. Boca Ciega and Terra Ceia bays link it with the Gulf of Mexico.

Joined, the individual bays form a shallow body of water with an average depth of 11 feet. Tampa Bay is a major seaport, though, and the bottom is a maze of deep-water channels. Forty-two miles of channels have been dredged in depths from 20 to 57 feet deep.

Tampa Bay draws nutrient-rich fresh water from a 2,161-square-mile mass of land hugging its shores. After large rivers like the Hillsborough, Manatee and Alafia, and creeks as small as Sweetwater, Rocky and Double Branch pour in a daily dose of 1 billion gallons, the bay estuarine system gives it one final mix and tumble before releasing the water to the outgoing tide and the Gulf.

An acre of Tampa Bay's estuary out-produces, many times over, an acre of farm land. From rooted plants on shore to submerged seagrass waving in the currents, this sytem is the nursery ground for more than 80 percent of the commercial and recreational fish species, as well as the oysters, clams, shrimps and crabs, produced on Florida's Suncoast.

(Continued)



This before (1950) and after (1982) photo series of the bay is not a pretty picture. The colors to note in the enhanced satellite shots are red (urban), light blue (seagrass), pea green (range/forest), light yellow (salt marsh), dark yellow (agriculture) and white (flats). Note the loss of seagrass and the increase of urban areas. Photo courtesy of the DNR Marine Research Inst., St. Petersburg.

Spend a weekend traveling the bay's 212 miles of shoreline and you can catch a 1-pound fish next to someone struggling with a 100-pounder. You can spend an afternoon on the shores of the Sunshine Skyway digging for clams while fishermen throw nets over vegetation-eating mullet. You can swim at the public beach on Courtney Campbell Parkway near anglers wading the grassflats in search of speckled trout.

You can do all this, and you still will see only a small fraction of all there is to see and experience on this grand lady of estuaries.

Fishermen who made their living on the bay before a boom of civilization altered its character tell stories of drift-fishing from Gulfport westward to Pass-A-Grille to catch 7-pound speckled trout on topwater plugs. They speak about a place called the Bird Key Middle Grounds, where deep-water varieties of fish such as grouper could be caught along with redfish and flounder.

(**Note:** Over the next several months in this three-part series on Tampa Bay, these veteran anglers will talk about how to fish Tampa Bay's three sections — the upper bay, the middle section and the lower bay. They'll share secret fishing spots, and discuss the best baits and methods to catch fish on the bay.)

The Bird Key Middle Grounds used to be located in the southern section of Boca Ciega Bay. But it disappeared long ago under tons of fill used for housing developments and the Bayway highway system.

Still, Tampa Bay means different things to different people. Ken Haddad, for instance, looks at Tampa Bay from a different perspective.

Haddad is the environmental administrator for Tampa Bay and its 2,000-plus-square-mile watershed. He has worked with the Florida Department of Natural Resources' Marine Research Institute, Bayboro, for 10 years, studying the environment and ecological make-up of the bay.

Using a NASA satellite orbiting 316 miles above Earth, he spends hours pouring over miles of highly technical computer tape information reporting on the bay's stresses and strains, the gouges and rips, and the thousands of acres of barren bay bottom where seagrasses and mangroves once grew.

"The problems with Tampa Bay started with the invention of air-conditioning," Haddad says. "Before that, few people from the North could live here, because of the intense heat."

With air-conditioning to make the heat bearable, hordes of people from the North migrated to the Suncoast. They needed houses, apartments, jobs and municipal services. Areas were dredged to provide landfill to build homes; dikes were built for bridges to link population centers; deep-water channels were dug to open the port to international trade.

St. Petersburg's Mark Rutan shows a Tampa Bay sea trout. The species is just one resource that has suffered from the "civilization" of the bay shoreline. Photo by Beirne Keefer.

Hundreds of commercial shrimpers, gill-netters and crabbers were lured to the bay's rich harvest by the public's demand for seafood. Using equipment that ripped up seagrass and boats with propellers that tore out chunks of bottom, they daily harvested tons of marine life from the bay to meet the needs of the marketplace.

The bay, strained by civilization along its shoreline, deteriorated.

"The result of all this growth is a documented loss of 60 percent of the seagrass and 45 percent of the mangroves, since 1950," Haddad states.

As the shoreline and bottom structure were modified, the water quality decayed due to industrial and municipal nutrients pouring in from unfiltered storm-water runoff and minimally treated human and industrial waste.

According to Haddad, the Hillsborough-McKay Bay areas have been pollution sinks for industrial, domestic and agricultural wastes, and are the areas most affected by urban and industrial growth. "The total shoreline of these bays has been altered," he says.

Boca Ciega Bay is recognized as being one of the most modified bays in the United States. Citing a 1976 report by the Department of Natural Resources, Haddad points out that almost every source imaginable has caused problems to the bay's water quality. Since hydraulic dredging was brought to Florida in the mid-1950s, about 3,000 acres of this bay have been filled or diked for development.

Thirty years later, the destruction of Boca Ciega Bay from dredging, filling, diking, urban runoff and domestic and industrial waste has resulted in a 70 percent loss of marine nursery and rearing areas.

Another factor that hurt bay resources: The four major bridges and parkways altered the tidal flow. This brought on silting, which destroyed large sections of fish habitat. And with a population bulging on the Tampa Bay shores, a few fishing areas simply disappeared under dirt fill.

Some of the bay's marine life, desperate to survive, has changed habits to cope with the changing character. Others, like scallops, became extinct in Tampa Bay.

But, Ken Haddad has hope, and good reasons for it.

"The bay is holding its own, now," he says. "I'm confident we've turned the corner on degradation. The water quality has improved; it's no longer in a declining mode.

"Still, it's going to take a lot of money — billions — to correct problems we've caused. And, it's going to take strong public opinion to get the movers and shakers in Florida to get the job done."

(Note: In next month's part 2 of the Tampa Bay series, we'll visit with some people who've made the upper, middle and lower sections of Tampa Bay their personal fishing grounds. They'll share fishing secrets — and fishing spots — few people know about, such as Old Bay Reef, Airplane Rock, the Old Oak Tree and Fisher Island. Those bay hotspots, and more, will be explored in the next issue of ***Florida Game & Fish.***) □

Task III: Carrying capacity and habitat utilization.

CARRYING CAPACITY

Gear Testing

This activity continued during 1988 with an emphasis on quantitative methods for sampling juvenile and small adult demersal and semidemersal fishes in seagrass beds. Six gear types (1 m^2 roving dropnets; 1 m^2, 2 m^2, and 4 m^2 tripod dropnets; otter trawls; and roller frame trawls) were compared for species density and diversity. Gear descriptions can be found in the 1986 and 1987 Annual Reports.

Data indicated obvious differences among our six gear types in fish species selectivity and density/diversity estimates. Percentages of demersal species were higher for dropnets than for trawls, and pelagic species were not captured by the 1 m^2 tripod dropnet or the roller frame trawl (Fig. 1). In fact, relatively few pelagic species were captured by any of the gears tested. Dropnets produced much higher density and diversity estimates than did trawls (Fig. 2). Underestimation of the numerical importance of demersal fishes in seagrass communities based on trawl data has been suggested in other studies (e.g., Leber and Greening, 1986). Among the dropnets tested, the 1 m^2 roving dropnet produced the highest estimates of both fish density and diversity.

Based on these data as well as comparisons with previous studies (Hellier, 1959; Hoese and Jones, 1963; Moseley and Copeland, 1969; Kushlan, 1974, 1981; Kjelson et al., 1975;

Gilmore et al., 1978; Freeman et al., 1984; Jacobsen and Kushlan, 1987), we consider dropnets to be capable of producing quantitative estimates of both diversity and density of demersal and semidemersal fishes. Because of the performance of the roving drop nets and the possible bias that may be introduced by supporting structures (Moseley and Copeland, 1969; Gilmore et al., 1978; Freeman et al., 1984), we will use the roving dropnet for future density and diversity estimates.

Standard methods were developed for retrieving organisms captured by the 1 m^2 roving dropnet. All organisms were removed by making several sweeps through the enclosure with a 1 m^2 seine. Tests conducted to determine the number of sweeps necessary to remove all of the enclosed organisms revealed that 10 sweeps were sufficient (Fig. 3).

Pelagic fishes present a different set of sampling problems from those presented by demersal and semidemersal species (Kjelson and Johnson, 1975; Gilmore et al., 1978; Clarke 1983). The dominant fishes in this group (e.g., Clupeidae, Engraulidae, Atherinidae) tend to be fast-swimming, schooling species which can avoid many gear types and exhibit clumped distributions. These characteristics necessitate the use of gear which can be towed rapidly or can be used to rapidly enclose a large area. In either case a large volume of water must be filtered.

Two types of sampling gear are being tested to sample pelagic fishes as a compliment to the dropnets. First, a 91 m purse seine was modified as a long-haul seine (sensu Kjelson and Johnson, 1975) and tested in Cockroach Bay. Feasibility testing proved successful, and additional long-haul seines are being constructed for further testing. Second, a bow-mounted pushnet was designed for use with existing vessels. Kriete and Loesch (1980) reported that such nets captured 27 times more fishes than standard trawls.

Thus, our future estimates of the carrying capacity of open water estuarine habitats will depend on a combination of roving dropnet samples for demersal and semidemersal species and either long-haul seine or pushnet samples for pelagic species. We are also examining techniques for quantitative sampling in fringing habitats such as mangrove and/or _Juncus_ marshes.

Density Estimates:

The grassbeds of Cockroach Bay Aquatic Preserve were sampled approximately monthly throughout the year using 1 m^2 roving dropnets. Twenty samples were collected on most dates. No samples were collected during April and June because of damage to the dropnet structure. Samples were returned to the laboratory where individuals were identified, measured, and weighed. All data were entered into SAS (SAS Institute, Inc., Cary, NC) data sets using full screen edit application programs.

Thirty four species and three multi-specific groups were identified from the 296 samples examined (Table 1). The latter groups consist of two or more similar species that are not readily separated as juveniles: _Brevoortia_ spp., probably including _B. smithi_ and _B. patronus_ (Springer and Woodburn, 1960); _Eucinostomus_ spp., including _E. gula_ and _E. harengulus_

(Matheson, pers. obs.); and Monacanthus spp., probably including M. hispidus and M. ciliatus (Springer and Woodburn, 1960).

Two other studies employing enclosure traps in the seagrass beds of Florida estuaries indicate a somewhat greater ichthyofaunal similarity between Tampa Bay and similar latitudes on the Atlantic coast of Florida (Indian River Lagoon) than between either of these two areas and the southern tip of Florida. Fishes occurring in densities as great as 1 m^{-2} during any month of our study included the following (range of monthly mean densities for each species in parentheses): Lagodon rhomboides (0-8.4), Gobiosoma robustum (0-4.9), Anchoa mitchilli (0-3.6), Lucania parva (0-2.6), Syngnathus scovelli (0.6-2.3), Bairdiella chrysoura (0-1.7), Eucinostomus spp. (0-1.2), and Symphurus plagiusa (0-1.0). Gilmore et al. (1976, 1978) found a similar suite of dominant species in the Indian River Lagoon with no differences in the top three species based on density. Sogard et al. (1987), however, found a quite different group of dominant species in Florida Bay with the relative scarcity of Lagodon rhomboides being the most striking difference. This pattern must be interpreted with caution, however, due to differences in gear and methodologies among the three studies.

A similar group of dominant species was evident based on percent frequency of occurrence over all drops. The following species occurred in more than 15% of the dropnet samples (percent frequency of occurrence in parentheses): Syngnathus scovelli (59%), Lagodon rhomboides (53%), Gobiosoma robustum (52%), Symphurus plagiusa (22%), Chasmodes saburrae (18%), and

Bairdiella chrysoura (18%). Presentation of the data in this format obviously decreases the importance of schooling species with clumped distributions (e.g., *Anchoa mitchilli*) and increases the importance of some demersal species with more uniform distributions (e.g., *Chasmodes saburrae*). This trend is also illustrated in the data set presented by Gilmore et al. (1976; 1978) for seagrass communities in the Indian River Lagoon. In that study *Anchoa mitchilli* ranked first in terms of density and sixth in terms of percent frequency of occurrence.

Seasonal trends in fish density were obvious for the community as whole as well as for individual species. Density estimates for individual samples varied between zero and 65 fish m^{-2}, and monthly average densities were higher (8.6-15.2 fish m^{-2}) from February through June and lower (3.4-7.7 fish m^{-2}) from July through January (Fig. 4). Data for one of the dominant species, *Lagodon rhomboides*, revealed pronounced seasonal density changes indicating the period of juvenile recruitment to the study area (Fig. 5). The observed trends for pinfish (high densities beginning in January and peaking in March with a precipitous decline thereafter) are similar to those observed in other studies conducted in Florida seagrass beds (e.g., Gilmore et al., 1976). Other species of fish found in Florida seagrass beds range from seasonal inhabitants (often utilizing the habitat as a nursery area) to permanent residents (Gilmore, 1987). Also, many of these species are economically valuable (e.g., snook, *Centropomus undecimalis*; various sciaenids including spotted seatrout, *Cynoscion nebulosus*). Nevertheless, there is little quantitative information regarding the utilization of this habitat by fishes in Tampa Bay (Lewis, 1989). A long term data base is necessary to determine the rates of utilization of seagrass by various species and to determine habitat carrying capacity while taking into account seasonal and interannual patterns of variation. Furthermore, gear selective for pelagic species is needed in order to develop a more complete picture of the seagrass fish community.

HABITAT UTILIZATION:

The Little Manatee River (LMR) was sampled approximately biweekly beginning on 26 January 1988. Fishes were sampled using a 22.7 m seine (3.2 mm mesh) and a 3.6 m otter trawl (3.2 mm mesh bag). Three sites were sampled at each of six stations for a total of 36 samples on each sampling date (total = 898). Station locations ranged from the mouth of the river (Station 1, Fig. 6) upstream to permanent freshwater (Station 6, Fig. 6). During the twelve month period covered in this annual report, 423,539 individuals, representing at least 98 species, were collected identified and measured.

Water temperature, salinity, dissolved oxygen (DO), and pH were determined at each station on each sampling date using a Hydrolab Surveyor II. Turbidity, irradiance, and chlorophyll concentrations were also measured at each station. All irradiance values are expressed as Quanta sec^{-1} cm^{-2} x 10^{15}; these units are omitted from the values presented below. All physical and biological data, January to December 1988, were coded using dBase III application programs and transferred as ASCII text files to the DNR mainframe computer for data verification and analysis.

In the discussion presented below, fish community data is treated mainly as rank or presence/absence data. This is due to the fact that sampling methodologies for this portion of the study (as well as physical habitat differences among sample sites) did not allow detailed quantitative comparisons among stations.

RESULTS

Station Descriptions and Physical data

Station 1, Sites 1A and 1B - These sites are located at the mouth of the LMR (Fig. 6) and are the highest salinity stations (range 7.8-28.1 ppt, Fig. 7a). They are also the only sites where seagrass beds were sampled. Although five species of seagrass occur in Tampa Bay (Lewis et al., 1985), *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii* dominate the grassbeds of lower Tampa Bay. The shoreline at both sites is occupied by red (*Rhizophora mangle*), black (*Avicennia germinans*), and white (*Laguncularia recemosa*) mangroves.

All physical data were collected in the channel adjacent to site 1A (mean depth = 1.74 m). Bottom salinities were generally high from January through July but decreased sharply during August and remained relatively low through December (Fig. 7a). Surface salinities displayed a similar pattern with the exception of sharp decreases in January and March. These patterns are a result of normal seasonal changes in freshwater input due to the meteorological patterns of the area (see Flannery 1989) coupled with two isolated periods of increased precipitation (in January and March). Temperature ranged from 12.2^{o} C in January to 29.4^{o} C in August with little or no difference between surface and bottom values (Fig. 7b). Dissolved oxygen decreased fairly steadily from February (7.33 ppm) to August (3.73 ppm) and then increased to 8.66 ppm in early November (Fig. 7c). Again, there was little difference between surface and bottom values. These DO values displayed the expected inverse relationship with temperature. At this site pH values generally declined throughout the year and were similar at surface and bottom (Fig. 7d). Irradiance values were uniformly quite low at the bottom, but generally fluctuated between 14 and 122.3 at the surface (Fig. 7e). Turbidity values generally remained at or below 3 NTU but exhibited two strong peaks during the summer months and another in December (Fig. 7f).

Station 1, Site 1C - The seine haul at this site covered a sand/rock substrate on the bay side of Bird Key. The trawl was towed through the channel on the east side of the island (Fig. 6). Shore vegetation consisted of sparce black mangrove and Australian pine.

All physical data were collected in the channel (mean depth = 1.62 m). As expected, salinity values followed similar trends to those at site 1A but with a somewhat smaller decline in January and March and a slightly greater decline from August through December (Fig. 8a). Temperature, DO, and pH values were nearly identical to those at site 1A (Fig. 8b, c, and d). Surface irradiance values again displayed wide fluctuations (24.6-159.6; Fig. 8e), but more light occasionally reached the bottom than at the previous site.

Station 2, Site 2A: This site is on the north side of Goat Island where the river cuts deeply into the island creating an erosional bank and steep shore (Fig. 6). The primary shoreline vegetation is scrub palmetto and upland grasses with a few overhanging trees. Seining was conducted along the north bank over a sand bottom. All trawls were fished, and physical data collected, in the channel adjacent to shore (mean depth = 1.89 m).

Salinity values were generally somewhat lower than those at Station 1 (ranging from 0.1 ppt in late August to 25.3 ppt in late June) but indicated the same seasonal trends (Fig. 9a). Also, vertical salinity stratification was less pronounced at this station. Temperature range (13.2^{o} C in January to 29.5^{o} C in August) and seasonal trends were quite similar to those at Station 1 (Fig. 9b). Dissolved oxygen values (Fig. 9c) followed the same seasonal pattern and covered nearly the same range (3.59-8.20 ppm) as at Station 1 but displayed a sharp decline at the bottom in early March. Site 2A values for pH displayed a similar pattern to those at Station 1 but often ranged somewhat lower (fluctuating around 7; Fig. 9d). Surface irradiance values ranged from 0.1 to 143 with measurable amounts of light reaching the bottom on several occasions (Fig. 9e). Turbidity generally fluctuated between 2 and 5 NTU but exhibited strong peaks in January and August (fig. 9f).

Station 2, Site 2B: This site is located at the mouth of Ruskin Inlet (Fig. 6). Seine samples were collected over an unvegetated sandy bottom; otter trawls were towed in the river west of the inlet mouth. Shore vegetation consists of mixed mangrove and scrub palmetto.

All physical data were collected in the channel adjacent to site 2B (mean depth = 2.33 m). Salinity was nearly identical to that at site 2A (0-23.9 ppt; Fig. 10a). Temperature values were generally similar to those at site 2A with the exception of a sharp drop in at the surface in March. The latter value is responsible for the broader overall temperature range recorded at this station (7.9-28.8° C; Fig. 10b). Dissolved oxygen values were also essentially the same as those at site 2A but did not include the sharp decline recorded in March at the latter site (Fig. 10c). Values for pH were similar to those at site 2A, again fluctuating around 7 (Fig. 10d). Surface irradiance values again displayed wide fluctuations (0.1-146.0) with measurable amounts of light reaching the bottom on a few occasions (Fig. 10e).

Station 2, Site 2C: This site is located within Ruskin Inlet (Fig. 6), a relatively heavily populated area of the LMR. The seine samples were collected over a sand/mud bottom at one of the few exposed shores within the inlet. Trawling was done over silty substrate in the middle of the inlet. This substrate had the highest silt content of any of our trawl stations, and net clogging led to aborted samples on several occasions. Most of the shoreline is armored, and vegetation consists mostly of well-manicured lawns.

All physical data were collected in the inlet (mean depth = 2.17 m). The seasonal salinity pattern evident at previous sites was again present at site 2C, but, in contrast to sites 2A and 2B, salinity stratification was often pronounced (Fig. 11a). Overall salinity range was from 1.3 to 24.6 ppt, but bottom salinity never dropped below 10 ppt. Temperature stratification was generally not evident, and seasonal patterns were similar to those at previous stations (Fig. 11b). The overall temperature range (13.6-36.6^{o} C) is somewhat exaggerated by a single high value in August. Fluctuations in DO were greater than at other sites (Fig. 11c). Bottom waters were nearly anoxic in March and again in August-September. Conversely, values for surface waters were often relatively high (>8 ppm) compared to other stations and rarely dropped much below 5 ppm. As at previous sites, pH values showed a general decline through the year, but there was a somewhat greater tendency for values at the bottom to be lower than those at the surface (Fig. 11d). Surface irradiance fluctuated between 17.2 and 127.6, but bottom irradiance was seldom above 0 (Fig. 11e).

Station 3 - The river is narrow (<30 m) at this point and at all stations further upstream (Fig. 6), therefore, physical data were collected once for each station (Stations 3-6). The south bank of the river at Station 3, adjacent to Sun City Heritage Park, is quite steep with a cliff of approximately 10 m in height. The bottom slopes rapidly to the channel. Shoreline vegetation consists mainly of upland grass and pine. The north bank has as gentler slope and a mud substrate. Shoreline vegetation is mostly mangrove. Two seine hauls were conducted along the north shore and one along the south shore. Trawling was conducted in the channel.

All physical data were collected in the channel (mean depth = 2.83 m). Salinity stratification was minimal at this station, and the same seasonal pattern as seen at previous stations was still evident (Fig. 12a). Salinities were generally somewhat lower than at Station 2, ranging from 0.0 to 22.0 ppt. There was little temperature stratification, and the range and seasonal pattern of variation were similar to those at previous stations (Fig. 12b). The seasonal pattern and range of DO values was also similar to most previous stations with elevated values from fall through early spring and depressed values from late spring through summer (Fig. 12c). There was some tendency for bottom DO values to be lower than those at the surface. The pH remained relatively constant throughout the year (both surface and bottom), values remaining within +/- 0.5 of 7 (Fig. 12d). Surface irradiance fluctuated between 13.8 and 132.0, and values at the bottom were >0 only on a few occasions (Fig. 12e). Turbidity values generally fluctuated between 1 and 4 NTU but increased sharply in January and August (Fig. 12f).

Station 4 - This station is located adjacent to the Interstate 75 bridge (Fig. 6). The south bank of the river at this point is quite steep with deep (>2 m) water close to shore. The north bank slopes more gradually. Shore vegetation consists of black needlerush (*Juncus roemerianus*) and other grasses, and the bottom is unvegetated with silt and patchy sand substrate. Two seine hauls were conducted on the south shore (one upstream and one downstream of the bridge) and one on the north shore (downstream of the bridge). All trawls were pulled in the channel.

All physical data were collected in the channel on the south side of the river (mean depth = 2.7 m). The seasonal trends in salinity observed at Stations 1-3 were also somewhat evident at Station 4, but the much reduced salinity range (0-13.9 ppt) masked some of the smaller seasonal oscillations (Fig. 13a). The temperature and DO ranges and patterns of variation were quite similar to the preceding stations (Fig. 13b and c). Values for pH (Fig. 13d) were fairly stable at or around 7 for much of the year but rose to 8 or above in October-December (the opposite trend was seen at Station 1, and no parallel trend was seen at any of the other downstream stations). A sharp drop in bottom pH (as well as a lesser drop at the surface) in March was paralleled by smaller drops at some downstream stations, especially Station 2C. Surface irradiance values fluctuated between 13.2 and 136.0 and bottom values seldom exceeded 0 (Fig. 13e). Turbidity fluctuated widely (between 1 and 7 NTU) with a pronounced increase in January (Fig. 13f).

Station 5 - This station is located approximately 1.5 km upriver from the Interstate 75 bridge (Fig. 6). Shore vegetation at this point is dominated by leather fern (<u>Acrostichum daneofolium</u>), cattail (<u>Typha domingensis</u>), and a variety of overhanging trees (red maple, sable palm, cabbage palm, and slash pine). The substrate is unvegetated but often covered by leaf litter. Two of the seine sites were located along the main bank of the LMR, and the third was located in a small cove that was covered with floating vegetation. September flood waters changed the characteristics of the latter site by removing all of the vegetative cover and importing coarse sands. All trawls were pulled in the channel.

Physical parameters were recorded in the channel (mean depth = 1.04 m). The salinity range was so limited at this station (0 to ca. 5 ppt) that only the major salinity increase from May to June was apparent (Fig. 14a). Surface and bottom salinities were at or near 0 ppt for most of the year. Temperature and DO ranges and seasonal patterns were similar to those of most of the previous stations (Fig. 14b and c). The seasonal pattern of pH variation at Station 5 paralleled that at Station 4, but the increase in the months of October through December was more pronounced (to as high as 8.95 in December; Fig. 14d). Surface irradiance fluctuated between 25.2 and 141.5, and bottom irradiance remained low but was often measurably above 0 (Fig. 14e). Turbidity generally fluctuated between 1 and 4 NTU with somewhat higher values in January and September (Fig. 14f).

Station 6 - This station is located approximately 2.5 km upriver from the Interstate 75 bridge (Fig. 6). Shoreline vegetation is similar to that at Station 5. The substrate varies from sand to mud and is often covered with detritus. Two seine hauls were made along the south shore and one along the north shore. Trawls were towed in the channel.

All physical data were collected at midstream (mean depth = 0.83 m). The highest salinity recorded at this station was 0.1 ppt (Fig. 15a). Temperature and DO patterns and ranges were similar to those at most downstream stations (Fig. 15b and c). Seasonal patterns and range for pH were almost identical to those at Station 5 including the strong increase during the months of October through December (Fig. 15d). Surface irradiance fluctuated between 8.7 and 115 with several obvious peaks in bottom irradiance in May, June, and October (Fig. 15e). Turbidity fluctuated widely (between 0 and 9 NTU; Fig. 15f).

Ichthyofauna

The section of the LMR covered for this study possesses a diverse ichthyofauna composed of marine, estuarine, and freshwater species. Ninety-five species and three multi-specific groups were identified from our samples (Table 2). The latter groups include menhaden (<u>Brevoortia</u> spp.), stingrays (<u>Dasyatis</u> spp.), and tilapia (<u>Tilapia</u> spp). The genus <u>Brevoortia</u> probably includes two species which occur in the LMR (Springer and Woodburn, 1960; see above). These fish were seasonally quite numerous, but juveniles are difficult to separate at the species level. Three species of stingrays (<u>Dasyatis</u> <u>americana</u>, <u>D</u>. <u>sabina</u>, and <u>D</u>. <u>sayi</u>) have been reported from Tampa Bay (Comp, 1985; Springer and Woodburn, 1960). We collected two specimens at Station 3 which were measured and returned to the water without being identified to species. Three species of tilapia (Tilapia aurea, T. melanotheron, and T. mossambica) have been reported from the Tampa Bay region (Comp, 1985; Lee et al., 1980). Juvenile tilapia were sporadically numerous in our samples (especially at Station 6), but species level identification of these young fish is difficult (representative specimens have been preserved for later identification by J. D. Williams of the U. S. Fish and Wildlife Service) . Several adults collected appeared to be T. aurea. Thus, at least 98 species of fish occur in the section of the LMR covered by our six stations. Based on various literature sources as well as unpublished FMRI data, we have calculated that this number represents approximately 20-30% of the total number of fish species known from the inshore marine, estuarine, and freshwaters of the Tampa Bay region.

In addition to the identification problems mentioned above, juveniles of several common species groups can only be separated by detailed morphological examination. Due to the large numbers of specimens involved, we were generally unable to identify these juveniles past the generic level. The four most important genera in this category are Eucinostomus, Menidia, Mugil, and Gobiosoma. Examination of hundreds of specimens has revealed the presence of only two species of Eucinostomus (E. harengulus and E. gula) in Tampa Bay (Matheson, 1983 and unpublished data). Preliminary examination of subsamples revealed that E. gula tended to occur at the more downstream stations, whereas E. harengulus displays a broader distribution, occurring from the river mouth into freshwater. This scenario agrees well with data from other geographic areas (Matheson, pers. obs.). The genus Menidia includes two species, M. peninsulae and M. beryllina in Tampa Bay (Duggins, 1980; Duggins et al., 1986). Our preliminary observations of these two species revealed that M. peninsulae is more abundant downstream or in higher salinity areas than is M. beryllina. This finding also agrees with previous literature from other areas (Duggins, 1980). The genus Gobiosoma is mainly represented by two species in the Little Manatee River (G. macrodon appears in our species list, Table 2, due to one specimen collected at the mouth of the river): G. robustum and G. bosci. These fish are very abundant throughout our sampling area, and, as would be predicted based on previous literature (Darcy, 1980), our preliminary observations indicate that G. robustum may be the higher salinity form. Finally, the genus Mugil consists of three species in the Tampa Bay area: M. cephalus, M. curema, and M. trichodon. In contrast to the previous groups this complex seems to be dominated by one species, M. cephalus, in the river, but we can say very little at this time regarding comparative longitudinal distribution of the three species in our study area. We are currently developing subsampling techniques that will allow us to determine the relative proportions of all of these important species in our samples.

Despite these caveats regarding identification problems, changes in the fish community as one proceeds upriver were quite obvious from our data. One means of representing these changes is to compare the dominant species at our six stations (Table 3). The bay anchovy, Anchoa mitchilli, was the only species occurring among the top five at all of our stations. This is a contagiously distributed, schooling species for which the chance capture of one large school could perhaps lead to a numerical ranking in the top ten at any station. Many previous studies from various areas along the Atlantic and Gulf coasts have found bay anchovies to be among the top few most abundant species (see comments in Vouglitois et al., 1987). Our first year's data indicated a peak in bay anchovy abundance at Stations 3 and 4; only with long term data will we be able to tell whether this was due to random occurrence of more schools at these stations or to an actual habitat preference by the species. No other species or species group occurred among the top five in abundance at more than four stations. In fact, data in Table 3 indicate that one species occurred six times among the top five, one species occurred four times, four species occurred three times, two species occurred twice, and four species occurred once. This changing pattern of community dominance can be interpreted as a community sequence proceeding from a relatively high salinity estuarine community through communities of intermediate character to a very low salinity or freshwater community. Two families of cyprinodontoid fishes (Cyprinodontidae and Poeciliidae) that are well-represented in our collections serve to illustrate this phenomenon. Many of these fishes are known for their abilities to tolerate wide ranges of salinity (Rosen, 1973), but preferred salinity ranges seemed evident in our data. Higher salinity areas were dominated by *Fundulus similis* which dropped to 7th place in numerical abundance by Station 3 and dropped out of the top ten by Station 4. *Fundulus grandis* also ranked among the top ten species at the moderately high salinity Stations 3 and 4. *Gambusia affinis* became very abundant by Station 4 and was dominant through Station 6 (i.e., moderately low salinity through freshwater). *Poecilia latipinna* also entered the top ten group by Station 4 and remained there through Station 6. *Fundulus seminolis* and *Lucania goodei* did not enter the top ten until Station 6 (although *F. seminolis* ranked 6th at Station 5).

One of the major potential effects of changing salinity regimes on estuarine communities is the contraction or expansion of the area of habitat available to a given species due to its salinity requirements or preferences (Boesch and Turner, 1984). In other words, if species A primarily utilizes estuarine areas with salinities ranging from 15-20 ppt, any changes in freshwater flow patterns which increase or decrease the proportion of the estuarine system represented by this salinity interval will have concomitant effects on the distribution of species A. This factor can thus affect the carrying capacity of the estuarine system in terms of particular species as well as its relative productivity in terms of economically valuable species. The latter effect may be expressed in future year class strength of a given fishes species due to interactions on at least two levels: 1) direct effects due to changes in amount of available nursery habitat, 2) indirect effects due increases/decreases in production of forage or competing species.

Some of the possible effects of changing salinity regimes on species occurring in the LMR can be predicted based on contractions/expansions in their distributions in relation to the annual pattern of salinity changes. As indicated above, the overall salinity pattern for our study area included relatively high values from January through July (with two sharp declines in January and March) and relatively low values from August through December. Figures 16 through 24 illustrate the changes in distribution over time for selected species in the LMR. It is obvious from these figures that factors other than salinity (i.e., recruitment periodicity, random population fluctuations or movements, variations in physical parameters other than salinity) must affect the distributions of these species. Two moderate to high salinity species of cyprinodontids (Fundulus similis and F. grandis) exhibited distributional changes not obviously linked to salinity patterns (Figs. 16 and 17). The distribution of F. similis expanded in June (high salinity) and September (low salinity), and that of F. grandis expanded in May and July (high salinity) as well as in October (low salinity). Two relatively low salinity forms (Gambusia affinis and Labidesthes sicculus) showed expanded distributions during low salinity periods (although the latter species also expanded its range during July; Figs. 18 and 19). Fundulus seminolis, another low salinity form, exhibited marked range expansion in the high salinity month of February and lesser expansions during the low salinities of March and August-September (Fig. 20). Three sciaenids (Bairdiella chrysoura, Leiostomus xanthurus, and Sciaenops ocellatus) and a sparid (Lagodon rhomboides) demonstrated rather broad salinity tolerances (occurring at at least five of our six stations) but marked seasonal changes in distribution (Figs. 21-24). These changes appear to be more closely related to recruitment and migration than to salinity (changes due to gear selectivity as members of a cohort grow in size must also be considered). Before any conclusions can be reached, these patterns need to be examined more carefully in terms of relative abundance in relation to salinity, ontogenetic variation in distribution, and other factors. Long term data will indicate whether observed distributional patterns in relation to salinity are repeated or vary randomly on an interannual basis.

Data analyses for this portion of the study are continuing with emphasis on finer scale differences in fish communities at different stations or sample sites and on multivariate approaches to understanding the distributional patterns evident in the data. The former analyses will include possible effects of specific microhabitat types on fish distribution and changes in the distribution of species over their life cycles. The latter analyses will consider distribution not only in relation to salinity but also in relation to other physical and biological (i.e., presence/absence of forage/competitors) variables.

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Table 1. Fishes collected in Cockroach Bay by roving dropnets

[Family arrangement based on Nelson (1976); names follow Robins et al. (1980) except as modified by more recent revisionary work]

Clupeidae
    Brevoortia spp. ... menhaden
Engraulidae
    Anchoa mitchilli (Valenciennes)...bay anchovy
Synodontidae
    Synodus foetens (Linnaeus)...inshore lizardfish
Gadidae
    Urophycis floridana (Bean and Dresel)...southern hake
Batrachoididae
    Opsanus beta (Goode and Bean)...Gulf toadfish
Cyprinodontidae
    Lucania parva Baird...rainwater killifish
Atherinidae
    Labidesthes sicculus (Cope)...brook silverside
    Menidia beryllina (Cope)...inland silverside
    Menidia peninsulae (Goode and Bean)...tidewater silverside
Syngnathidae
    Hippocampus zosterae Jordan and Gilbert...dwarf seahorse
    Syngnathus louisianae Gunther...chain pipefish
    Syngnathus scovelli (Evermann and Kendall)...Gulf pipefish
Triglidae
    Prionotus scitulus Jordan and Gilbert...leopard searobin
    Prionotus tribulus Cuvier...bighead searobin
Carangidae
    Chloroscombrus chrysurus (Linnaeus)...Atlantic bumper
    Oligoplites saurus (Schneider)...leatherjacket
Gerreidae
    Eucinostomus spp. ... mojarras
Haemulidae
    Orthopristis chrysoptera (Linnaeus)...pigfish
Sparidae
    Archosargus probatocephalus (Walbaum)...sheepshead
    Lagodon rhomboides (Linnaeus)...pinfish
    Diplodus holbrooki (Bean) ...spotted pinfish
Sciaenidae
    Bairdiella chrysoura (Lacepede)...silver perch
    Cynoscion nebulosus (Cuvier)...spotted seatrout
    Leiostomus xanthurus Lacepede...spot
    Sciaenops ocellatus (Linnaeus)...red drum
Ephippidae
    Chaetodipterus faber (Broussonet)...Atlantic spadefish
Blenniidae
    Chasmodes saburrae Jordan and Gilbert...Florida blenny
    Hypsoblennius hentzi (Lesueur)...feather blenny
Gobiidae
    Bathygobius soporator (Valenciennes)..frillfin goby
    Gobiosoma robustum Ginsburg...code goby

Gobiesocidae

Gobiesox strumosus Cope...skilletfish

Bothidae

Paralichthys albigutta Jordan and Gilbert...Gulf flounder

Soleidae

Achirus lineatus (Linnaeus)...lined sole

Cynoglossidae

Symphurus plagiusa (Linnaeus)...blackcheek tonguefish

Balistidae

Monacanthus spp. (Linnaeus)...planehead filefish

Tetraodontidae

Sphoeroides nephelus (Goode and Bean)...southern puffer

Diodontidae

Chilomycterus schoepfi (Walbaum)...striped burrfish

Table 2:Fishes collected from the Little Manatee River

[Family arrangement based on Nelson (1976); names follow Robins et al. (1980) except as modified by more recent revisionary work]

Rhinobatidae
- *Rhinobatos lentiginosus* (Garman)... Atlantic guitarfish

Dasyatidae
- *Dasyatis* spp...stingray

Myliobatidae
- *Rhinoptera bonasus* (Mitchill)...cownose ray

Lepisosteidae
- *Lepisosteus osseus* (Linnaeus)...longnose gar
- *Lepisosteus platyrhinchus* DeKay...Florida gar

Amiidae
- *Amia calva* Linnaeus...bowfin

Clupeidae
- *Brevoortia* spp...menhaden
- *Dorosoma petenense* (Gunther)...threadfin shad
- *Harengula jaguana* Poey...scaled sardine
- *Sardinella aurita* Valenciennes...Spanish sardine

Engraulidae
- *Anchoa hepsetus* (Linnaeus)...striped anchovy
- *Anchoa mitchilli* (Valenciennes)...bay anchovy

Elopidae
- *Elops saurus* Linnaeus...ladyfish

Characidae
- *Aphyocharax anisitsi* Eigenmann and Kennedy...bloodfin

Cyprinidae
- *Notemigonus crysoleucas* (Mitchill)...golden shiner
- *Notropis maculatus* (Hay)...taillight shiner
- *Notropis petersoni* Fowler...coastal shiner

Catostomidae
- *Erimyzon sucetta* (Lacepede)...lake chubsucker

Ictaluridae
- *Ictalurus* c.f. *catus* (Linnaeus)...white catfish
- *Ictalurus natalis* (Leseuer)...yellow bullhead

Ariidae
- *Arius felis* (Linnaeus)...hardhead catfish
- *Bagre marinus* (Mitchill)...gafftopsail catfish

Synodontidae
- *Synodus foetens* (Linnaeus)...inshore lizardfish

Gadidae
- *Urophycis floridana* (Bean and Dresel)...southern hake

Batrachoididae
- *Opsanus beta* (Goode and Bean)...Gulf toadfish

Belonidae
- *Strongylura marina* (Walbaum)...Atlantic needlefish
- *Strongylura notata* (Poey)...redfin needlefish

Cyprinodontidae
- *Adinia xenica* (Jordan and Gilbert)...diamond killifish
- *Cyprinodon variegatus* Lacepede...sheepshead minnow
- *Floridichthys carpio* (Gunther)...goldspotted killifish
- *Fundulus confluentus* Goode and Bean...marsh killifish

Fundulus _grandis_ Baird and Girard...Gulf killifish
Fundulus _similis_ (Baird and Girard)...striped killifish
Fundulus _seminolis_ Girard...Seminole killifish
Jordanella _floridae_ Goode and Bean...flagfish
Lucania _goodei_ Jordan...bluefin killifish
Lucania _parva_ Baird...rainwater killifish

Poeciliidae
Gambusia _affinis_ (Baird and Girard)...mosquitofish
Heterandria _formosa_ Agassiz...least killifish
Poecilia _latipinna_ (Lesueur)...sailfin molly

Atherinidae
Labidesthes _sicculus_ (Cope)...brook silverside
Membras _martinica_ (Valenciennes)...rough silverside
Menidia _beryllina_ (Cope)...inland silverside
Menidia _peninsulae_ (Goode and Bean)...tidewater silverside

Syngnathidae
Hippocampus _erectus_ Perry...lined seahorse
Hippocampus _zosterae_ Jordan and Gilbert...dwarf seahorse
Syngnathus _floridae_ (Jordan and Gilbert)...dusky pipefish
Syngnathus _louisianae_ Gunther...chain pipefish
Syngnathus _scovelli_ (Evermann and Kendall)...Gulf pipefish

Triglidae
Prionotus _scitulus_ Jordan and Gilbert...leopard searobin
Prionotus _tribulus_ Cuvier...bighead searobin

Centropomidae
Centropomus _undecimalis_ (Bloch)...snook

Centrarchidae
Enneacanthus _gloriosus_ (Holbrook)...bluespotted sunfish
Lepomis _gulosus_ (Cuvier)...warmouth
Lepomis _macrochirus_ Rafinesque...bluegill
Lepomis _microlophus_ (Gunther)...redear sunfish
Lepomis _punctatus_ (Valenciennes)...spotted sunfish
Micropterus _salmoides_ (Lacepede)...largemouth bass

Percidae
Etheostoma _fusiforme_ (Girard)...swamp darter

Carangidae
Chloroscombrus _chrysurus_ (Linnaeus)...Atlantic bumper
Oligoplites _saurus_ (Schneider)...leatherjacket

Lutjanidae
Lutjanus _griseus_ (Linnaeus)...gray snapper

Gerreidae
Eucinostomus _gula_ (Quoy and Gaimard)...silver jenny
Eucinostomus _harengulus_ Goode and Bean...tidewater mojarra
Eugerres _plumieri_ (Cuvier)...striped mojarra

Haemulidae
Haemulon _plumieri_ (Lacepede)...white grunt
Orthopristis _chrysoptera_ (Linnaeus)...pigfish

Sparidae
Archosargus _probatocephalus_ (Walbaum)...sheepshead
Lagodon _rhomboides_ (Linnaeus)...pinfish

Sciaenidae
Bairdiella _chrysoura_ (Lacepede)...silver perch
Cynoscion _arenarius_ Ginsburg...sand seatrout
Cynoscion _nebulosus_ (Cuvier)...spotted seatrout

Leiostomus xanthurus Lacepede...spot
Menticirrhus americanus (Linnaeus)...southern kingfish
Menticirrhus saxatilis (Bloch and Schneider)...northern kingfish
Micropogonias undulatus (Linnaeus)...Atlantic croaker
Pogonias cromis (Linnaeus)...black drum
Sciaenops ocellatus (Linnaeus)...red drum

Ephippidae
Chaetodipterus faber (Broussonet)...Atlantic spadefish

Cichlidae
Tilapia spp....tilapia

Mugilidae
Mugil cephalus Linnaeus...striped mullet
Mugil curema Valenciennes...white mullet
Mugil trichodon (Poey)...fantail mullet

Blenniidae
Chasmodes saburrae Jordan and Gilbert...Florida blenny

Gobiidae
Bathygobius soporator (Valenciennes)..frillfin goby
Gobionellus boleosoma (Jordan and Gilbert)...darter goby
Gobiosoma bosci (Lacepede)...naked goby
Gobiosoma macrodon Beebe and Tee-Van...tiger goby
Gobiosoma robustum Ginsburg...code goby
Microgobius gulosus (Girard)...clown goby

Gobiesocidae
Gobiesox strumosus Cope...skilletfish

Bothidae
Paralichthys albigutta Jordan and Gilbert...Gulf flounder

Soleidae
Achirus lineatus (Linnaeus)...lined sole
Trinectes maculatus (Bloch and Schneider)...hogchoker

Cynoglossidae
Symphurus plagiusa (Linnaeus)...blackcheek tonguefish

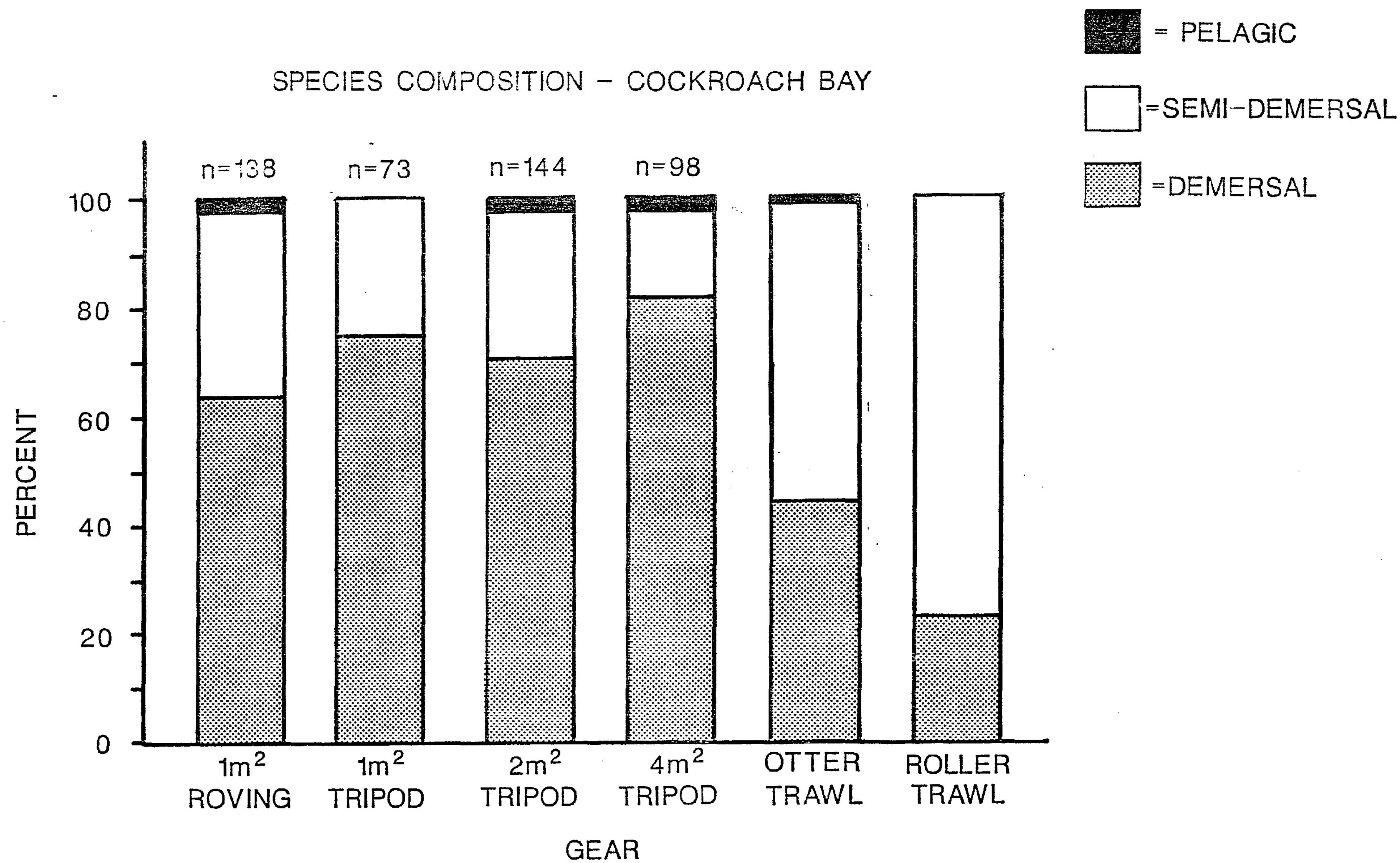
Balistidae
Monacanthus hispidus (Linnaeus)...planehead filefish

Tetraodontidae
Sphoeroides nephelus (Goode and Bean)...southern puffer

Diodontidae
Chilomycterus schoepfi (Walbaum)...striped burrfish

Table 3: Abundant Fishes collected from the Little Manatee River

Scientific name	Common name	Total collected
STATION 1		
Menidia spp.	silversides	15,224
Anchoa mitchilli	bay anchovy	11,479
Lagodon rhomboides	pinfish	7,349
Eucinostomus spp.	mojarras	3,331
Fundulus similis	striped killifish	2,119
STATION 2		
Anchoa mitchilli	bay anchovy	20,342
Menidia spp.	silversides	9,158
Leiostomus xanthurus	spot	5,061
Eucinostomus spp.	mojarras	3,694
Fundulus similis	striped killifish	1,014
STATION 3		
Anchoa mitchilli	bay anchovy	57,463
Menidia spp.	silversides	7,317
Leiostomus xanthurus	spot	5,097
Brevoortia spp.	menhaden	1,829
Eucinostomus spp.	mojarras	1,270
STATION 4		
Anchoa mitchilli	bay anchovy	64,343
Gambusia affinis	mosquitofish	11,521
Brevoortia spp.	menhaden	8,224
Menidia spp.	silversides	6,445
Trinectes maculatus	hogchoker	2,991
STATION 5		
Gambusia affinis	mosquitofish	19,490
Anchoa mitchilli	bay anchovy	17,367
Trinectes maculatus	hogchoker	7,300
Brevoortia spp.	menhaden	4,809
Poecilia latipinna	sailfin molly	4,190
STATION 6		
Anchoa mitchilli	bay anchovy	14,851
Gambusia affinis	mosquitofish	8,809
Trinectes maculatus	hogchoker	8,899
Lucania goodei	bluefin killifish	2,246
Fundulus seminolis	Seminole killifish	2,075



SPECIES COMPOSITION - COCKROACH BAY
= PELAGIC
=SEMI-DEMERSAL
=DEMERSAL
n=138
n=73
n=144
n=98
100
80
60
40
20
0
PERCENT
1m2 ROVING
1m2 TRIPOD
2m2 TRIPOD
4m2 TRIPOD
OTTER TRAWL
ROLLER TRAWL
GEAR

Figure 1

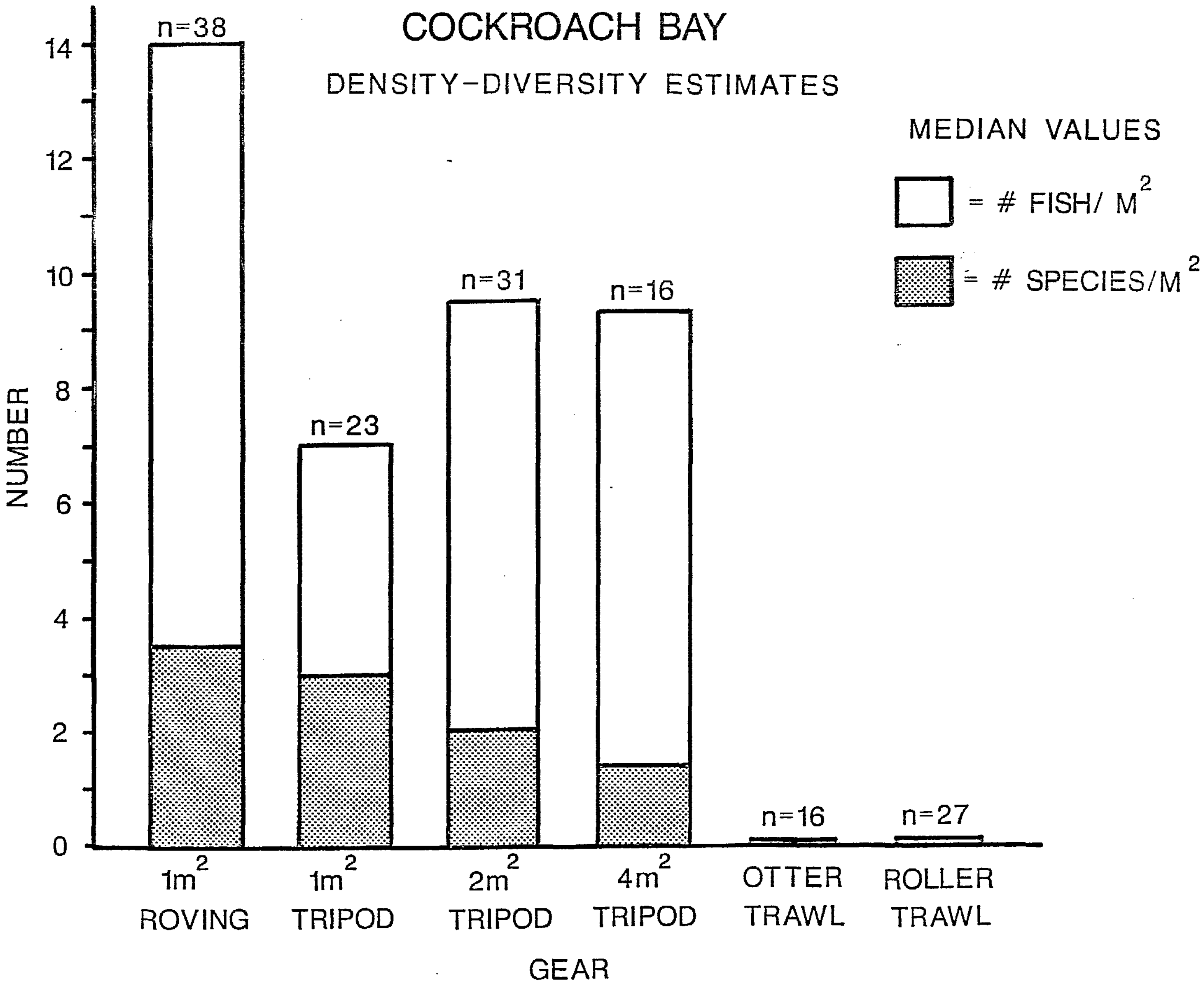
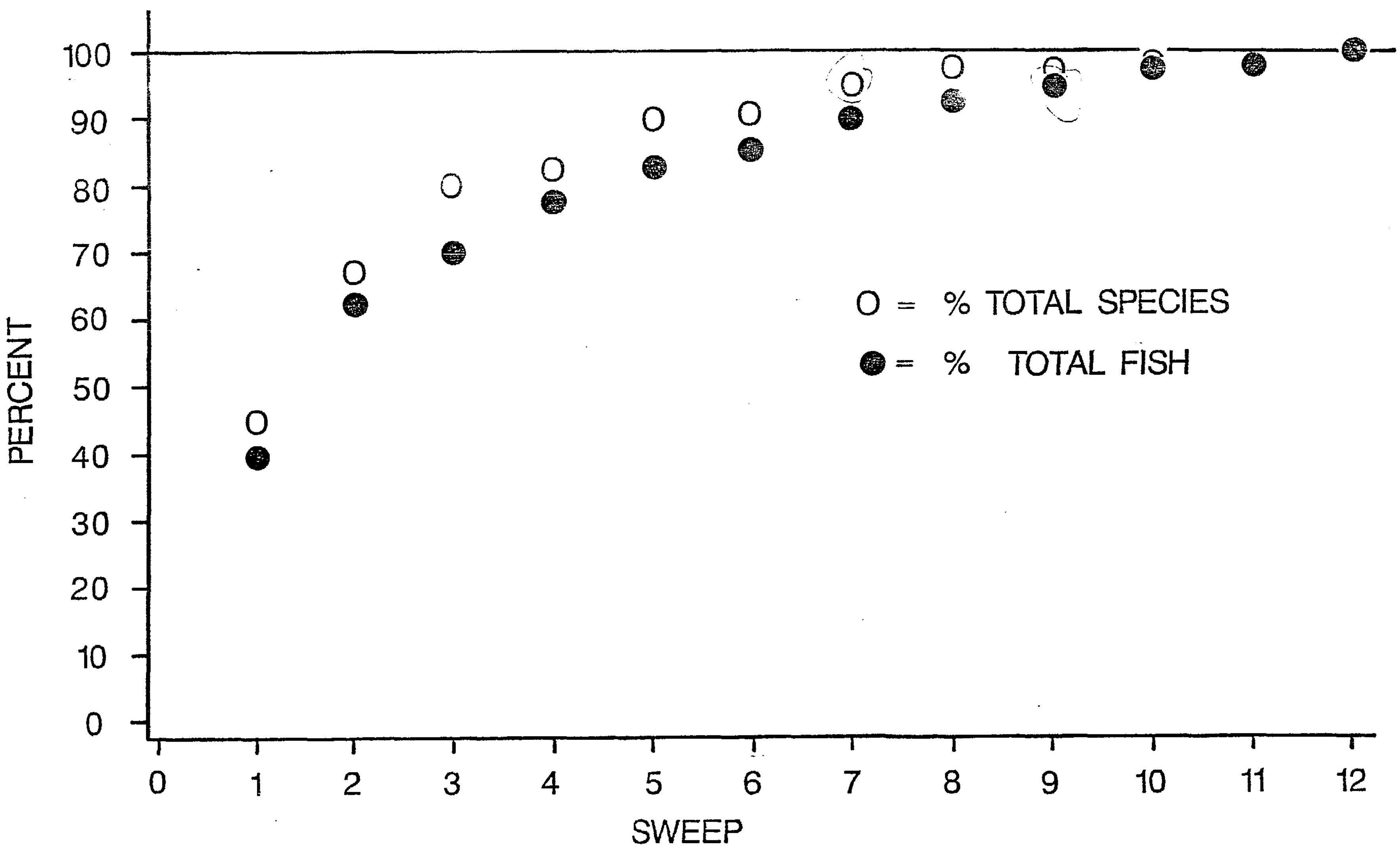
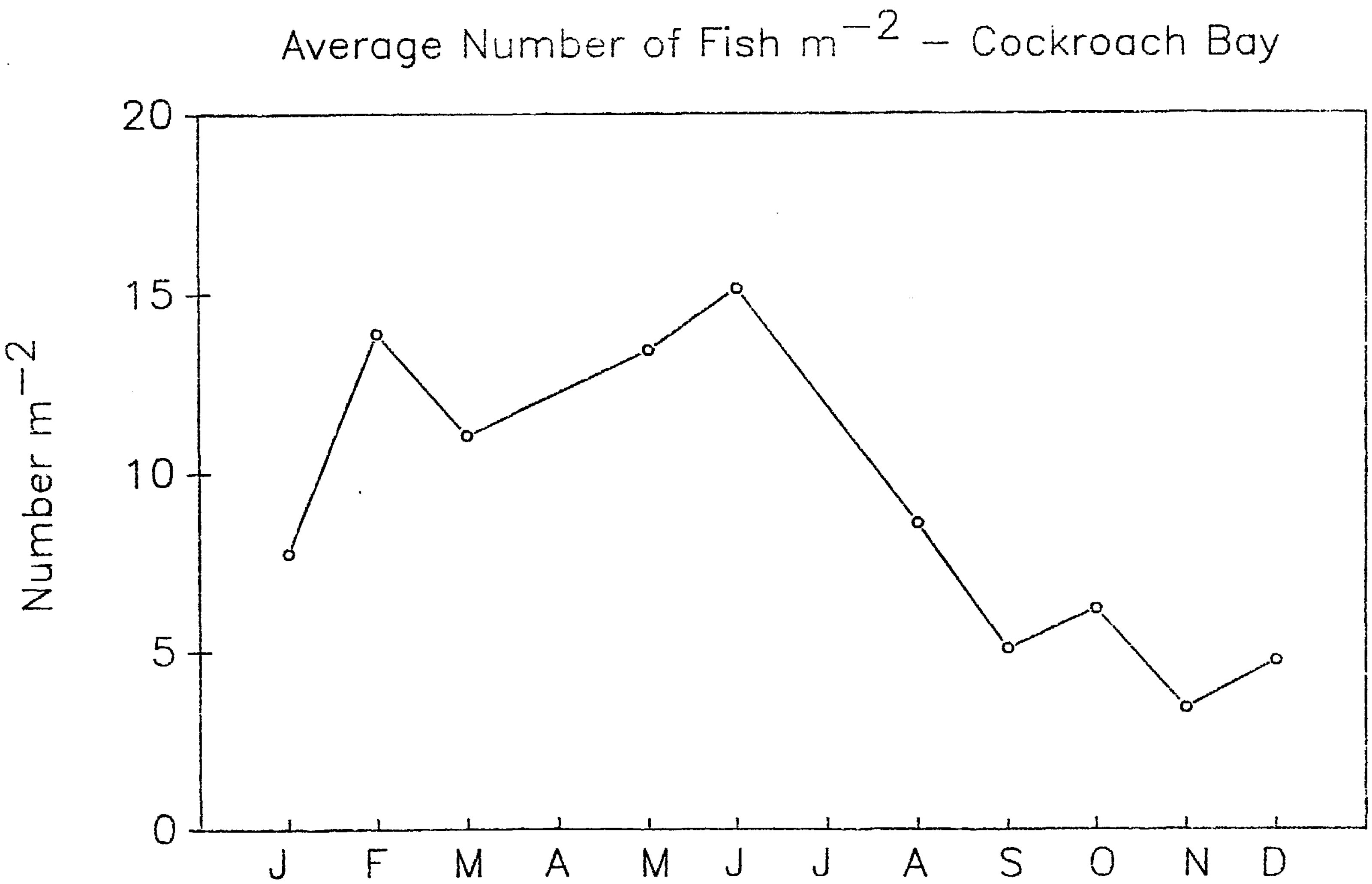

COCKROACH BAY
DENSITY-DIVERSITY ESTIMATES
MEDIAN VALUES
= # FISH/ M²
= # SPECIES/M²
NUMBER
0
2
4
6
8
10
12
14
n=38
n=23
n=31
n=16
n=16
n=27
1m² ROVING
1m² TRIPOD
2m² TRIPOD
4m² TRIPOD
OTTER TRAWL
ROLLER TRAWL
GEAR

Figure 2



100
90
80
70
60
50
40
30
20
10
0
PERCENT
O = % TOTAL SPECIES
= % TOTAL FISH
0
1
2
3
4
5
6
7
8
9
10
11
12
SWEEP

Figure 3



Average Number of Fish m⁻² – Cockroach Bay
Number m⁻²
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 4

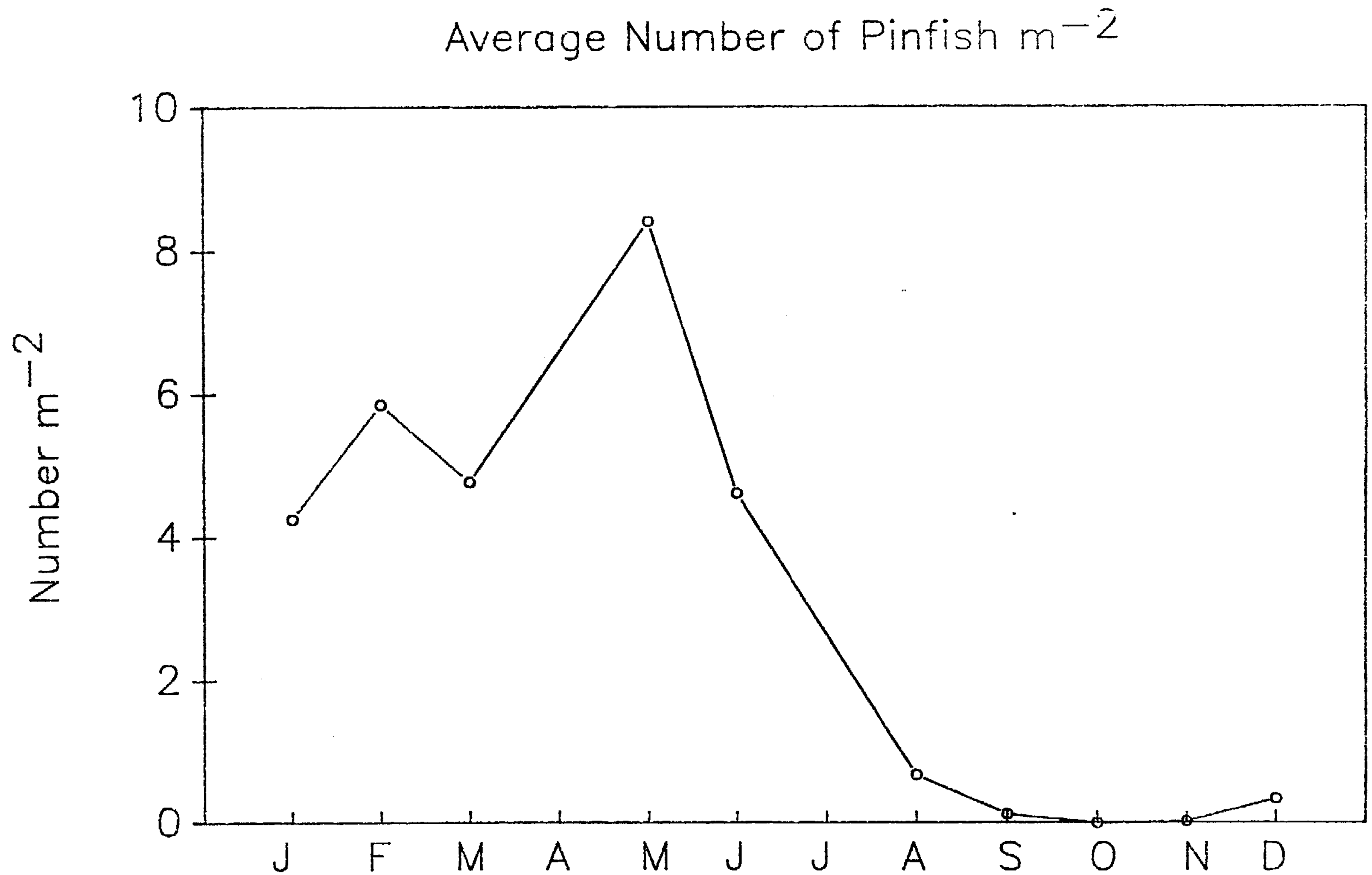

Average Number of Pinfish m−2
Number m−2
10
8
6
4
2
0
J F M A M J J A S O N D

Figure 5

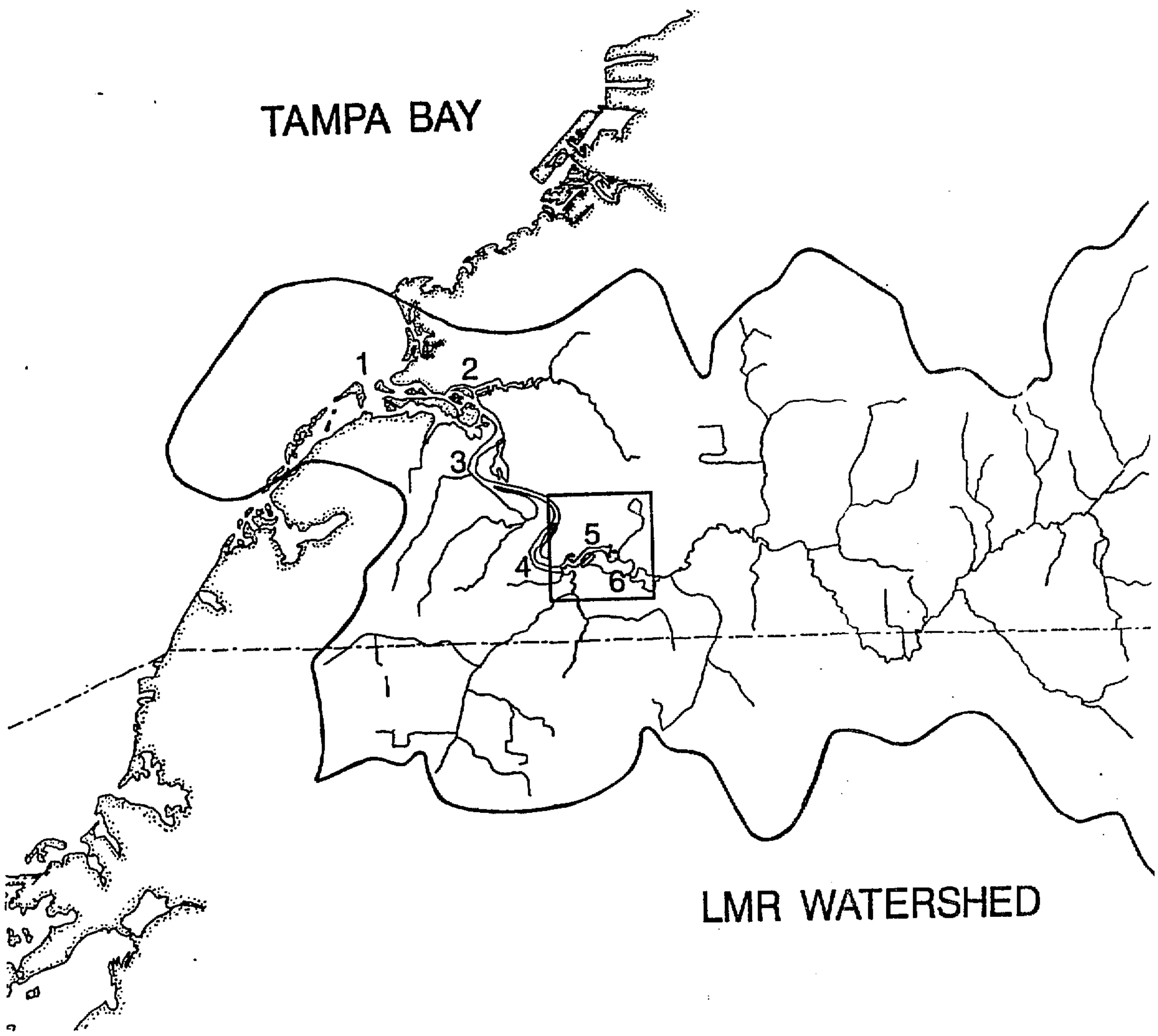


Figure 6: Little Manatee River watershed

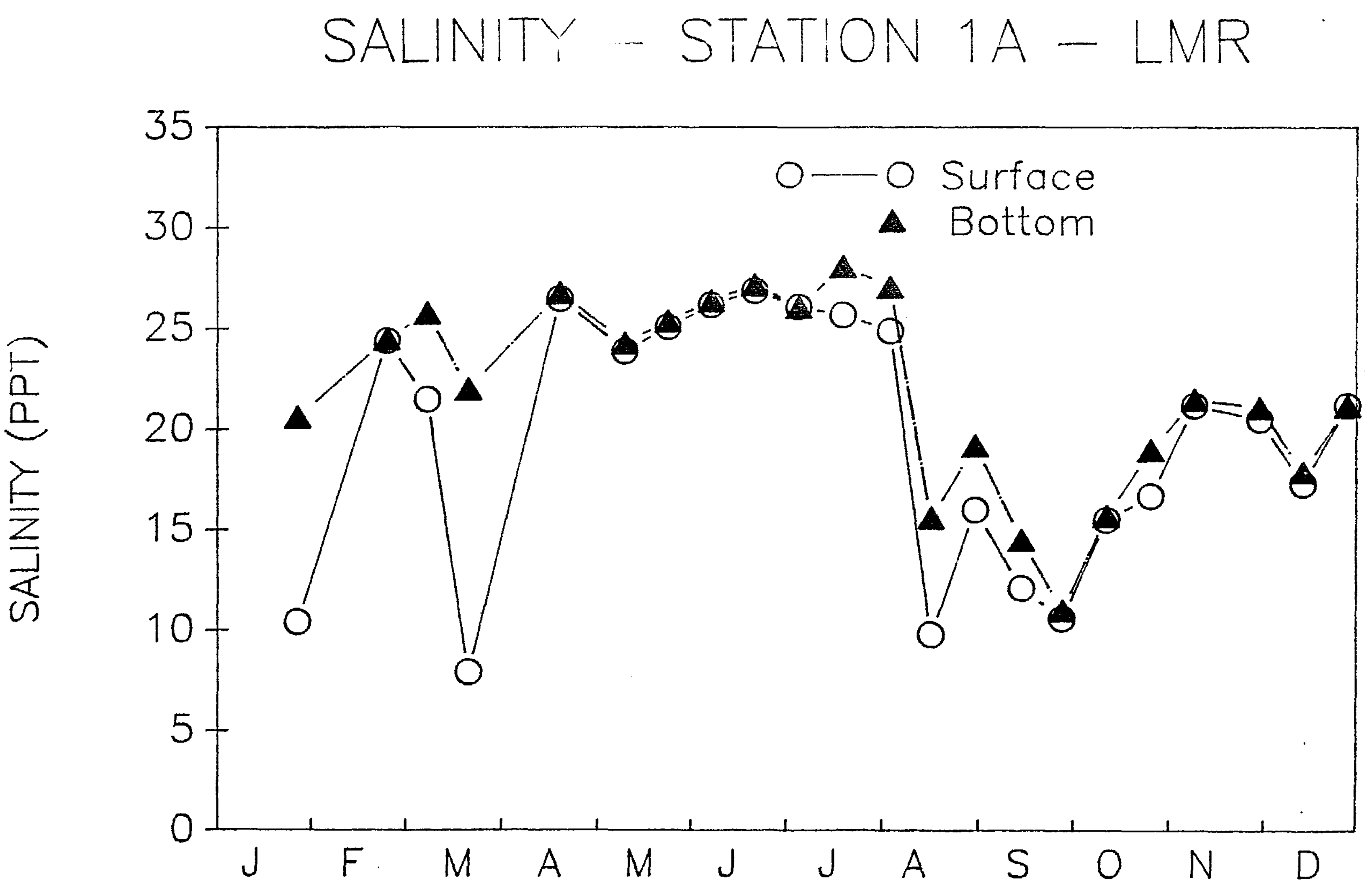

SALINITY - STATION 1A - LMR
Surface
Bottom
SALINITY (PPT)
35
30
25
20
15
10
5
0
J F M A M J J A S O N D

Figure 7a

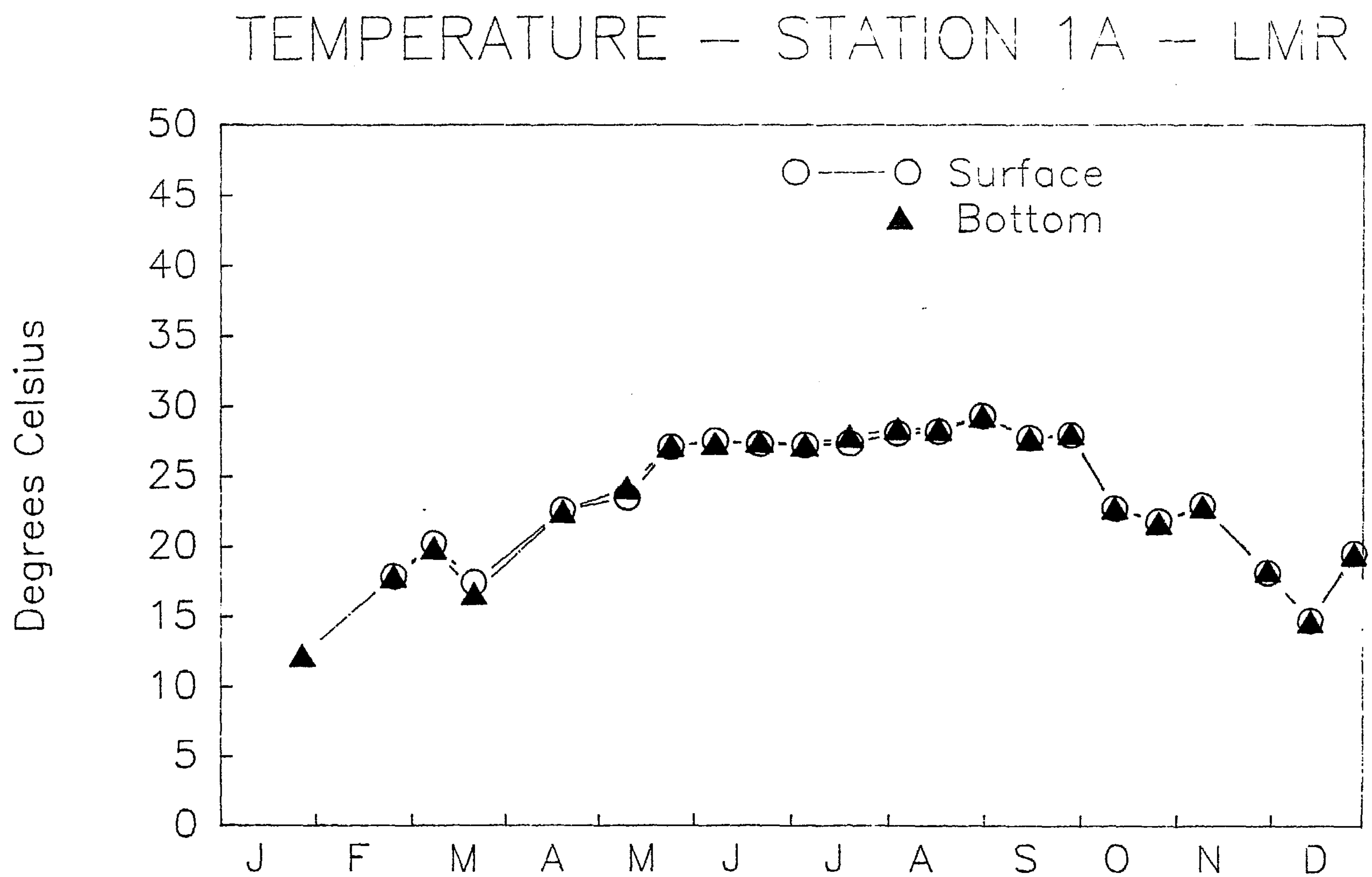
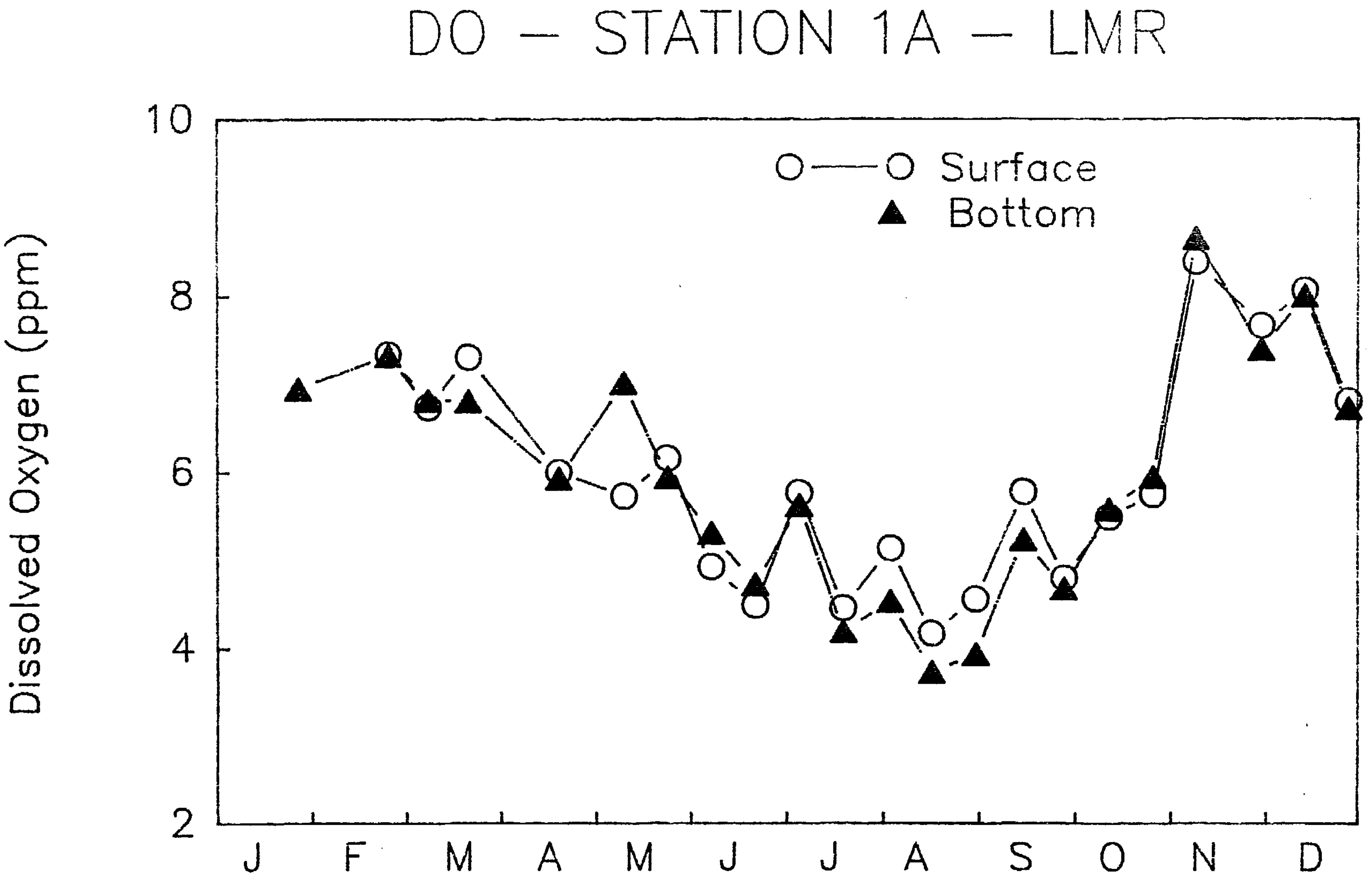

TEMPERATURE – STATION 1A – LMR
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 7b



DO - STATION 1A - LMR
Surface
Bottom
Dissolved Oxygen (ppm)
10
8
6
4
2
J F M A M J J A S O N D

Figure 7c

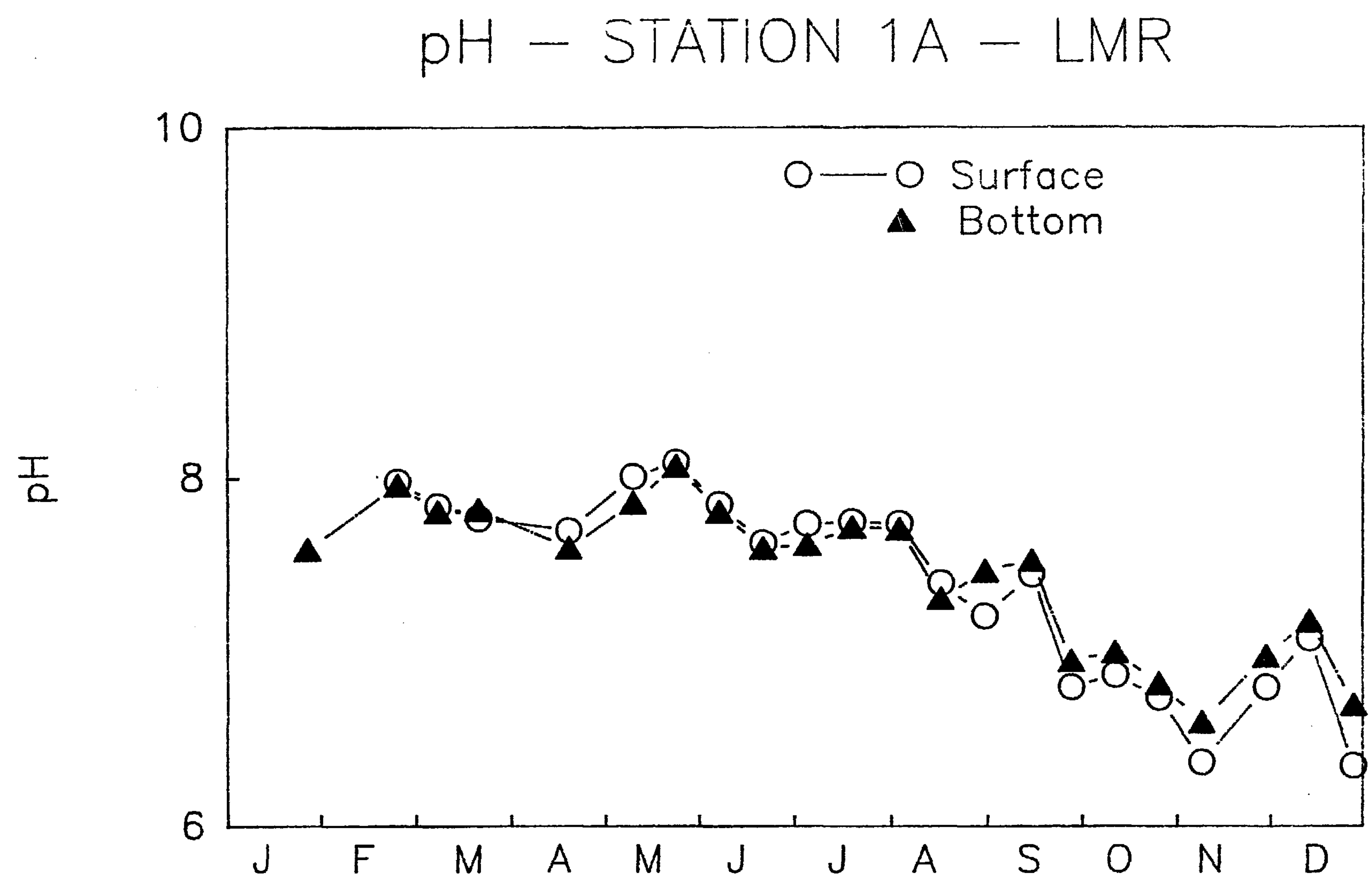
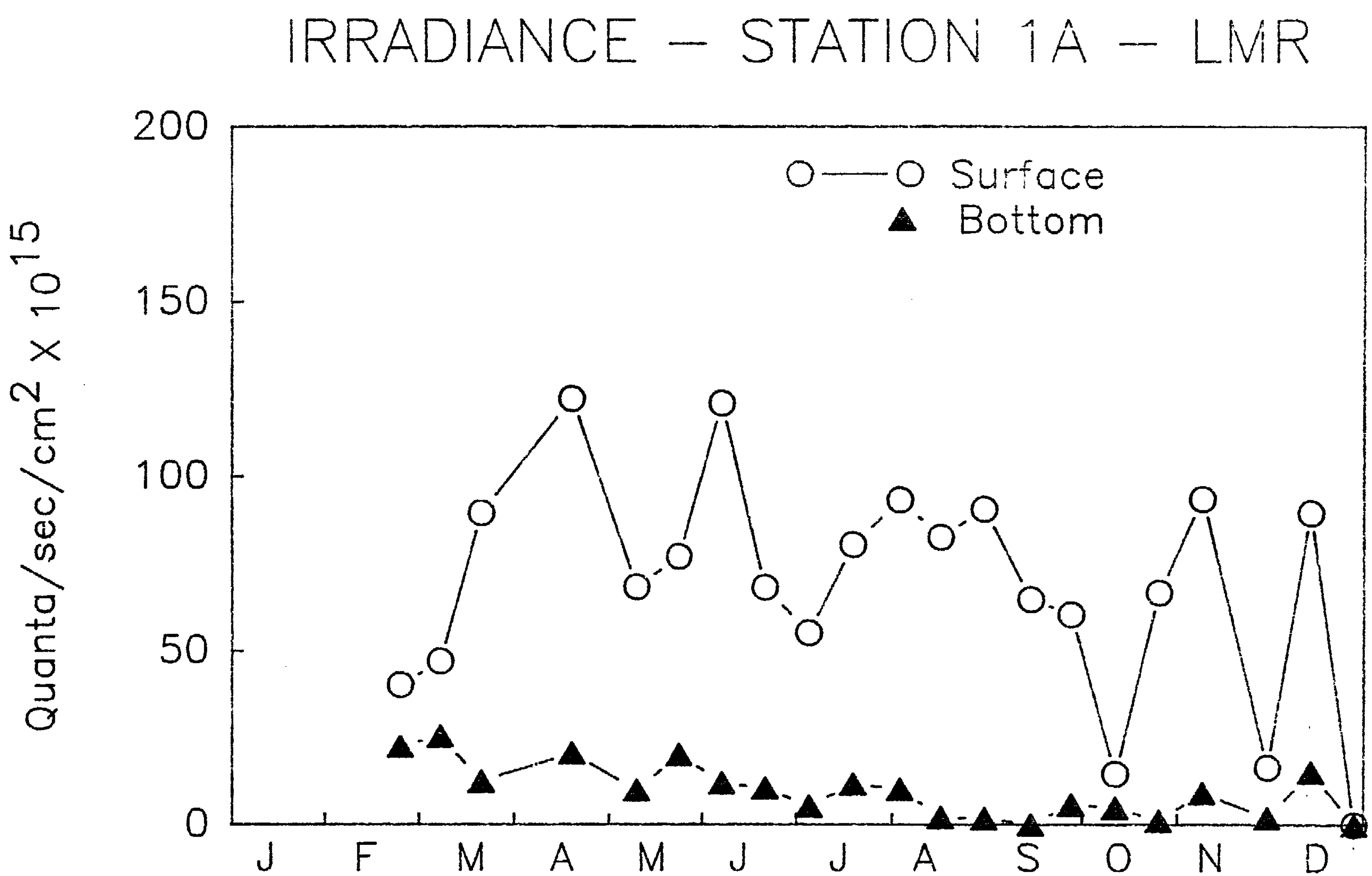


Figure 7d



IRRADIANCE – STATION 1A – LMR
Surface
Bottom
Quanta/sec/cm^2 X 10^{15}
200
150
100
50
0
J F M A M J J A S O N D

Figure 7e

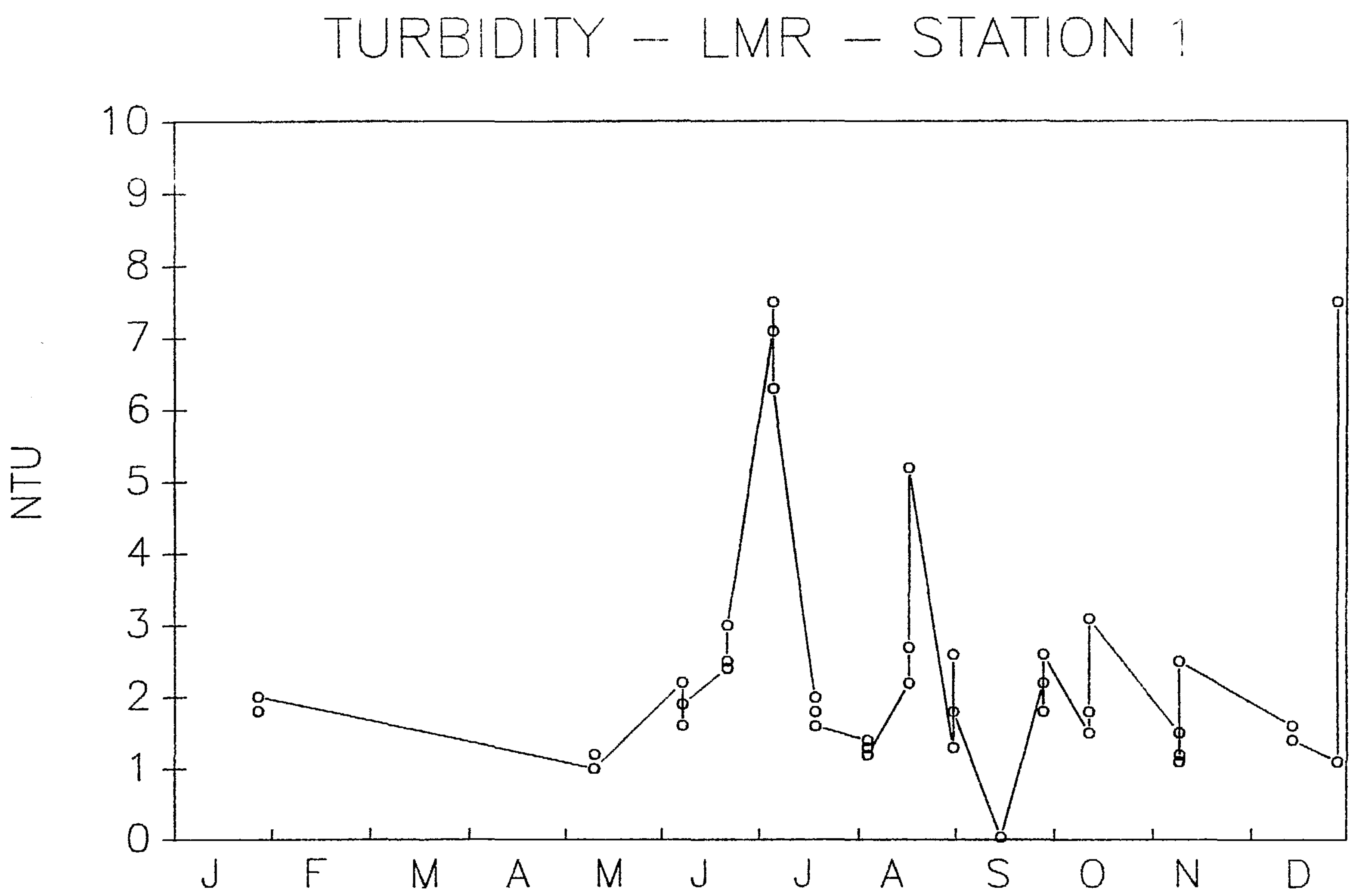


Figure 7f

SALINITY – STATION 1C – LMR

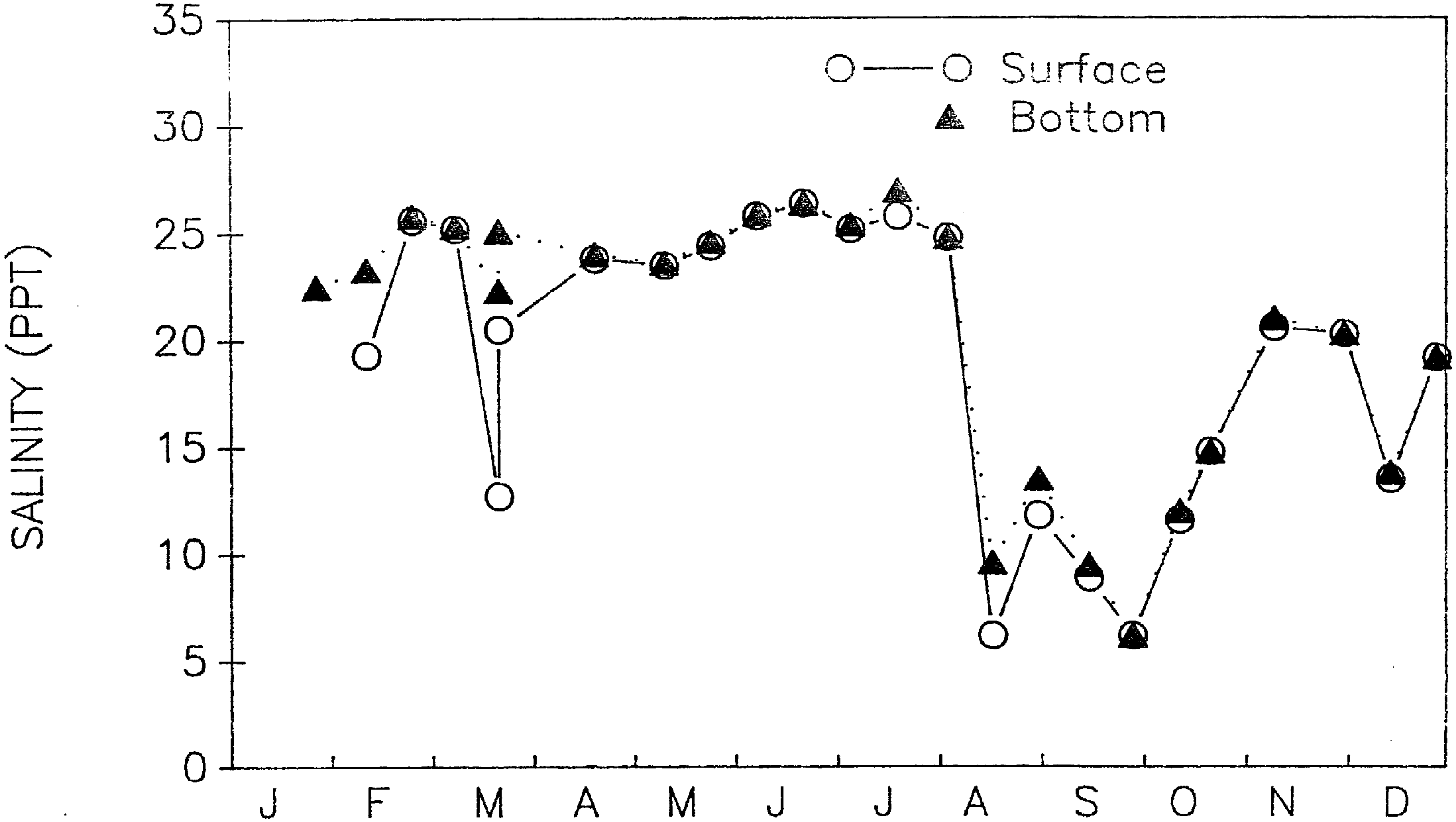


Figure 8a

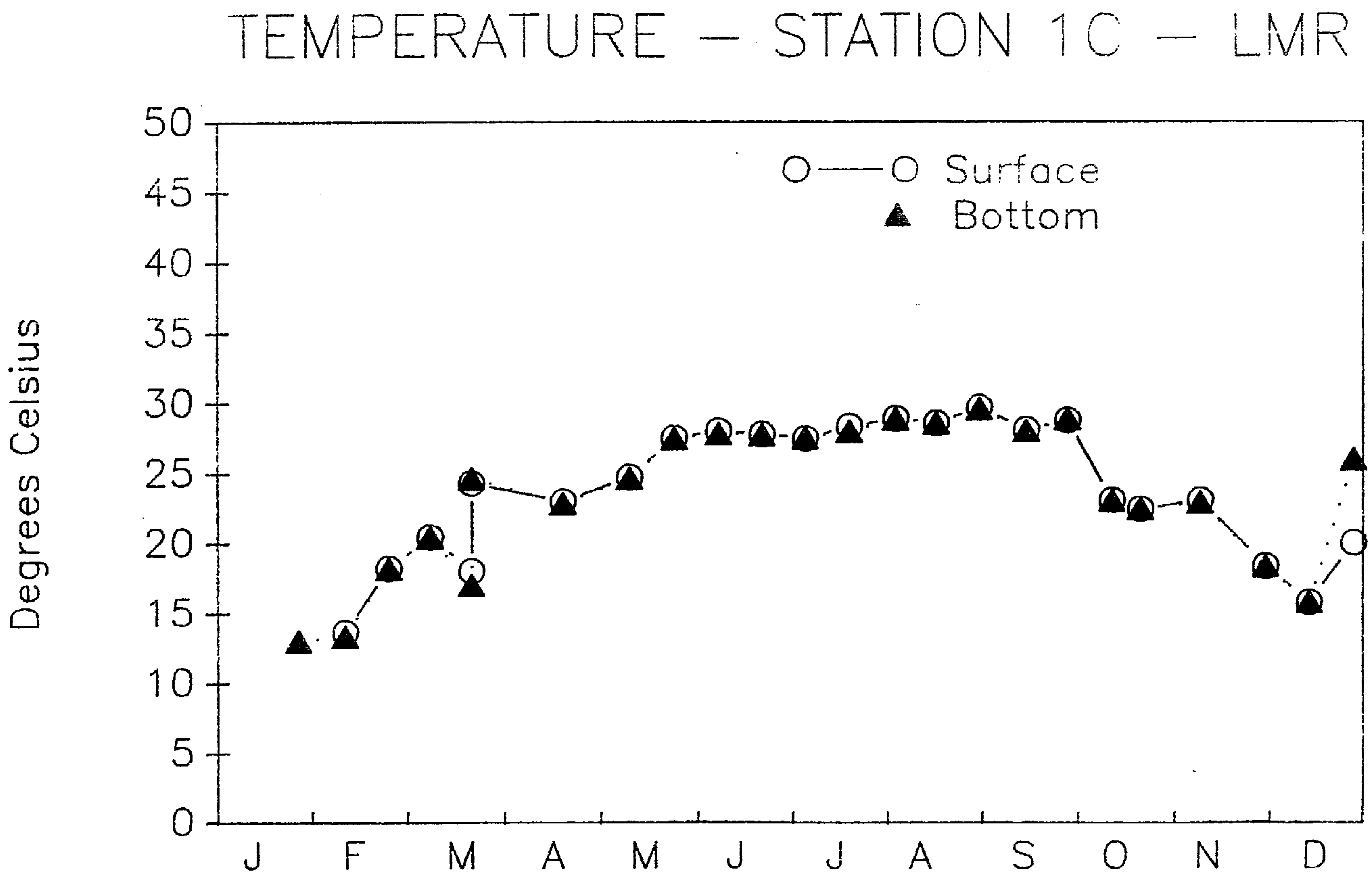
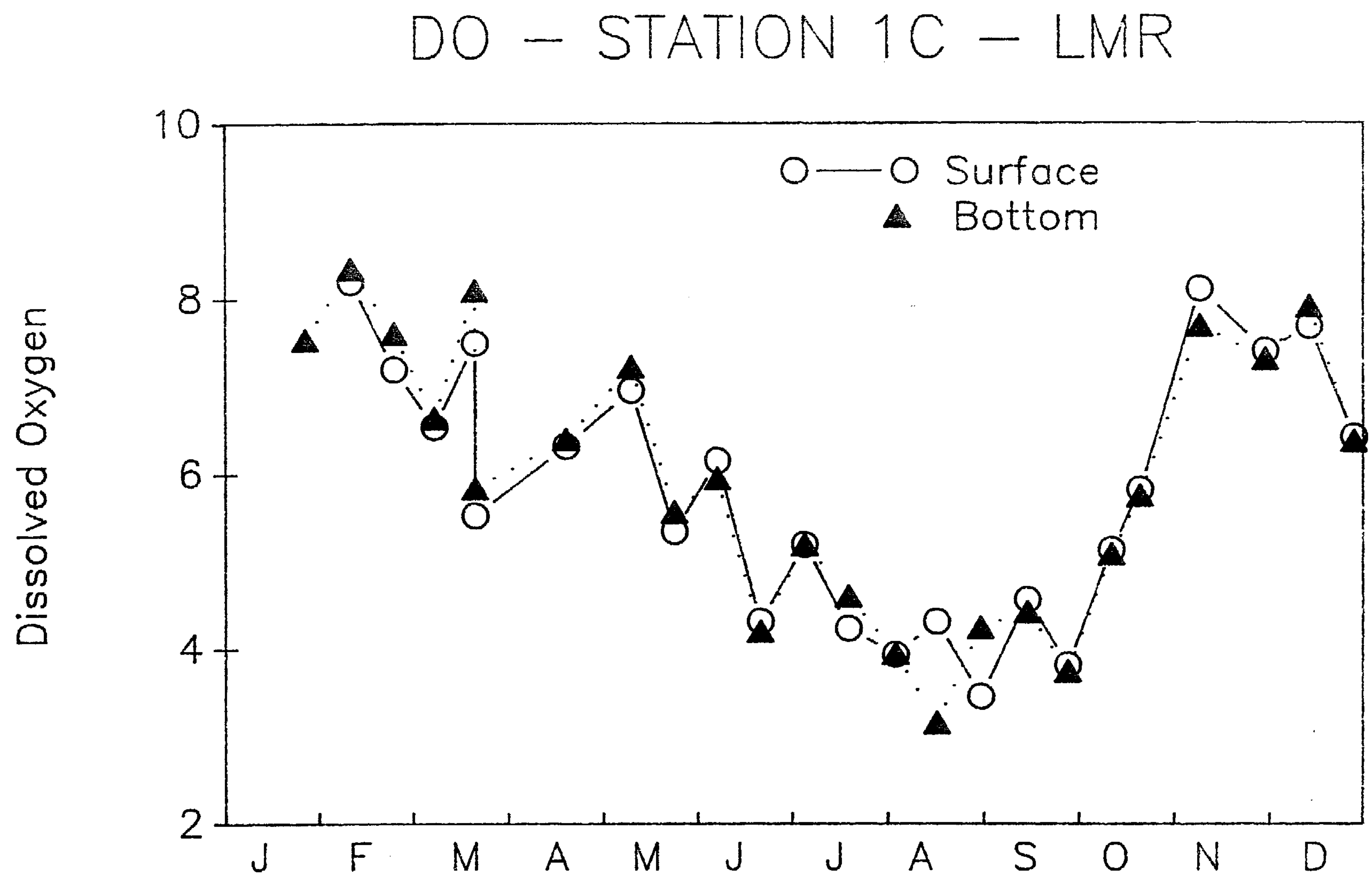

TEMPERATURE - STATION 1C - LMR
Surface
Bottom
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
J F M A M J J A S O N D

Figure 8b



DO – STATION 1C – LMR
10
8
6
4
2
Dissolved Oxygen
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 8c

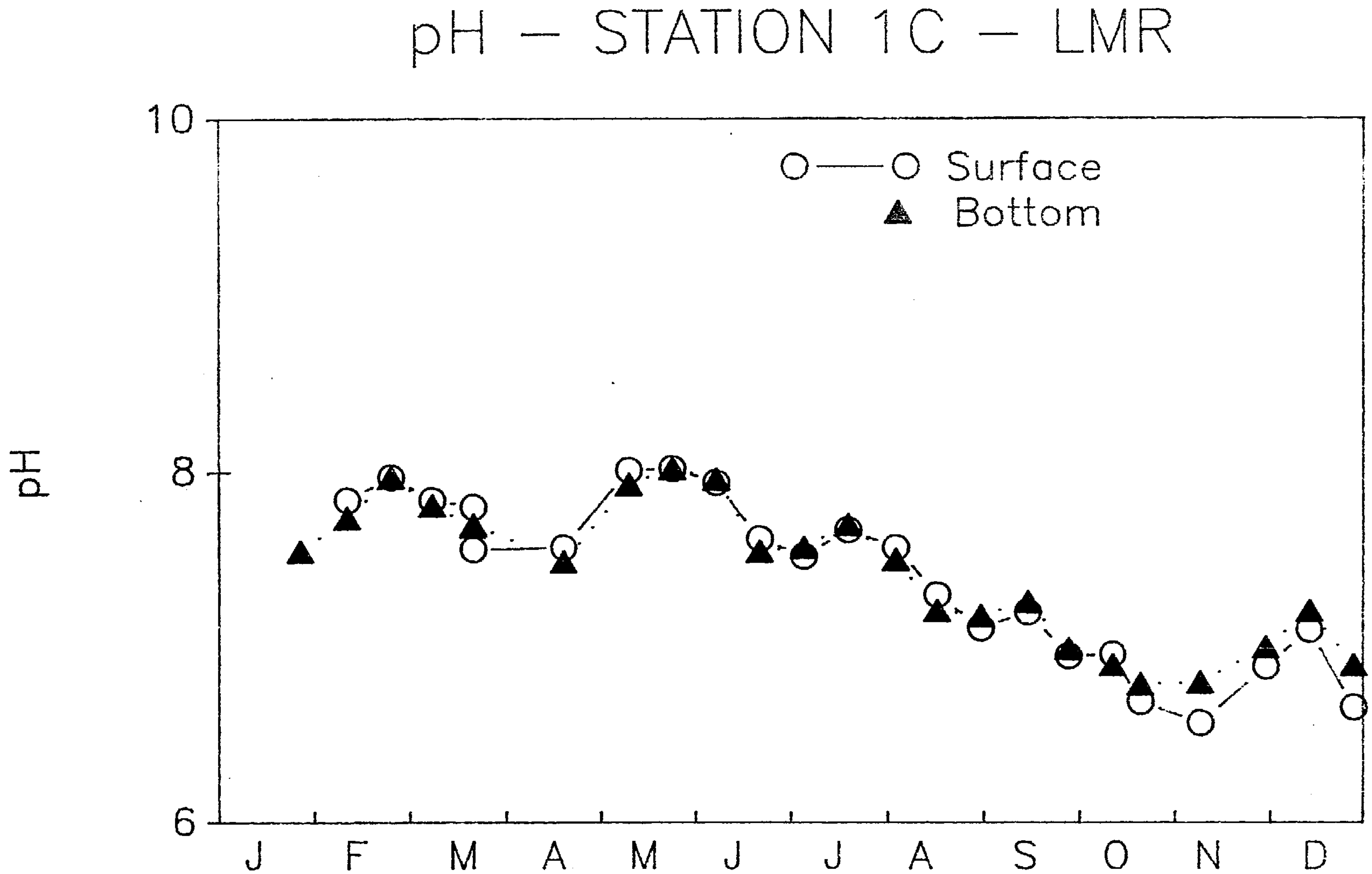


Figure 8d

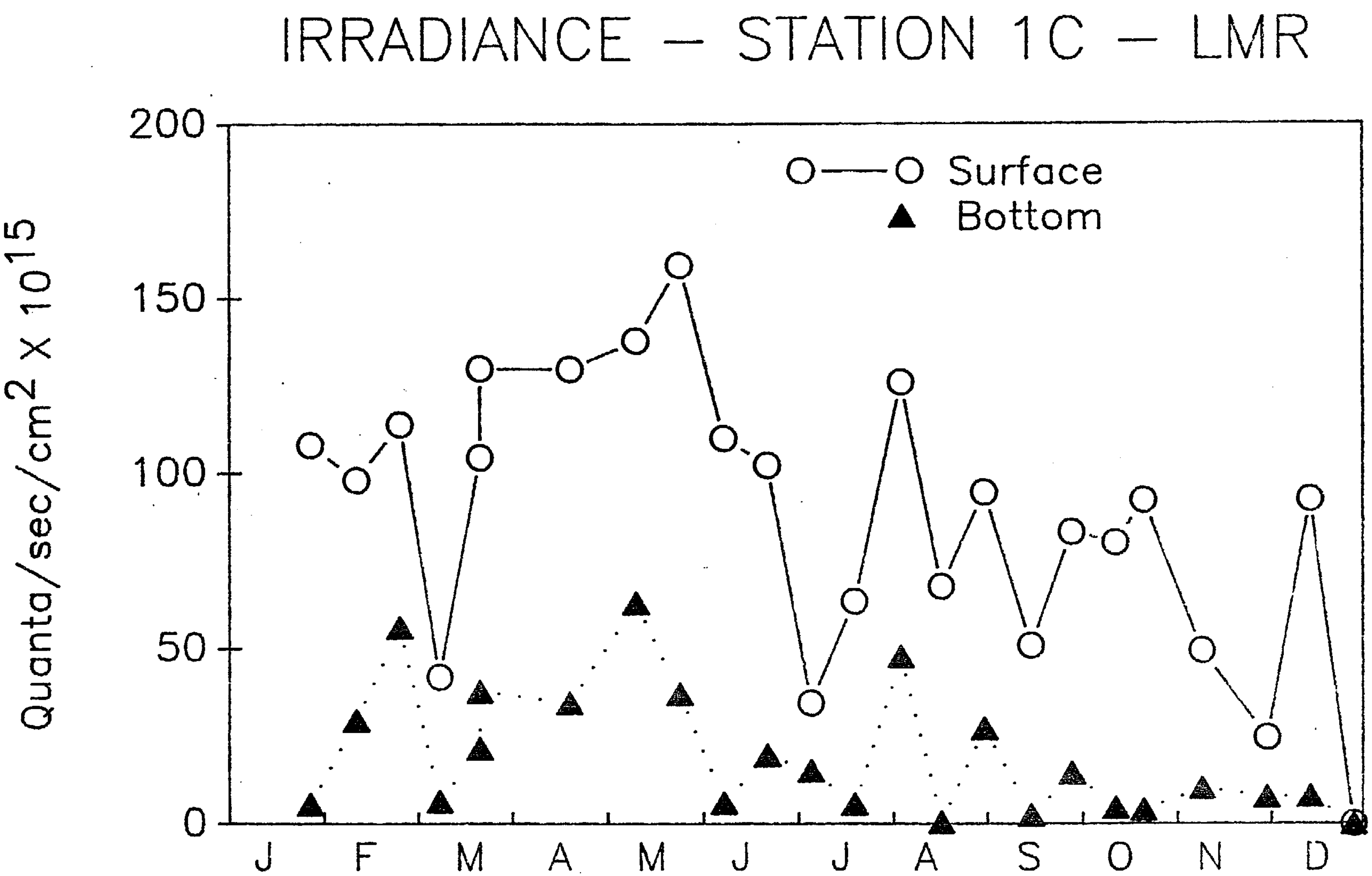

IRRADIANCE – STATION 1C – LMR
Surface
Bottom
Quanta/sec/cm^2 x 10^{15}
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 8e

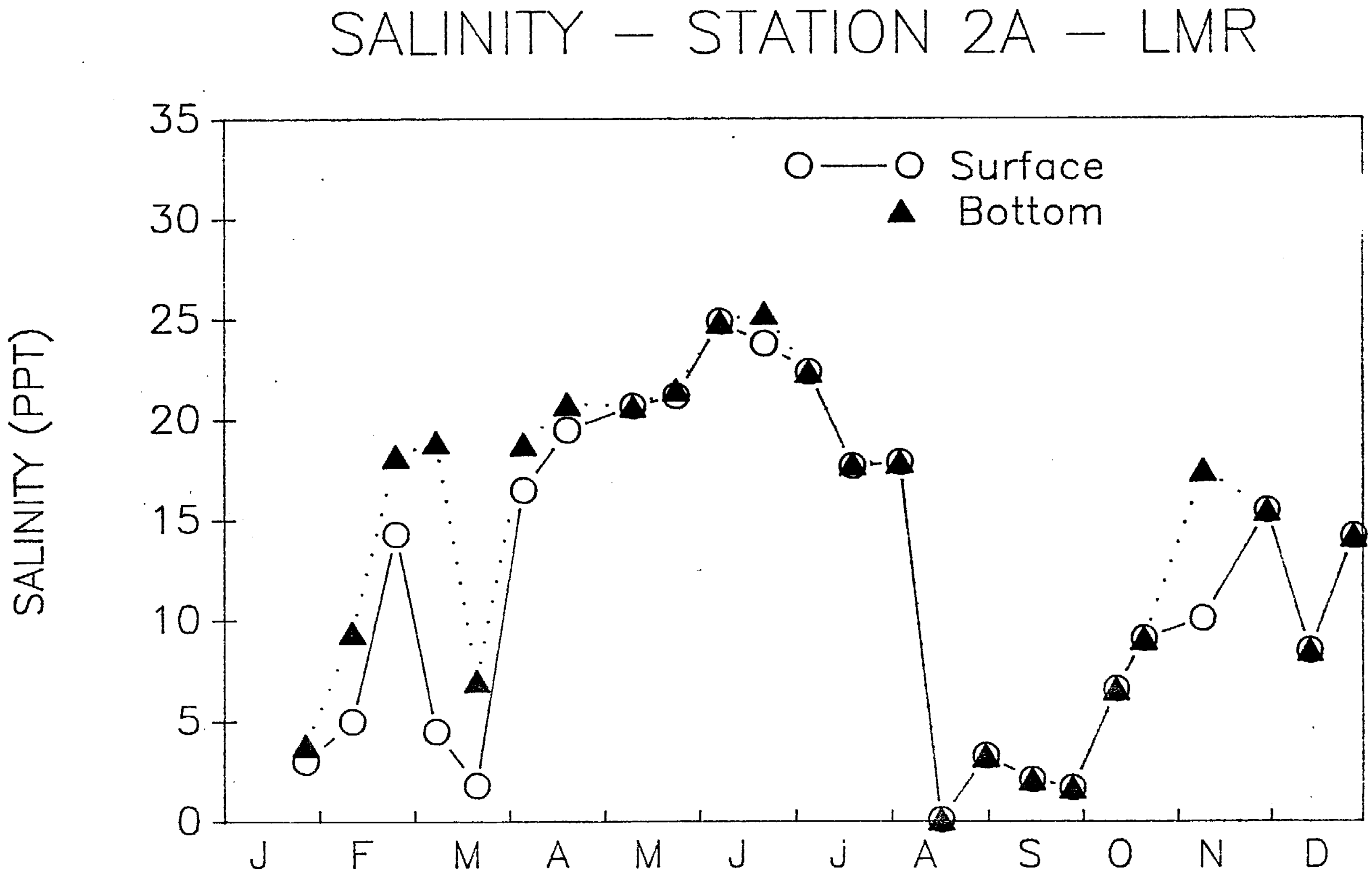

SALINITY - STATION 2A - LMR
Surface
Bottom
SALINITY (PPT)
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 9a

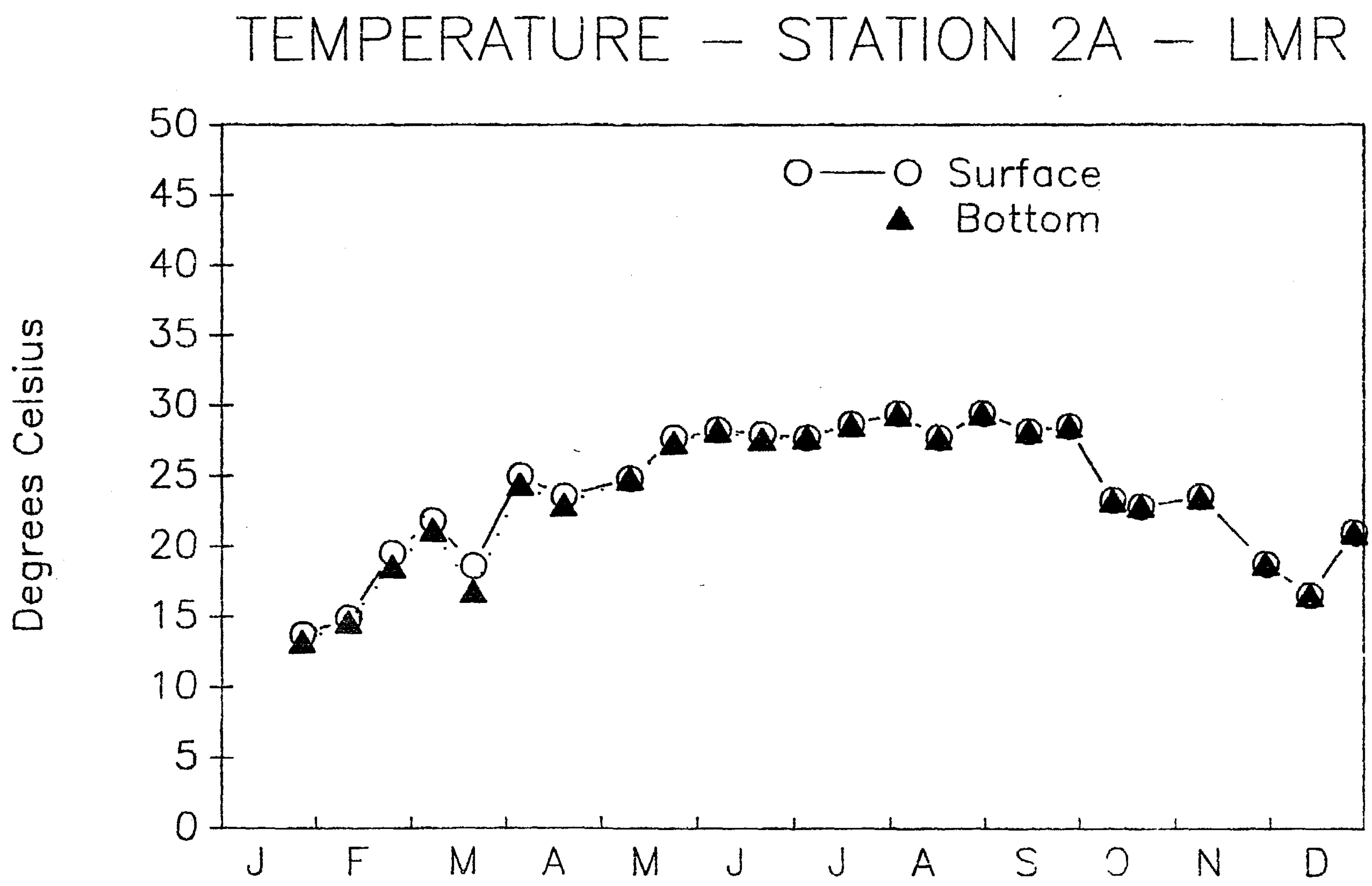

TEMPERATURE - STATION 2A - LMR
O—O Surface
▲ Bottom
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
J F M A M J J A S O N D

Figure 9b

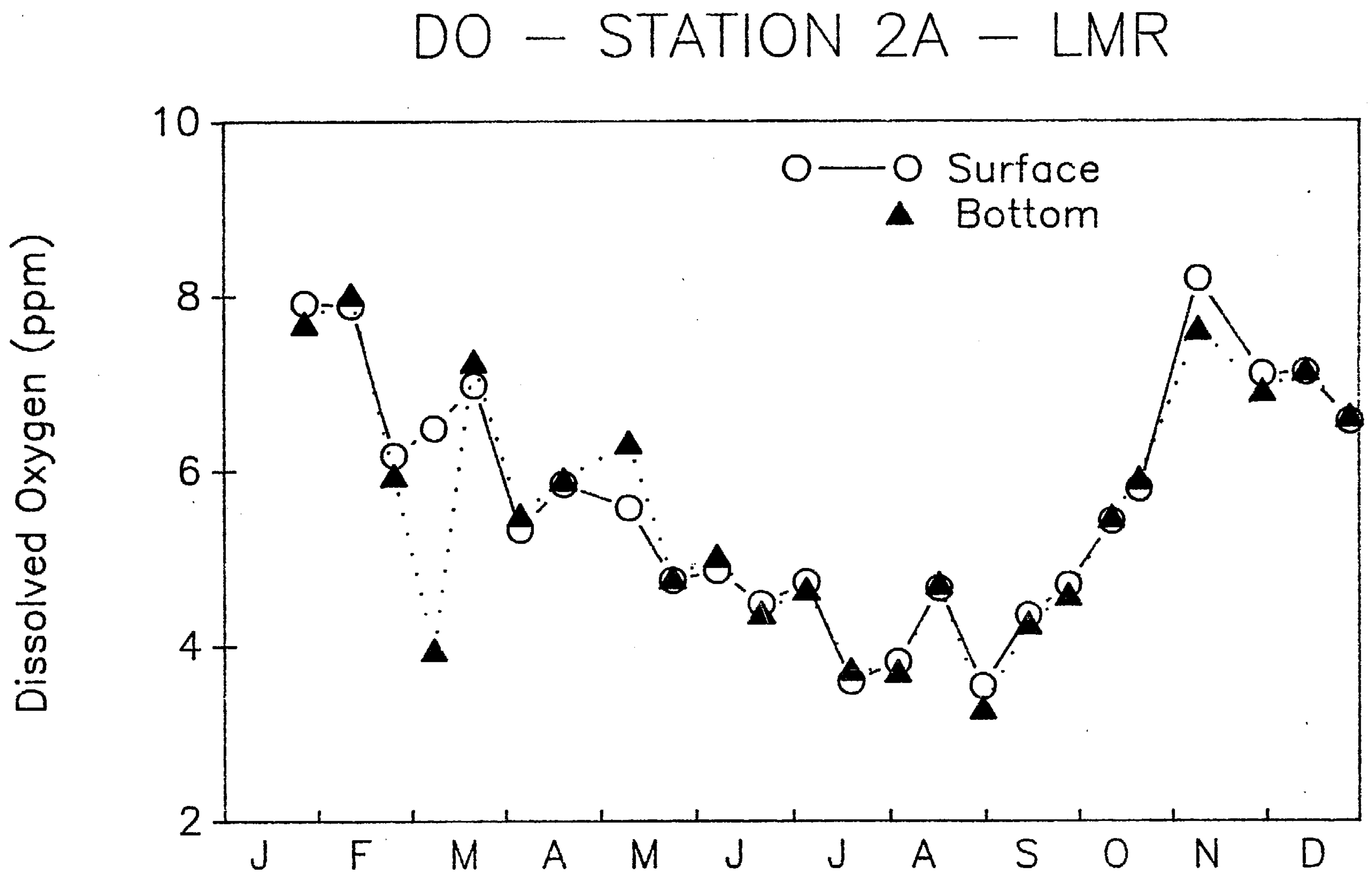

DO — STATION 2A — LMR
Surface
Bottom
Dissolved Oxygen (ppm)
10
8
6
4
2
J
F
M
A
M
J
J
A
S
O
N
D

Figure 9c

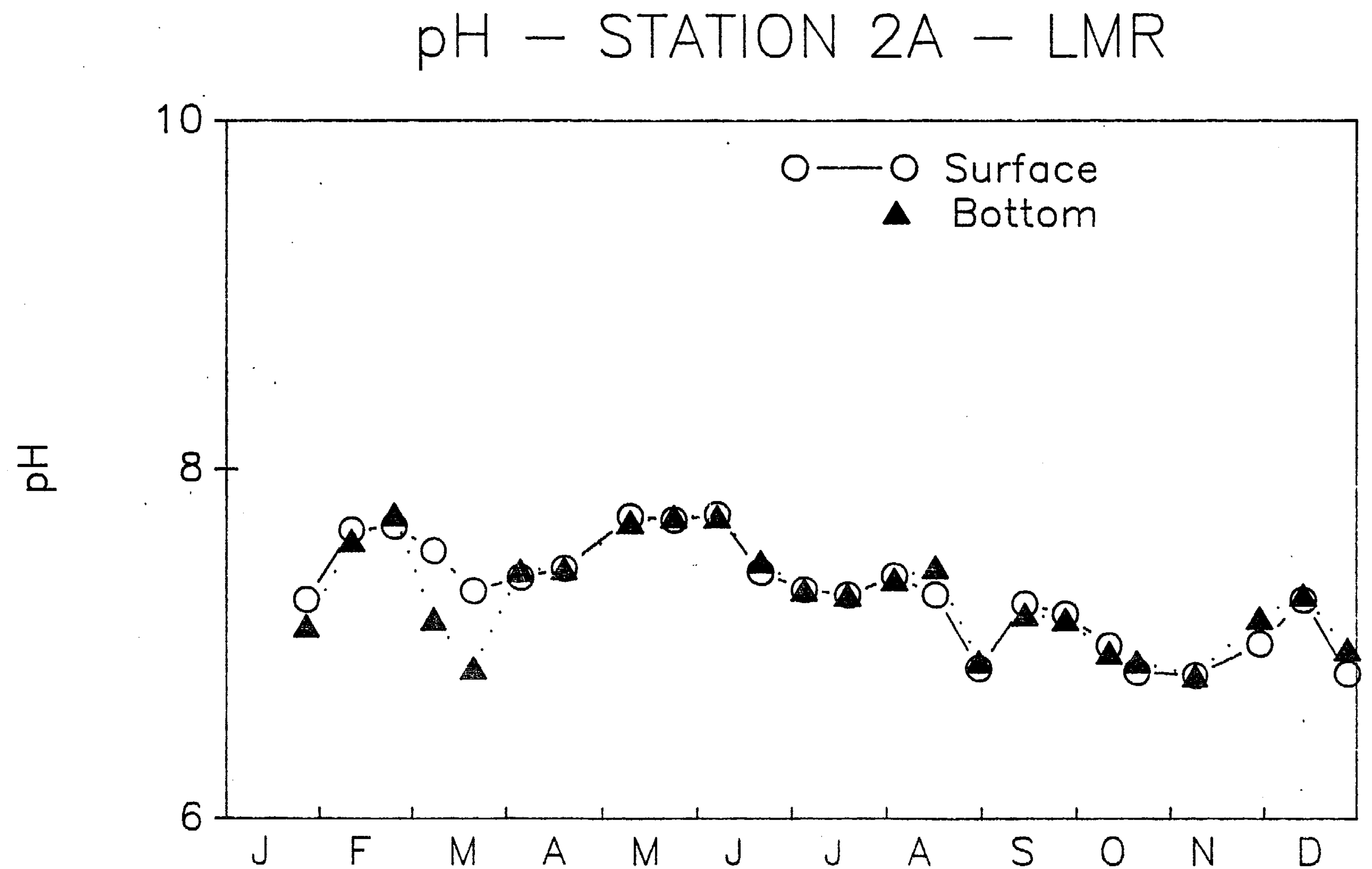


Figure 9d

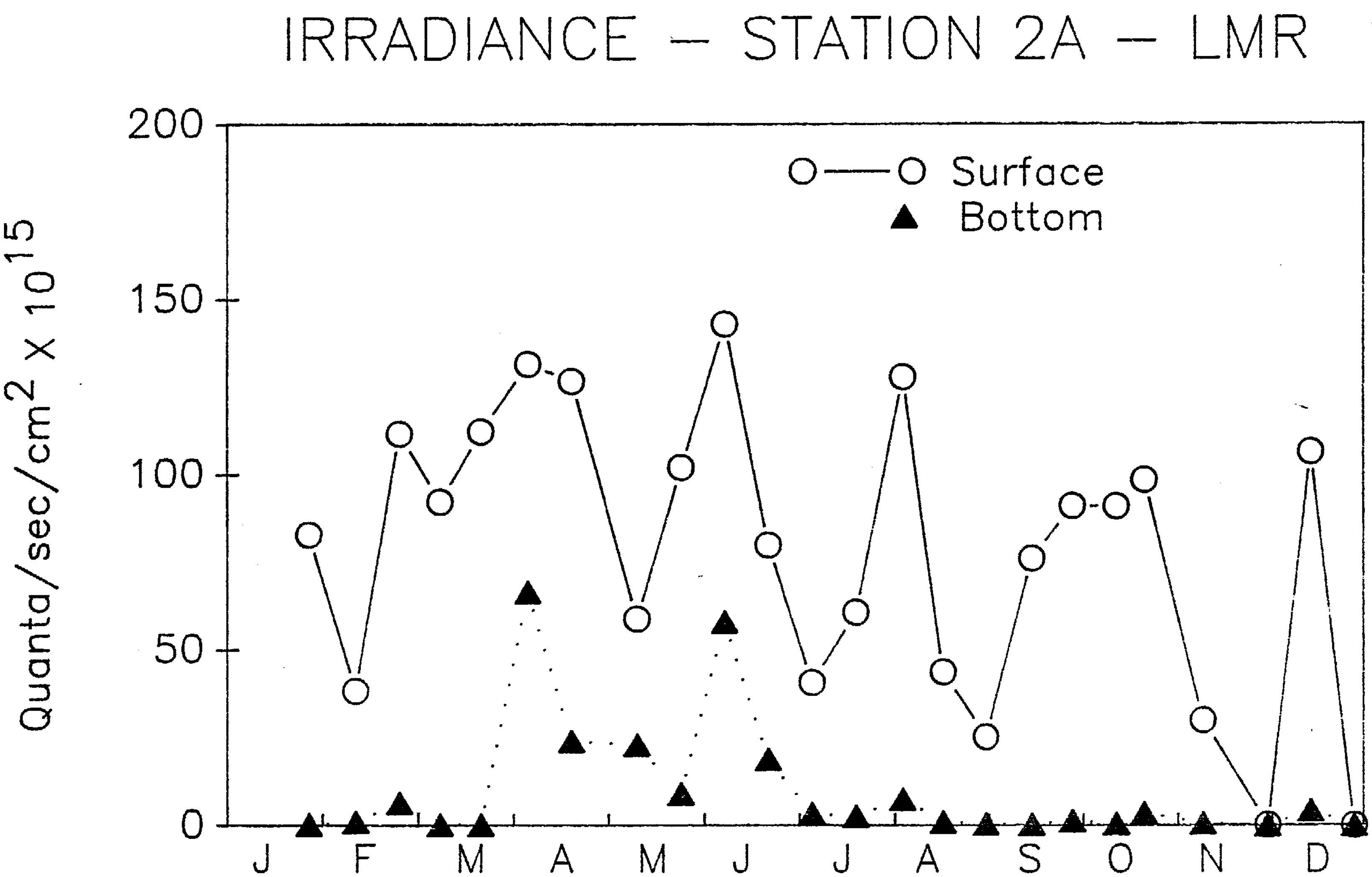

IRRADIANCE – STATION 2A – LMR
Surface
Bottom
Quanta/sec/cm2 X 10^15
0
50
100
150
200
J
F
M
A
M
J
J
A
S
O
N
D

Figure 9e

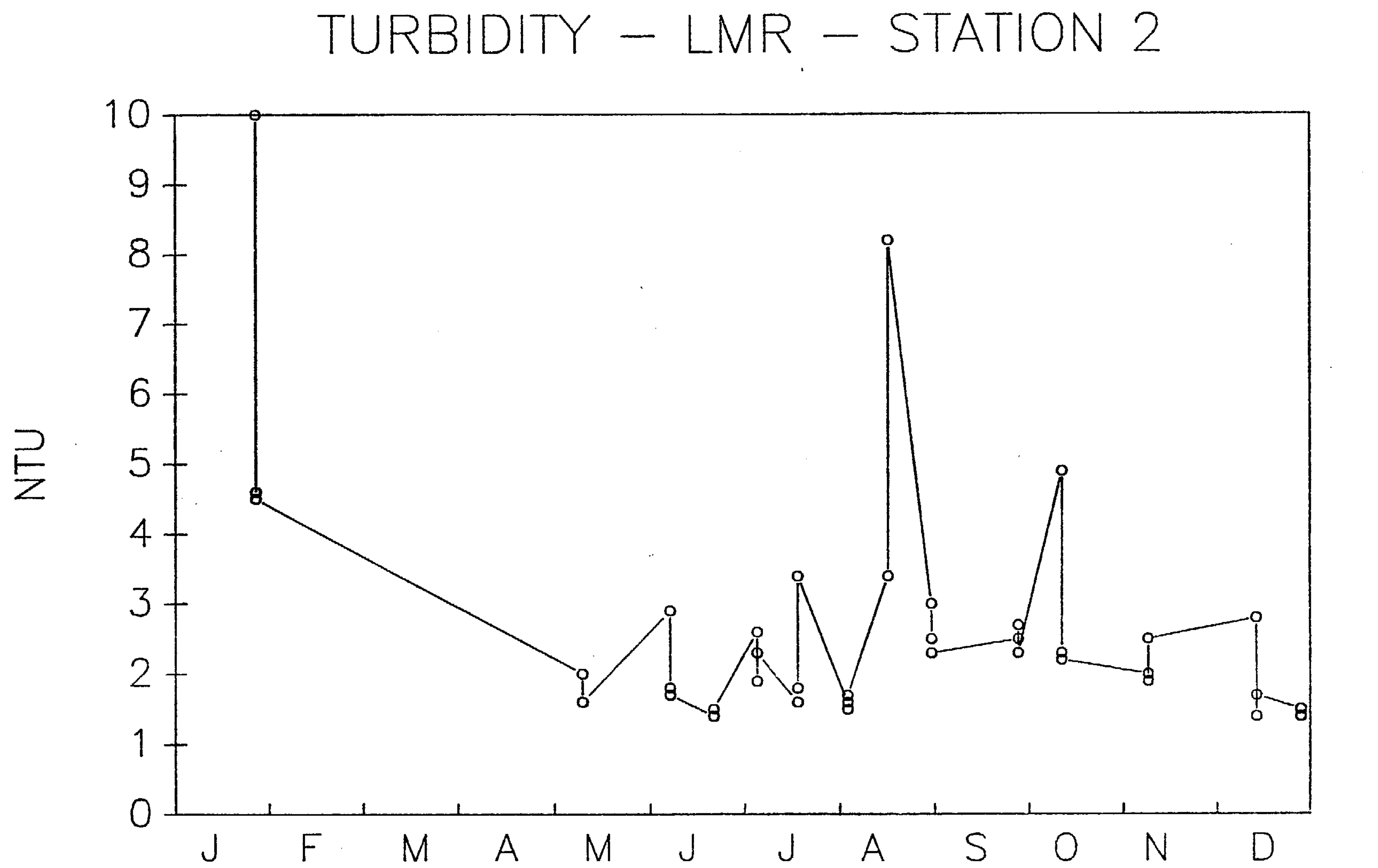


Figure 9f

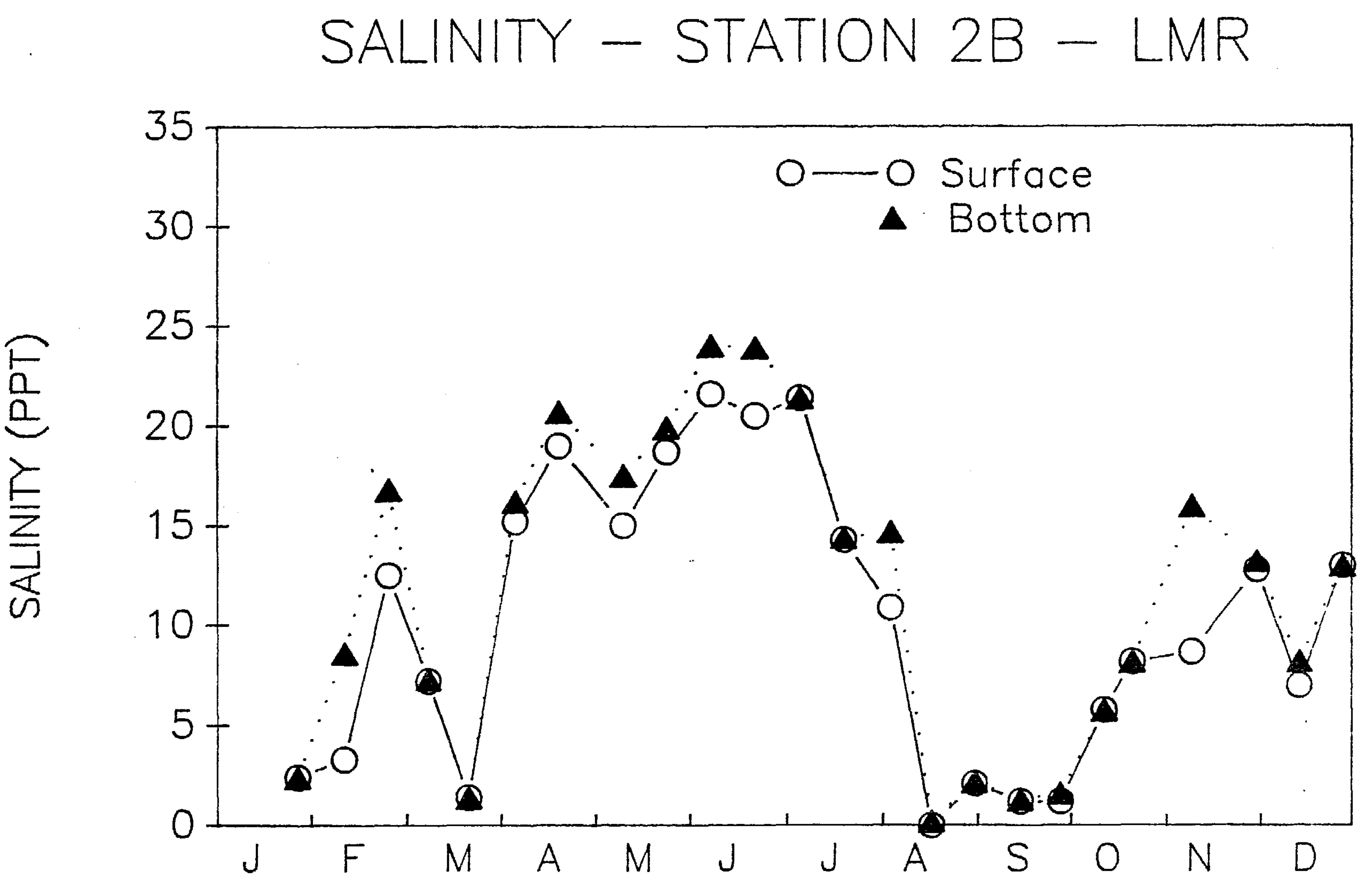

SALINITY - STATION 2B - LMR
SALINITY (PPT)
35
30
25
20
15
10
5
0
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 10a

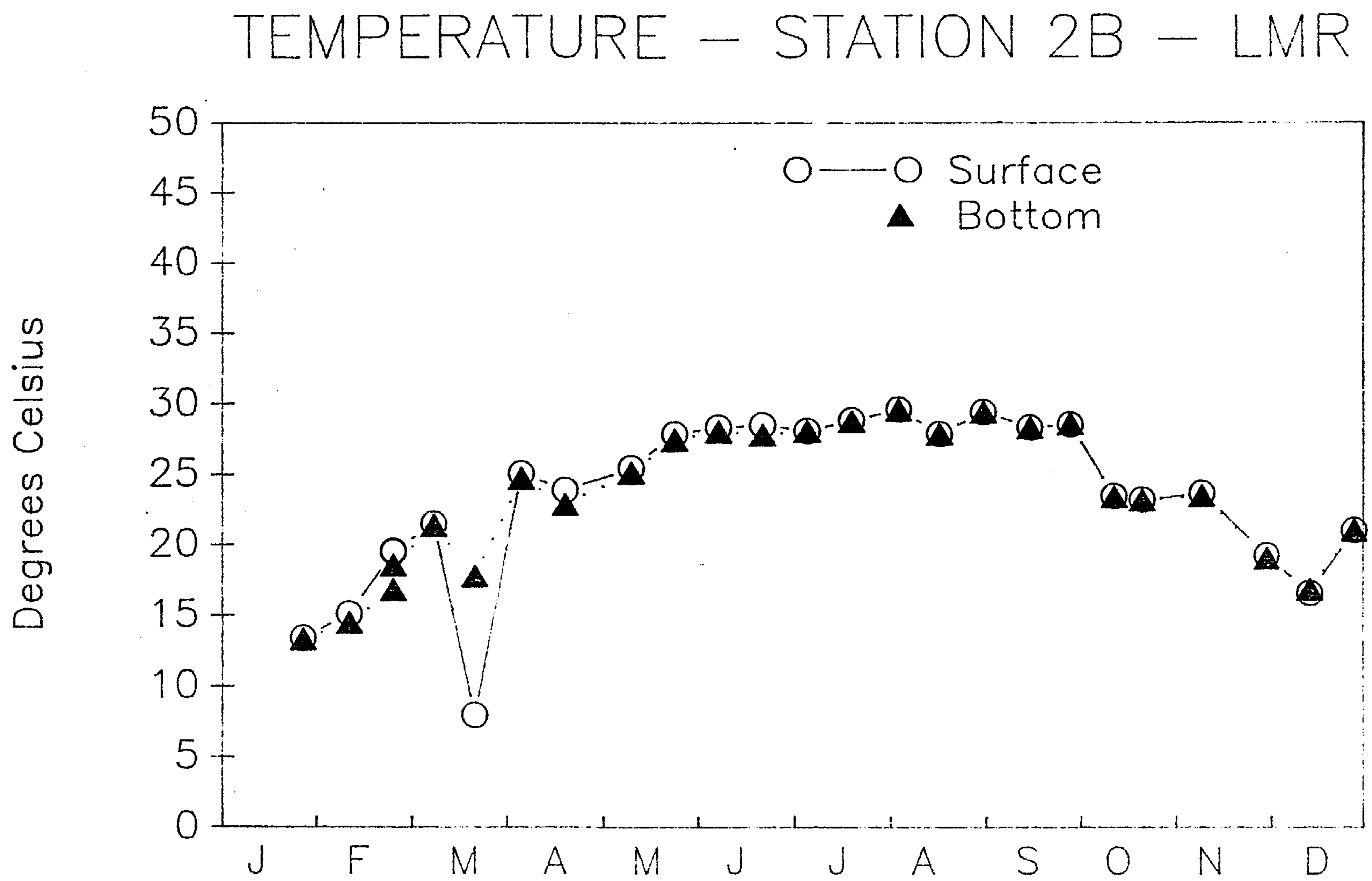

TEMPERATURE - STATION 2B - LMR
Surface
Bottom
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 10b

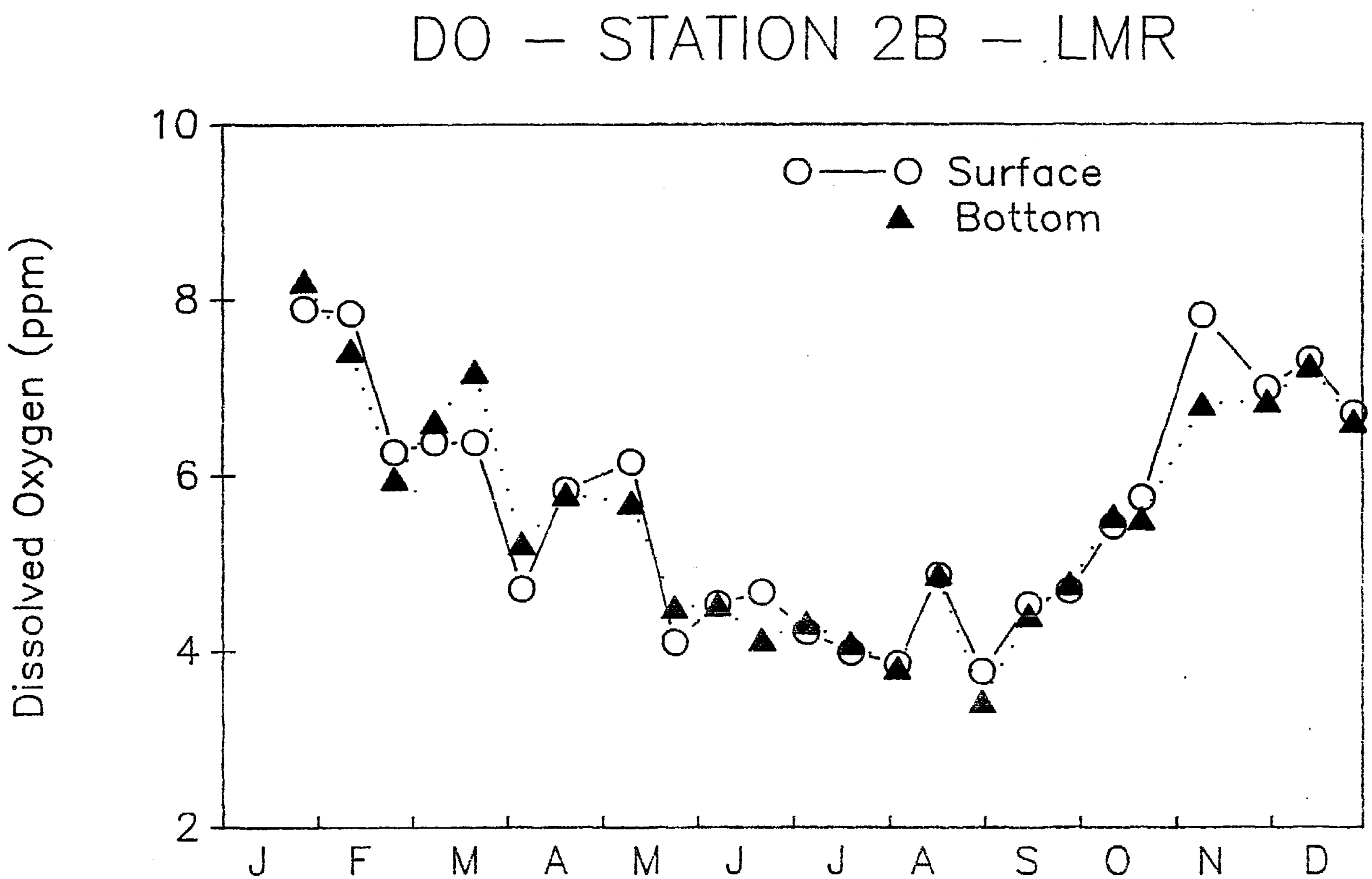

DO - STATION 2B - LMR
10
8
6
4
2
Dissolved Oxygen (ppm)
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 10c

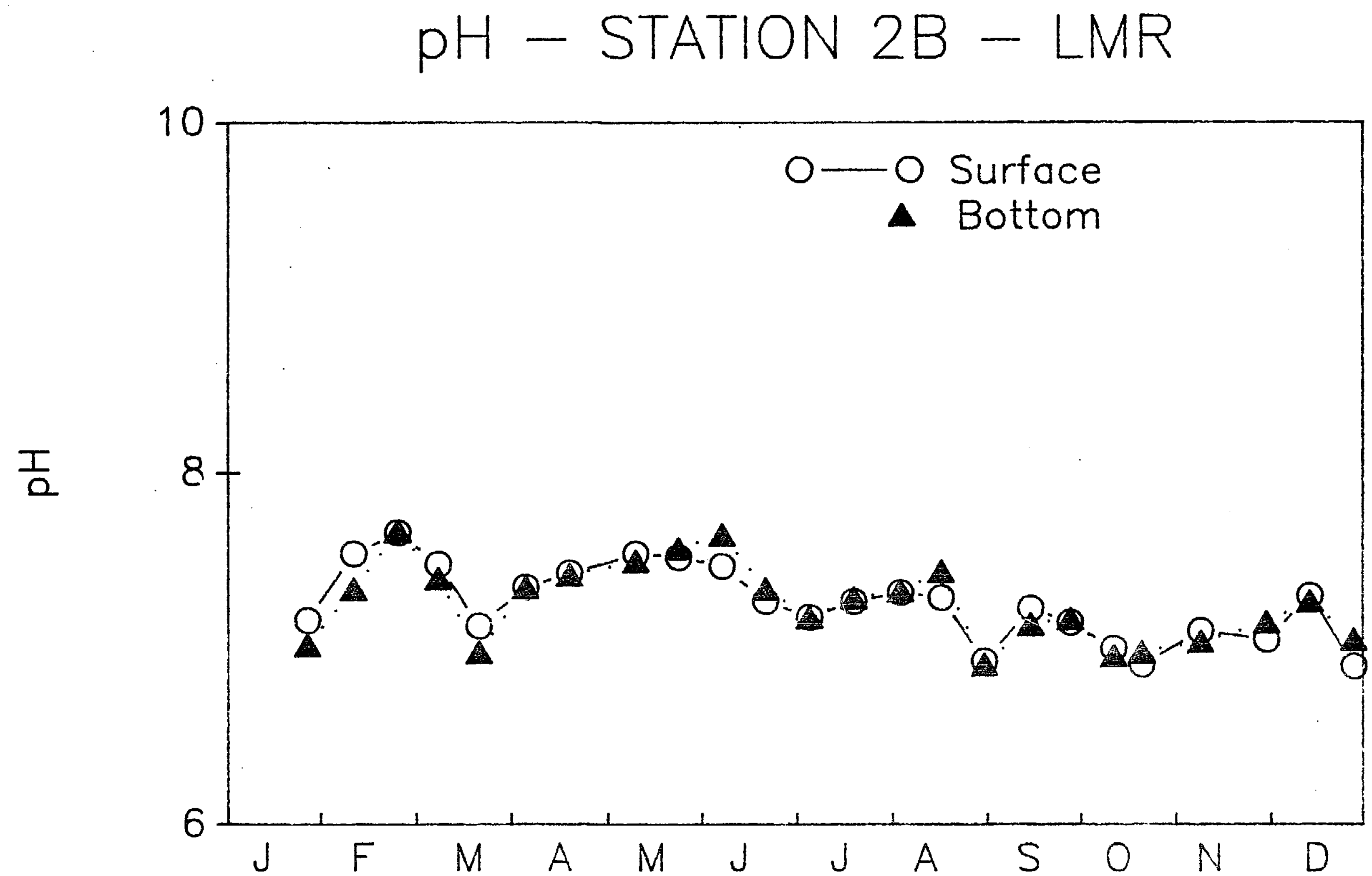


Figure 10d

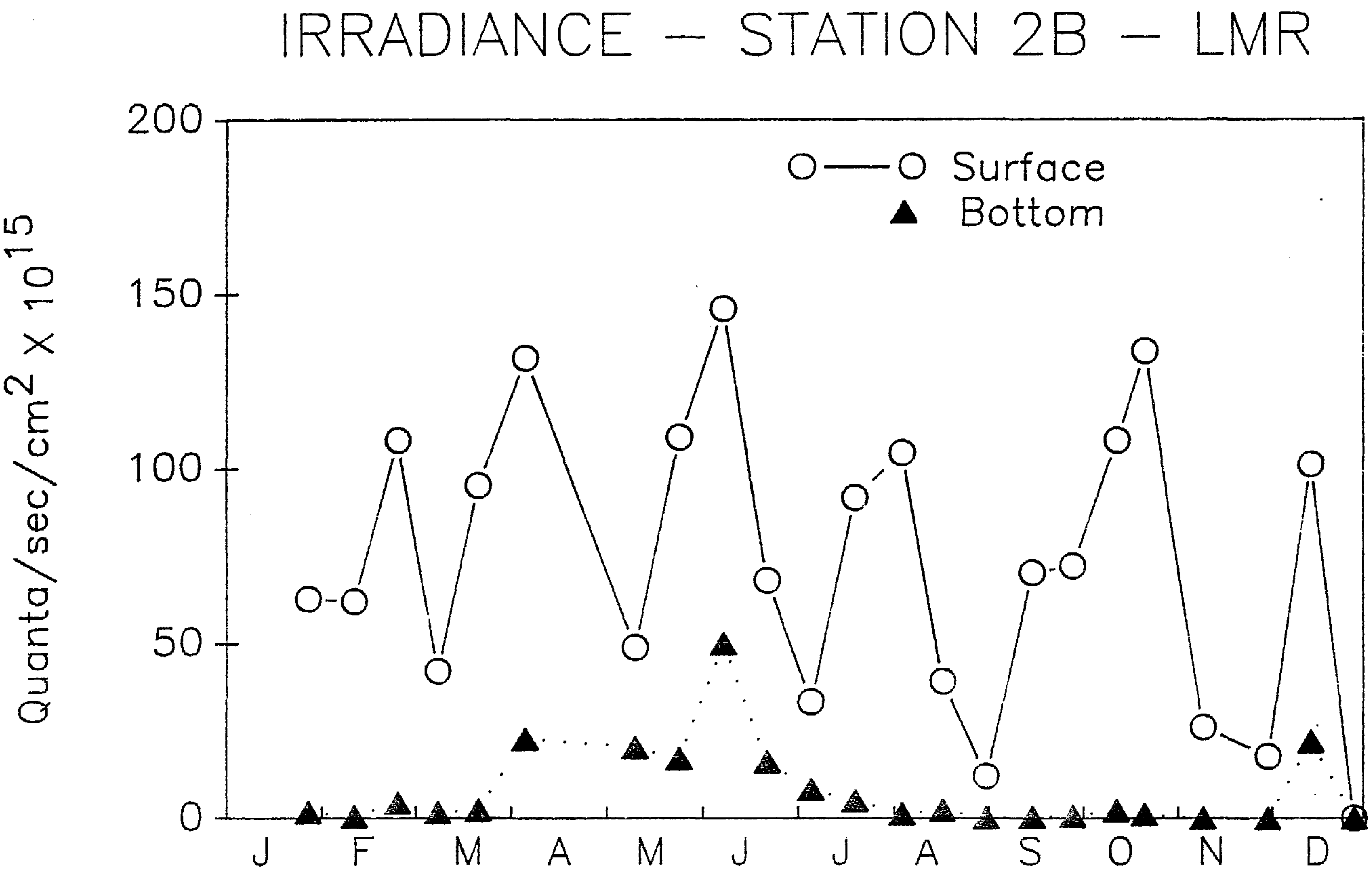

IRRADIANCE — STATION 2B — LMR
Surface
Bottom
Quanta/sec/cm2 X 1015
200
150
100
50
0
J F M A M J J A S O N D

Figure 10e

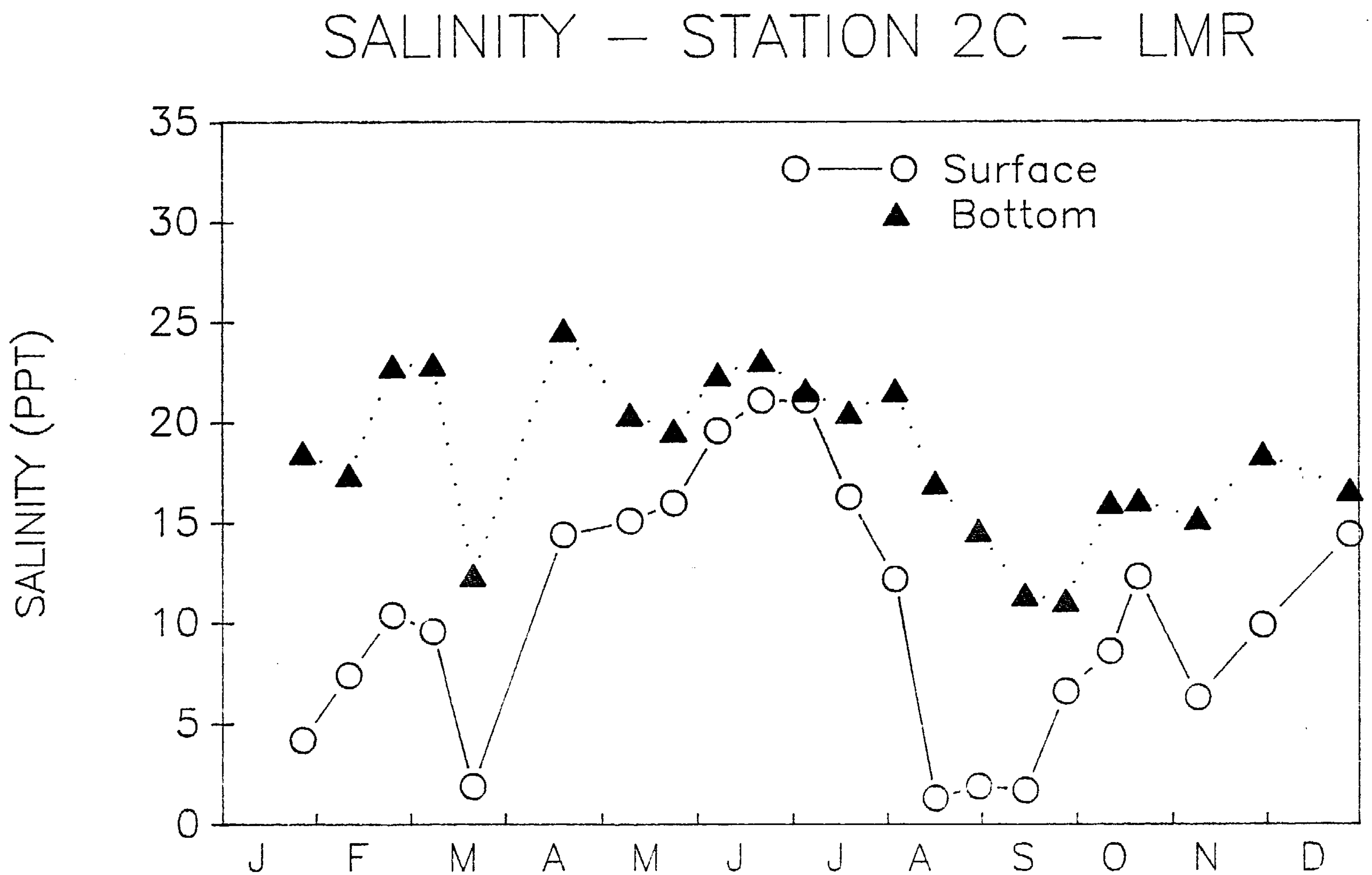
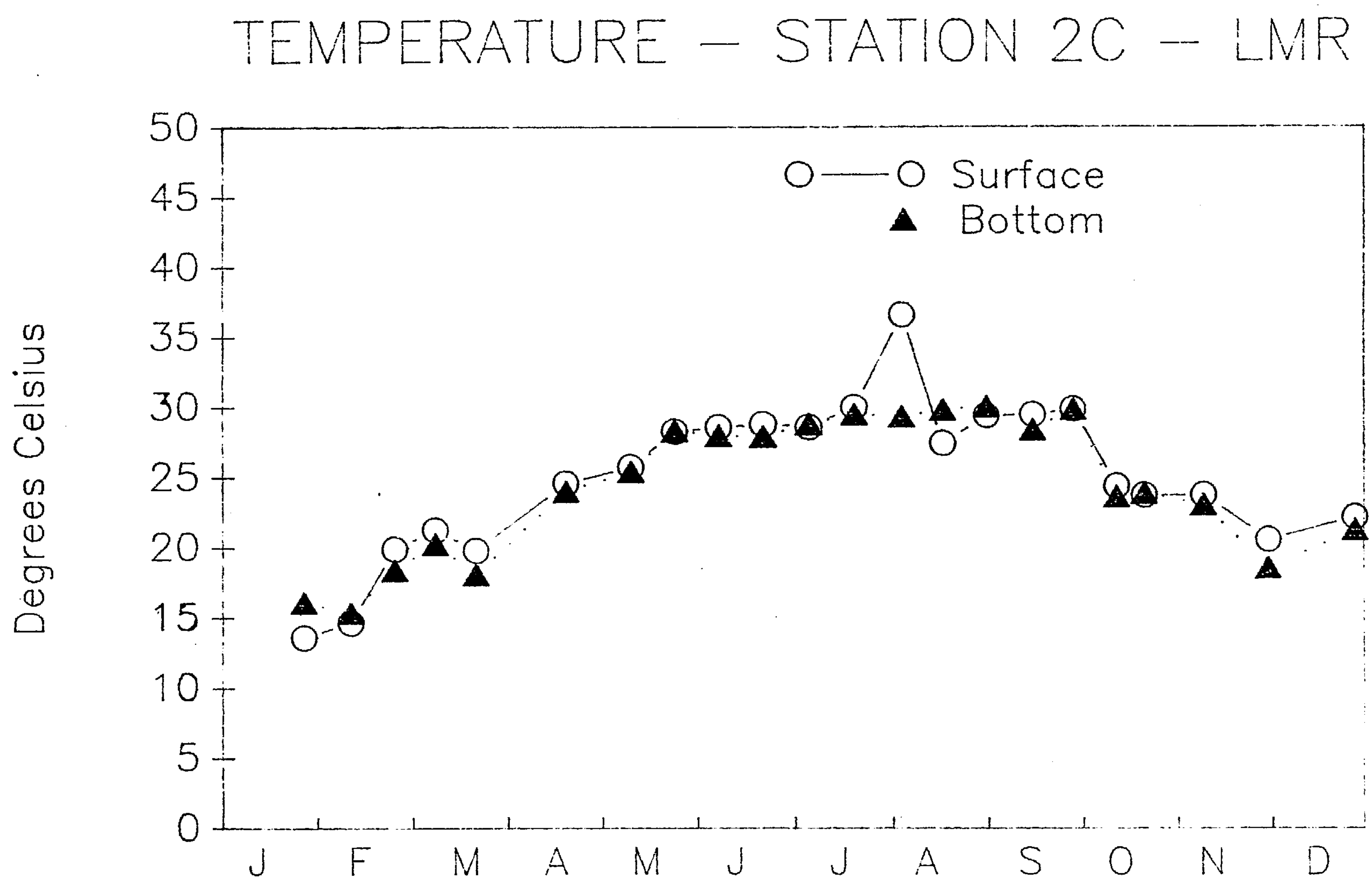

SALINITY - STATION 2C - LMR
Surface
Bottom
SALINITY (PPT)
35
30
25
20
15
10
5
0
J F M A M J J A S O N D

Figure 11a



TEMPERATURE – STATION 2C – LMR
Surface
Bottom
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 11b

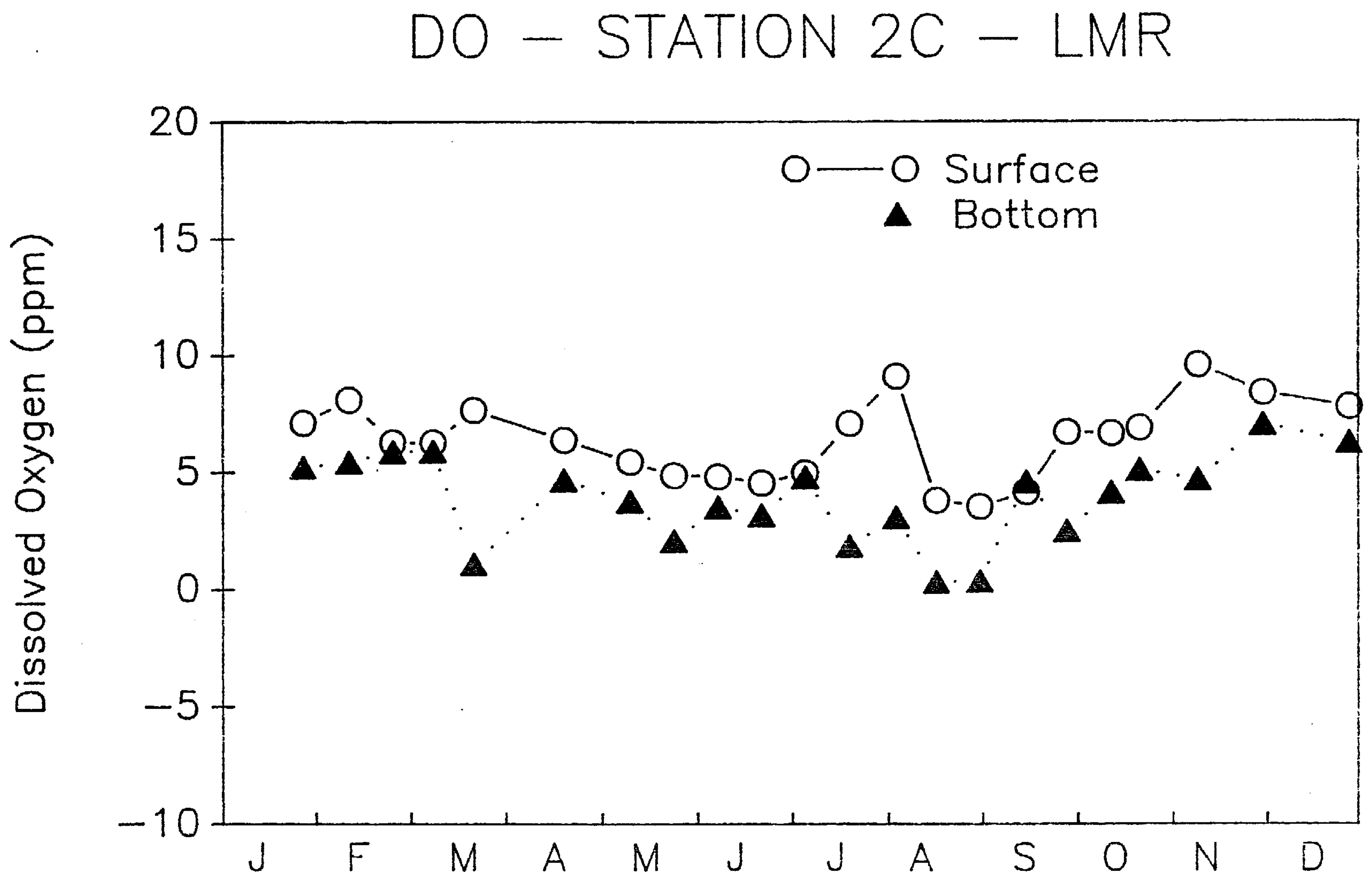

DO – STATION 2C – LMR
Surface
Bottom
Dissolved Oxygen (ppm)
20
15
10
5
0
−5
−10
J
F
M
A
M
J
J
A
S
O
N
D

Figure 11c

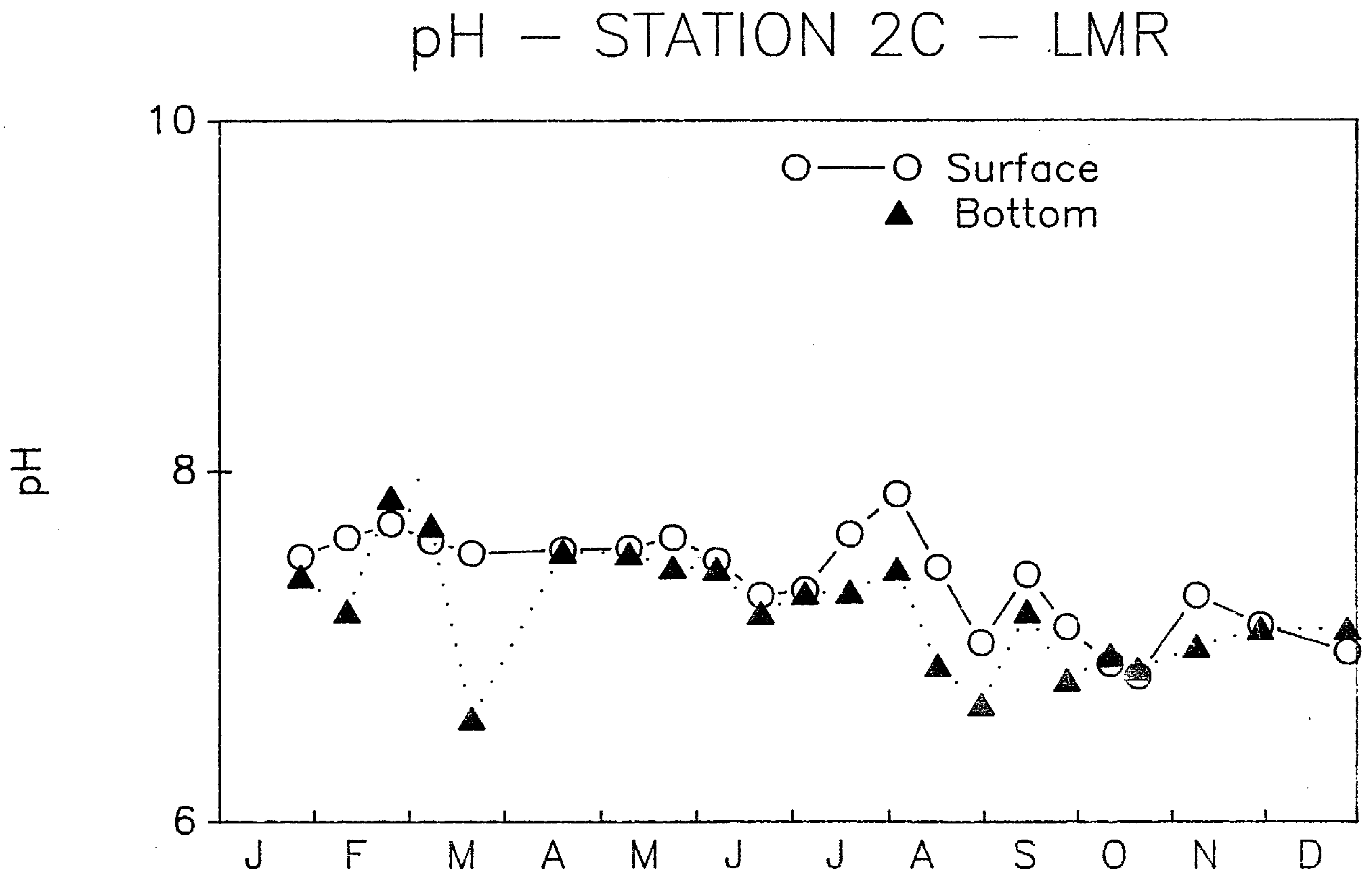


Figure 11d

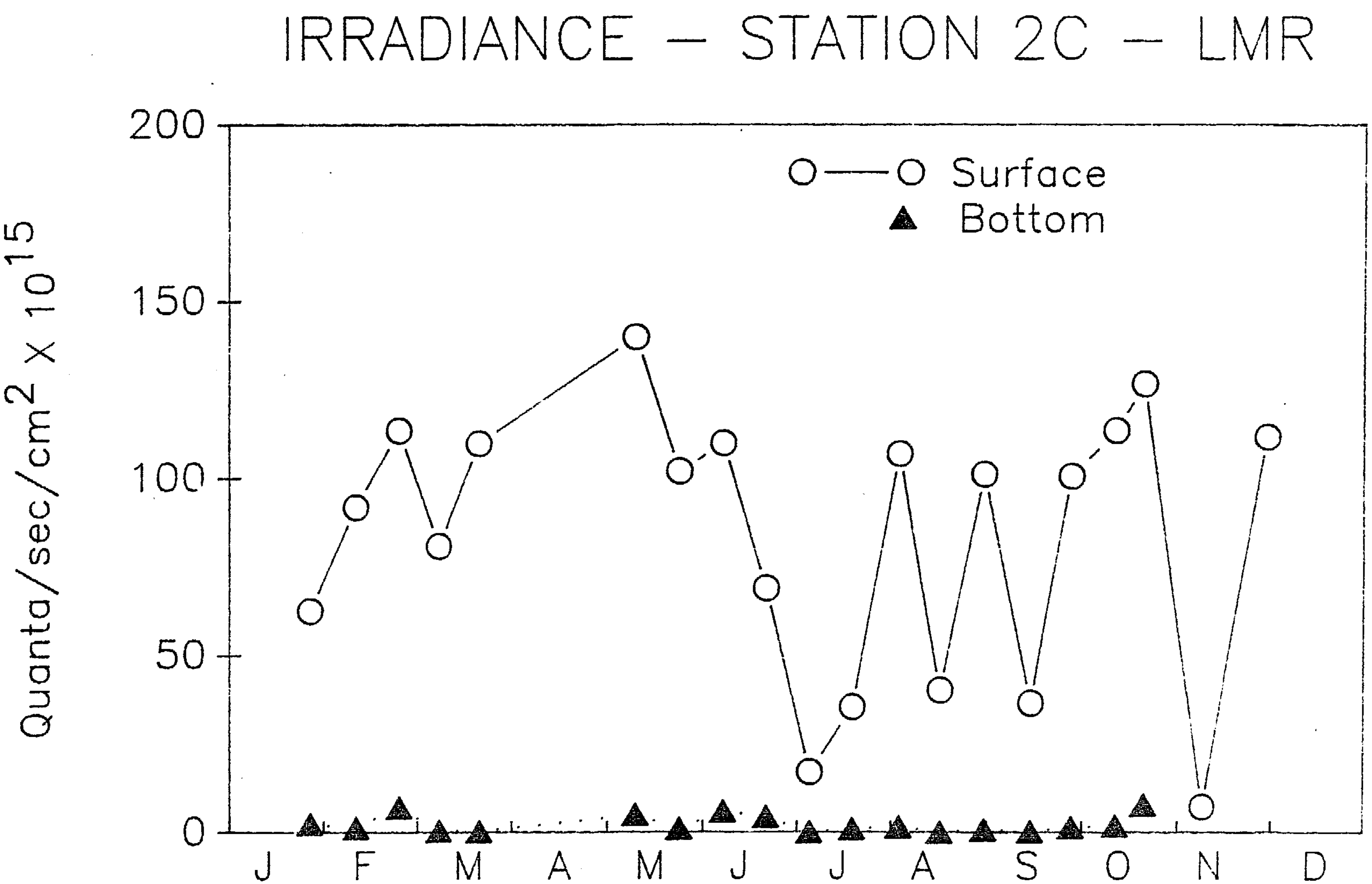

IRRADIANCE – STATION 2C – LMR
Surface
Bottom
Quanta/sec/cm^2 x 10^{15}
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 11e

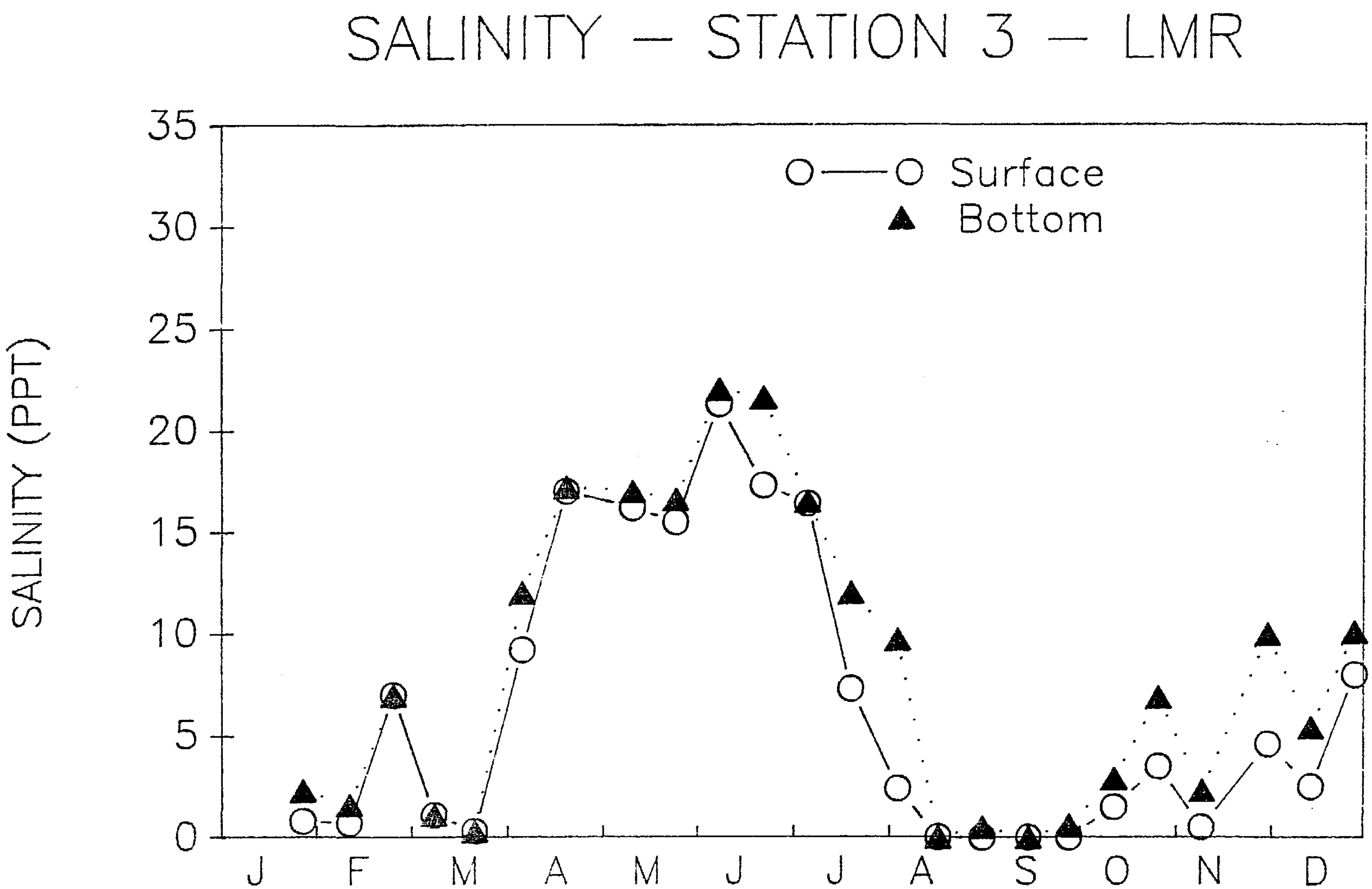
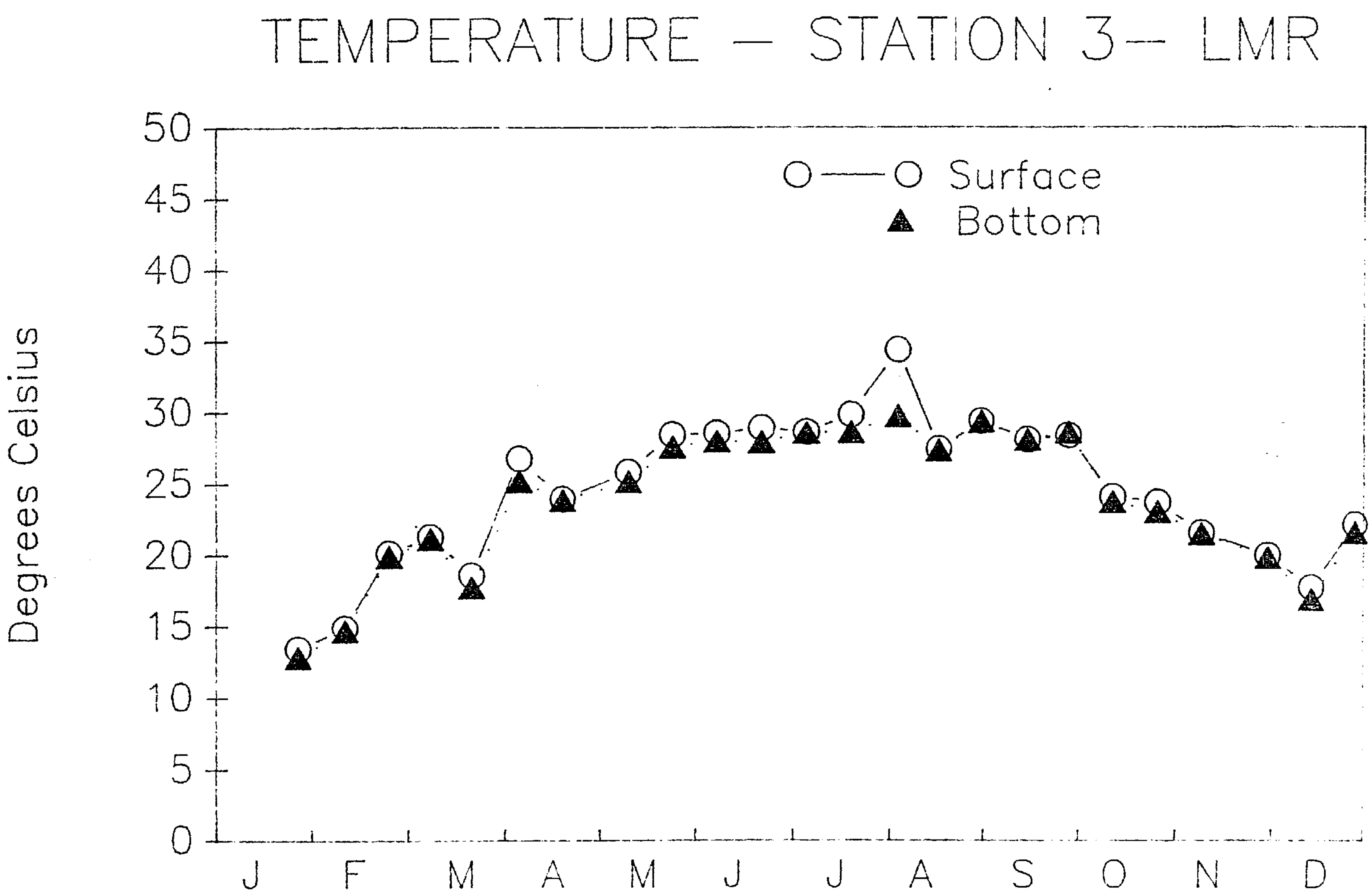

SALINITY - STATION 3 - LMR
35
30
25
20
15
10
5
0
SALINITY (PPT)
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 12a



TEMPERATURE — STATION 3— LMR
Surface
Bottom
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 12b

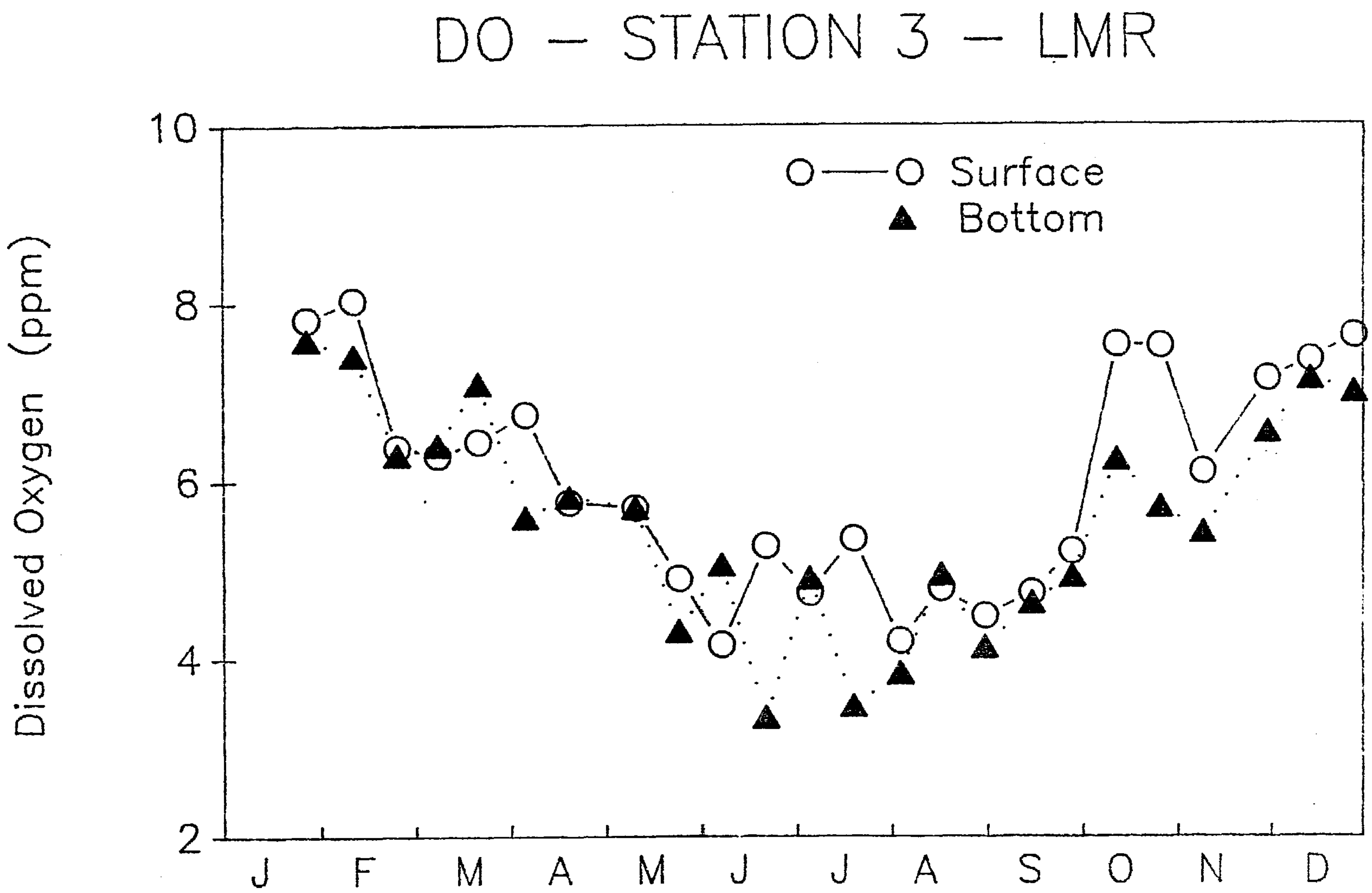

DO - STATION 3 - LMR
10
8
6
4
2
Dissolved Oxygen (ppm)
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 12c

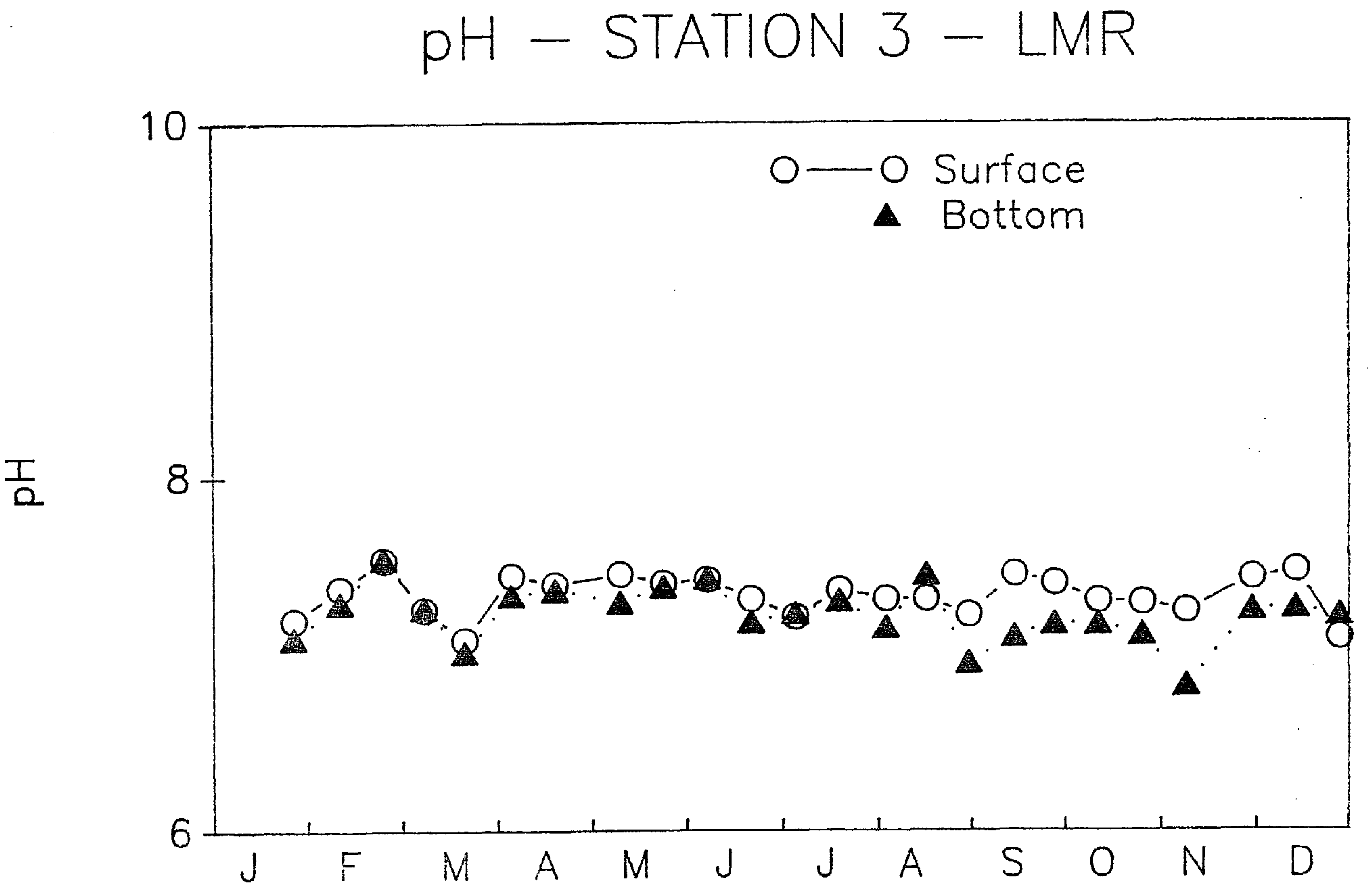
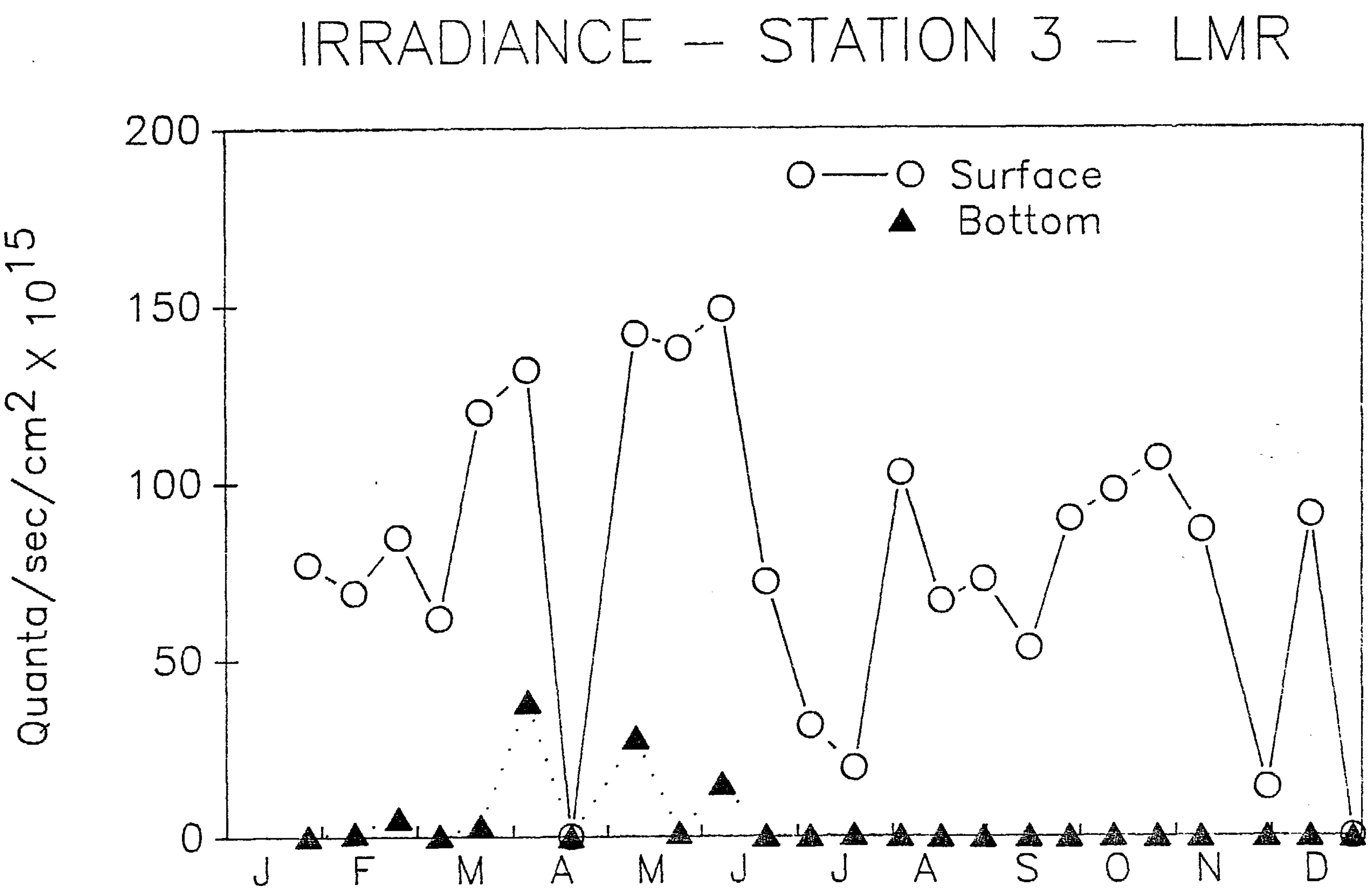


Figure 12d



IRRADIANCE – STATION 3 – LMR
Surface
Bottom
Quanta/sec/cm2 X 10 15
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 12e

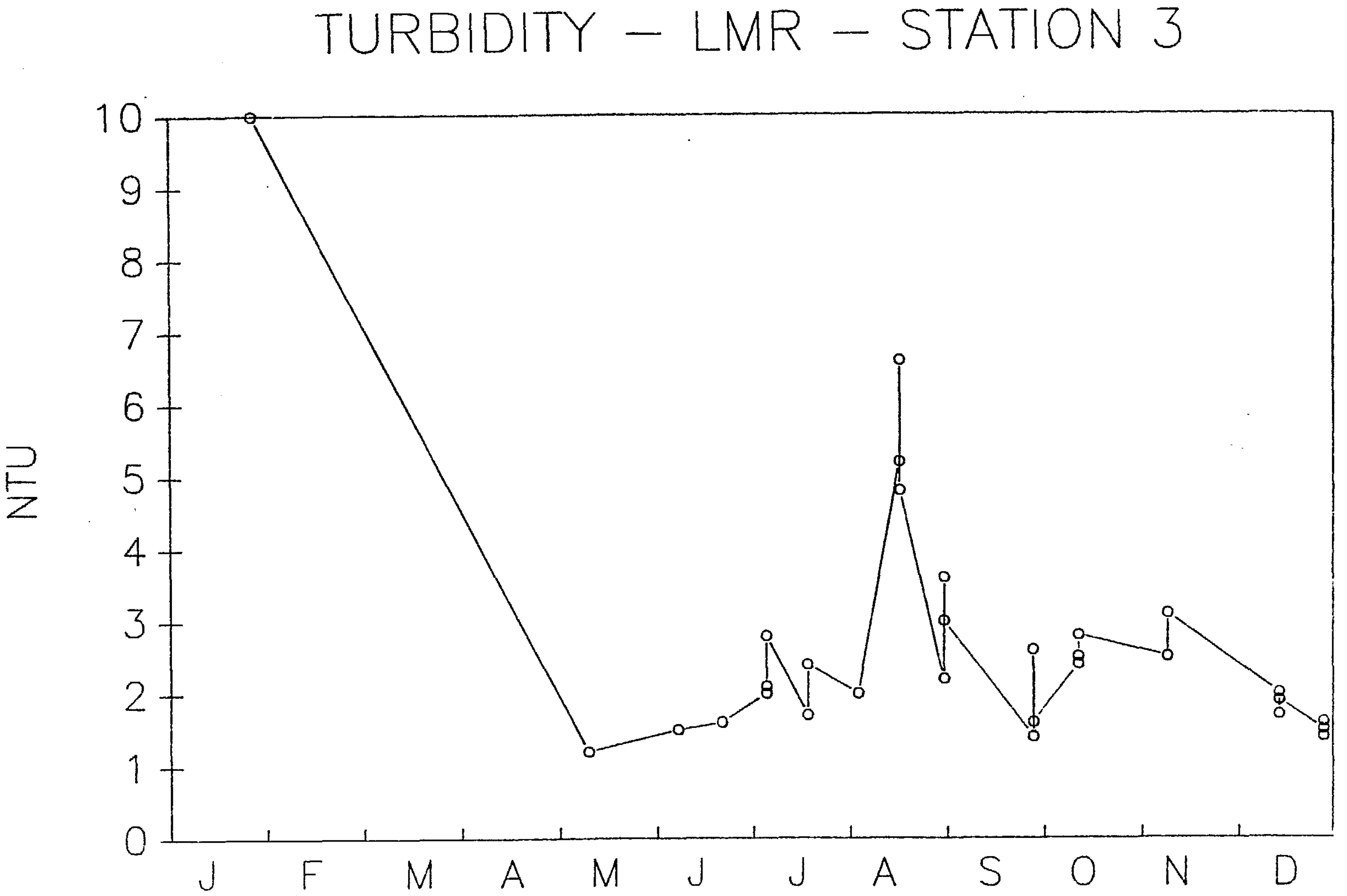
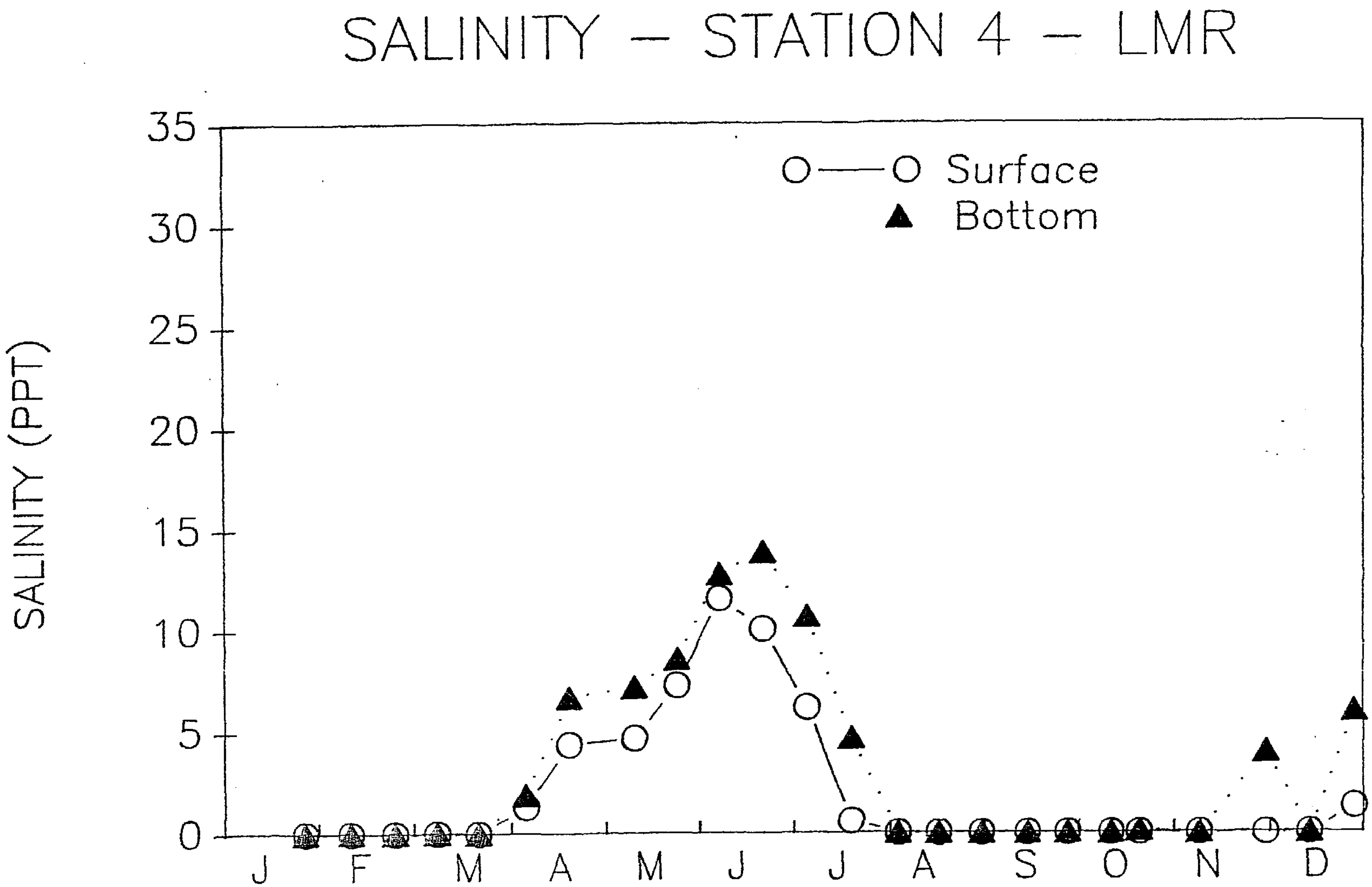


Figure 12f



SALINITY - STATION 4 - LMR
35
30
25
20
15
10
5
0
SALINITY (PPT)
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 13a

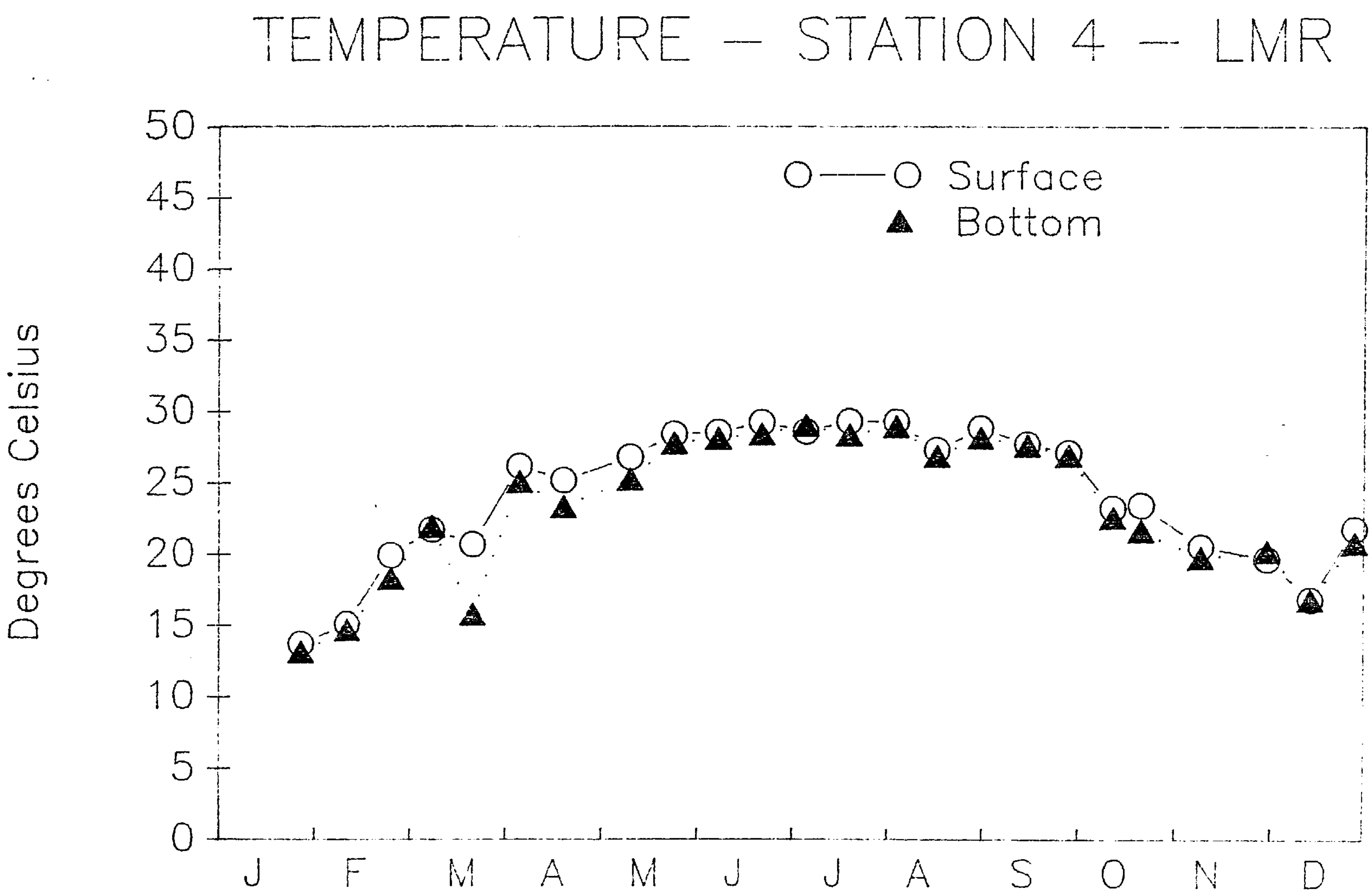

TEMPERATURE - STATION 4 - LMR
Surface
Bottom
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 13b

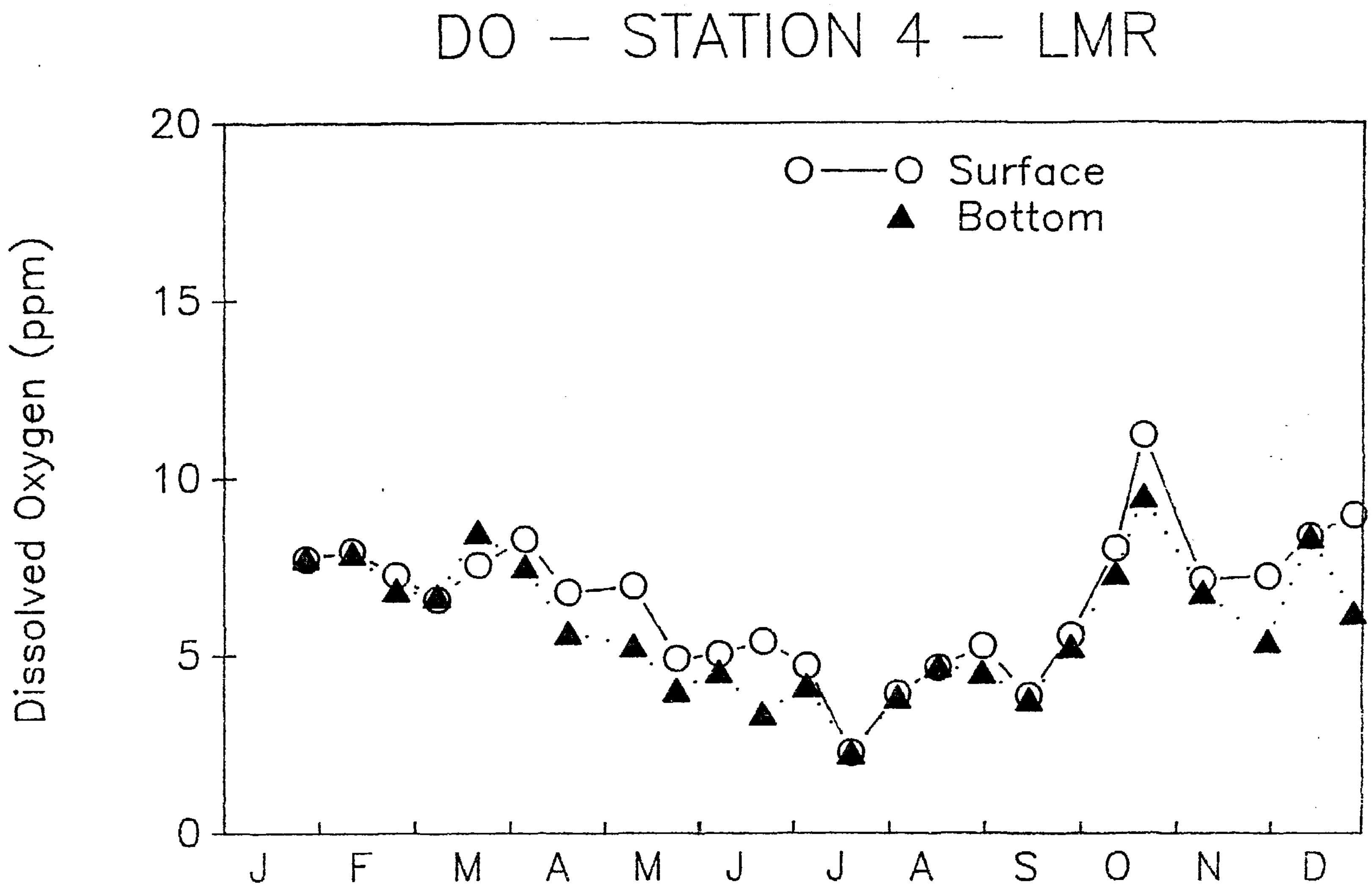

DO - STATION 4 - LMR
Surface
Bottom
Dissolved Oxygen (ppm)
0
5
10
15
20
J
F
M
A
M
J
J
A
S
O
N
D

Figure 13c

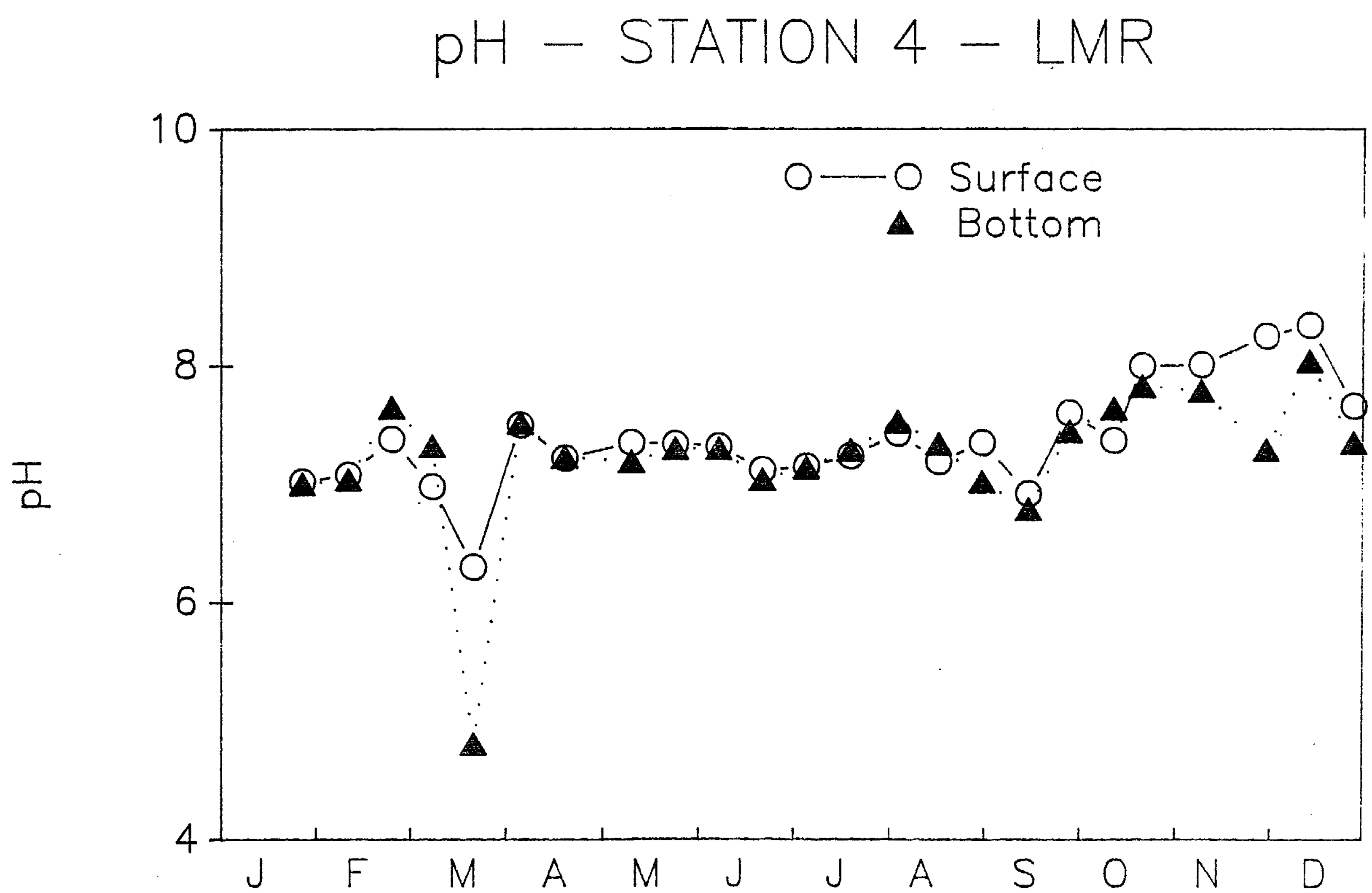


Figure 13d

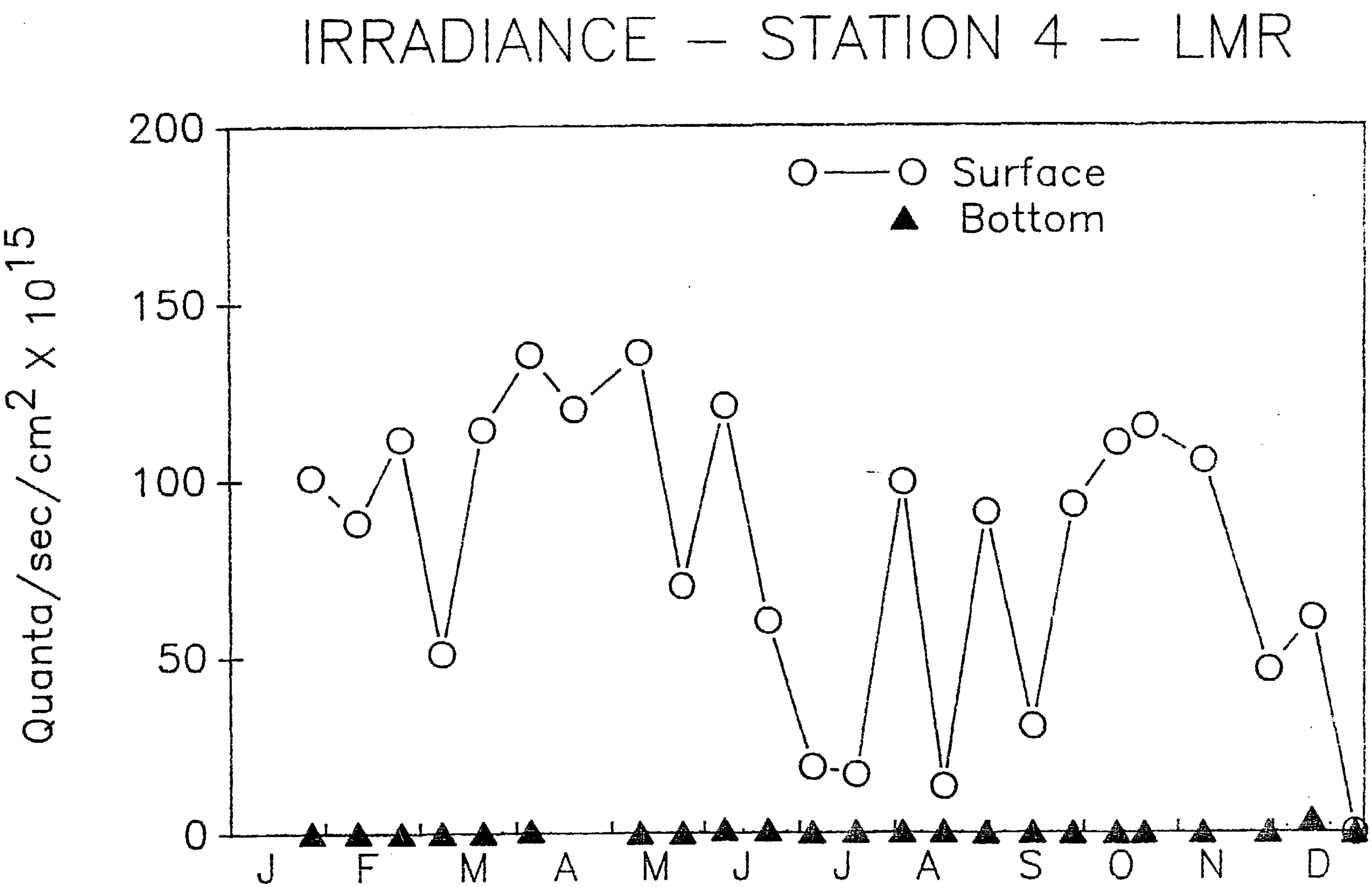

IRRADIANCE - STATION 4 - LMR
Surface
Bottom
Quanta/sec/cm^2 X 10^{15}
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 13e

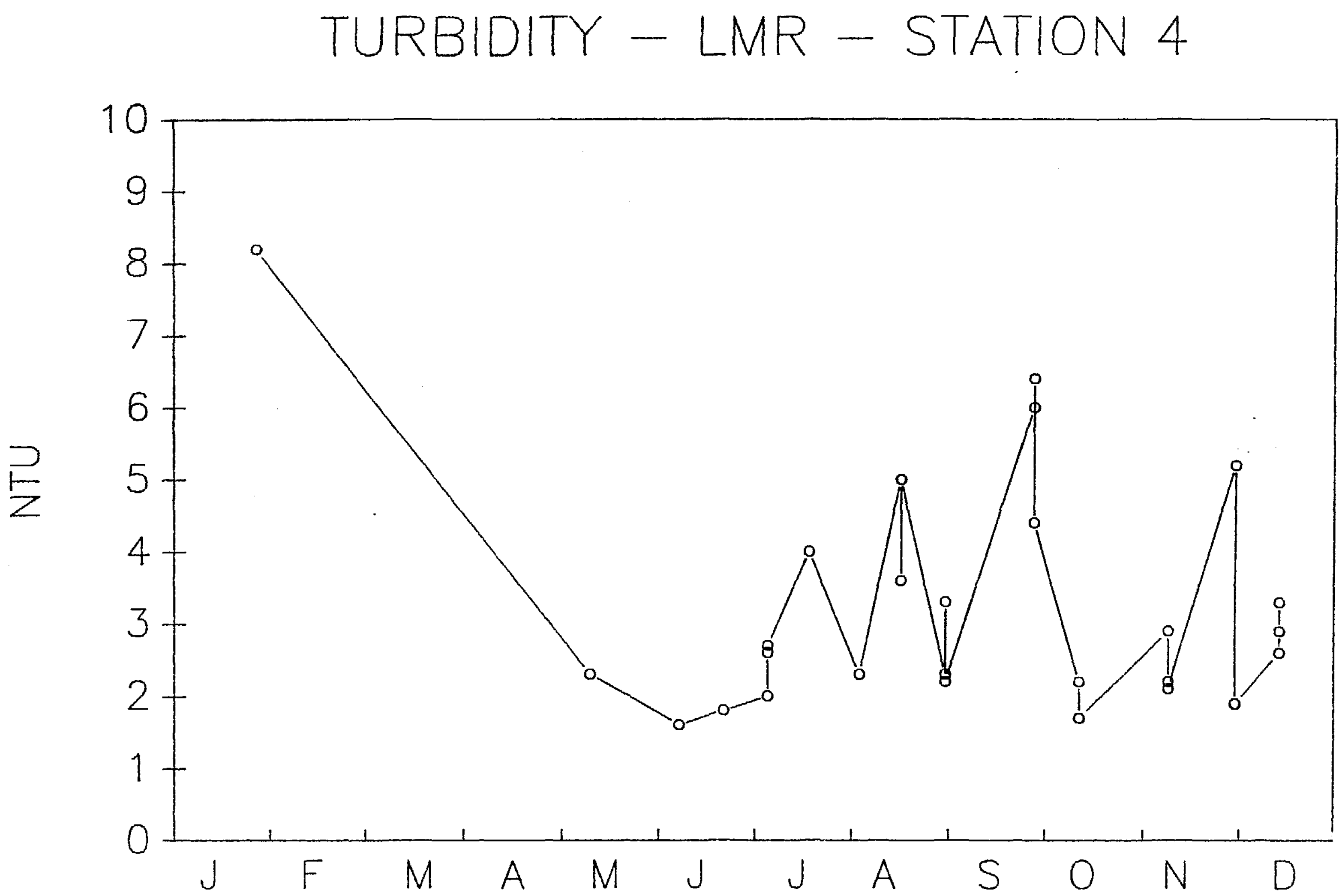


Figure 13f

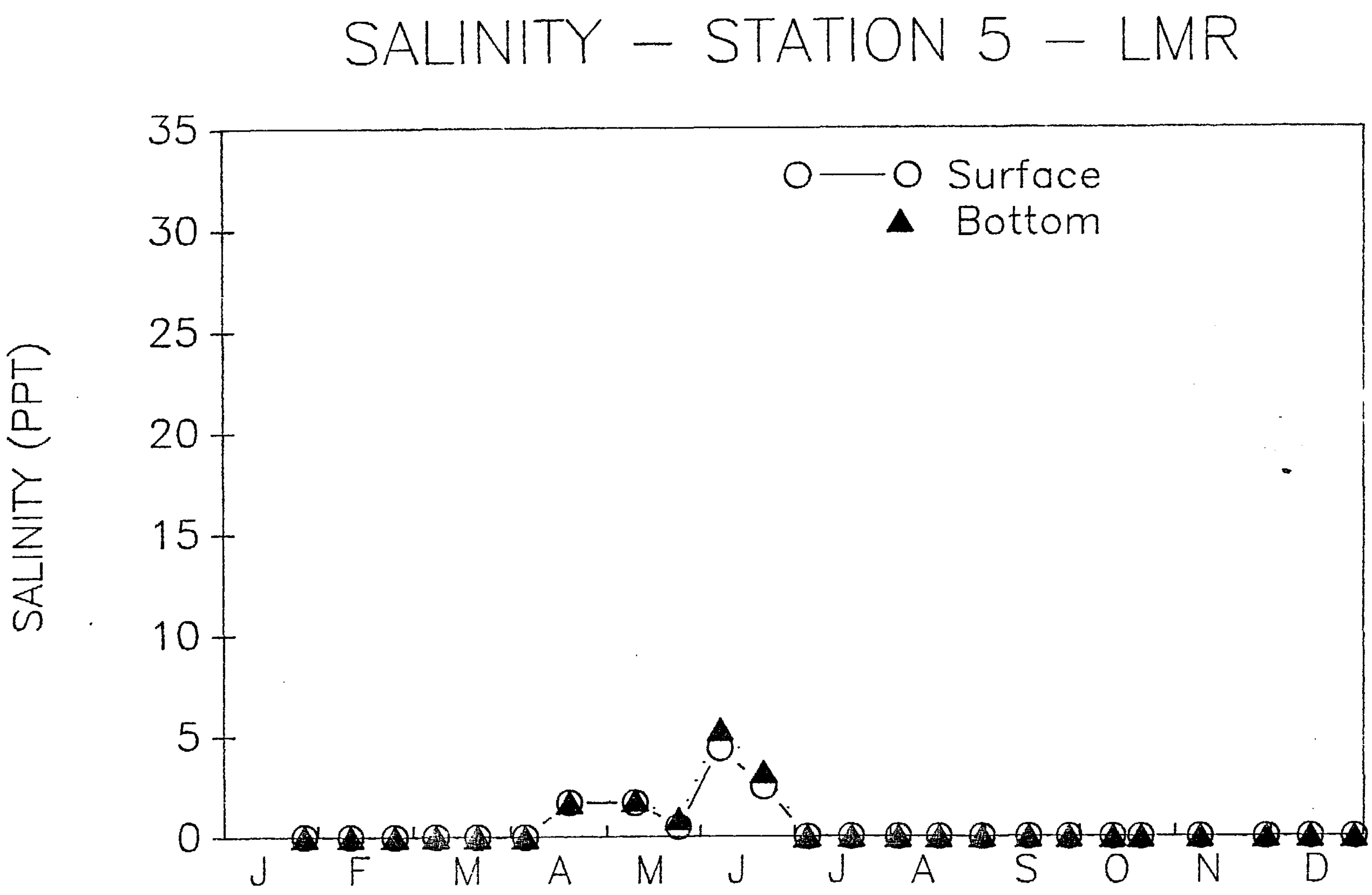
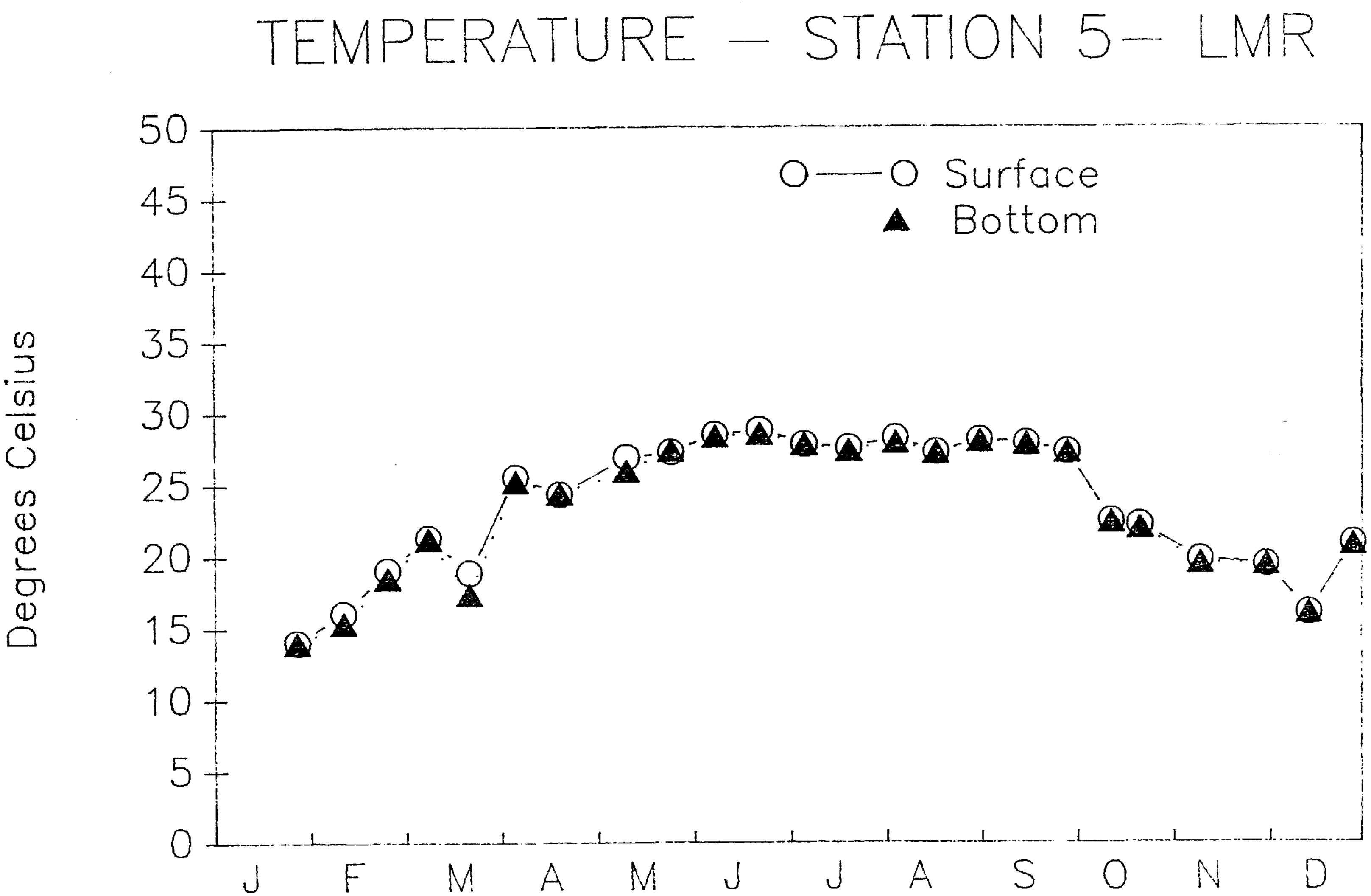

SALINITY - STATION 5 - LMR
SALINITY (PPT)
35
30
25
20
15
10
5
0
Surface
Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 14a



TEMPERATURE — STATION 5— LMR
Degrees Celsius
50
45
40
35
30
25
20
15
10
5
0
O——O Surface
▲ Bottom
J
F
M
A
M
J
J
A
S
O
N
D

Figure 14b

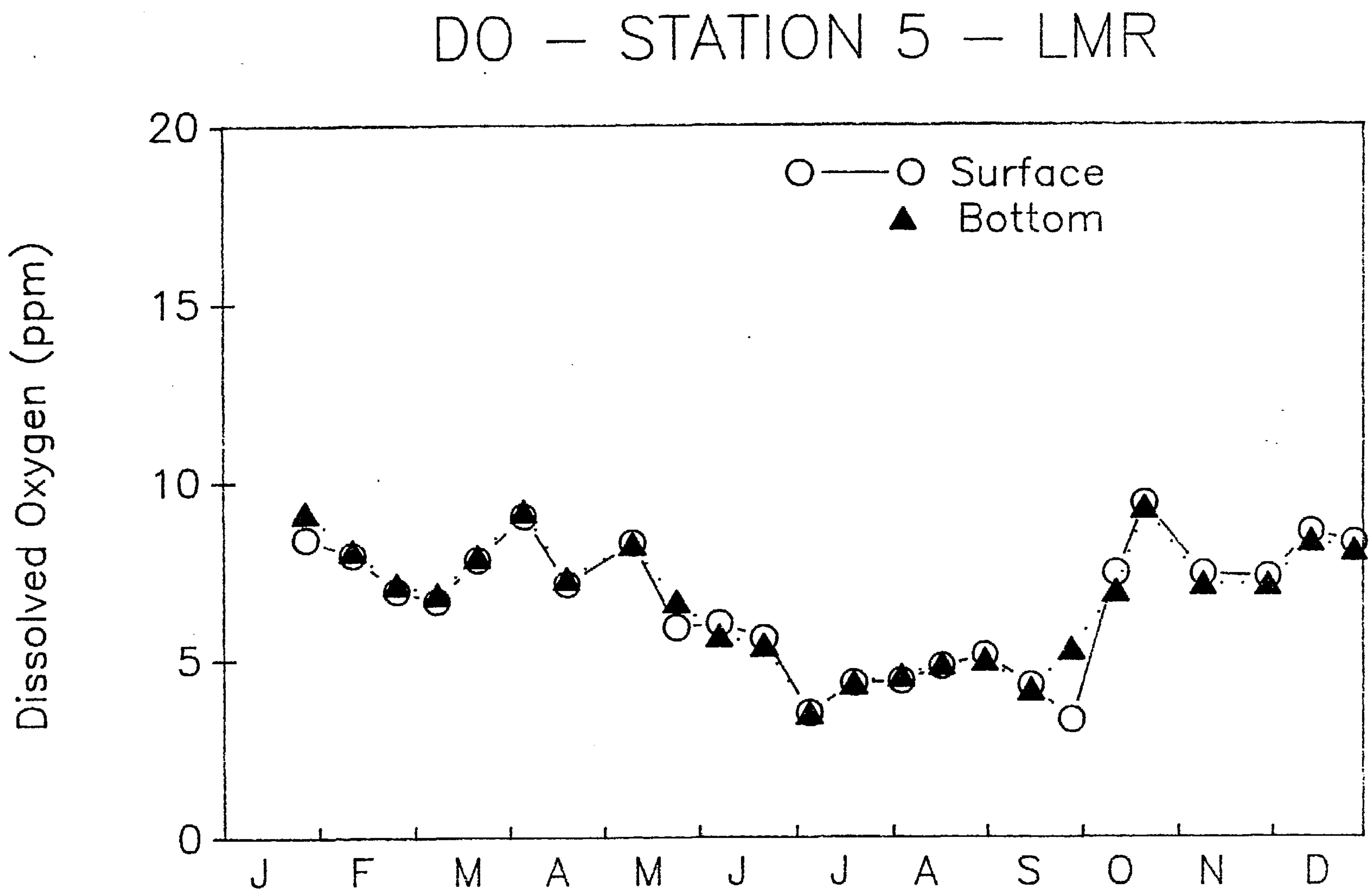

DO - STATION 5 - LMR
Surface
Bottom
Dissolved Oxygen (ppm)
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 14c

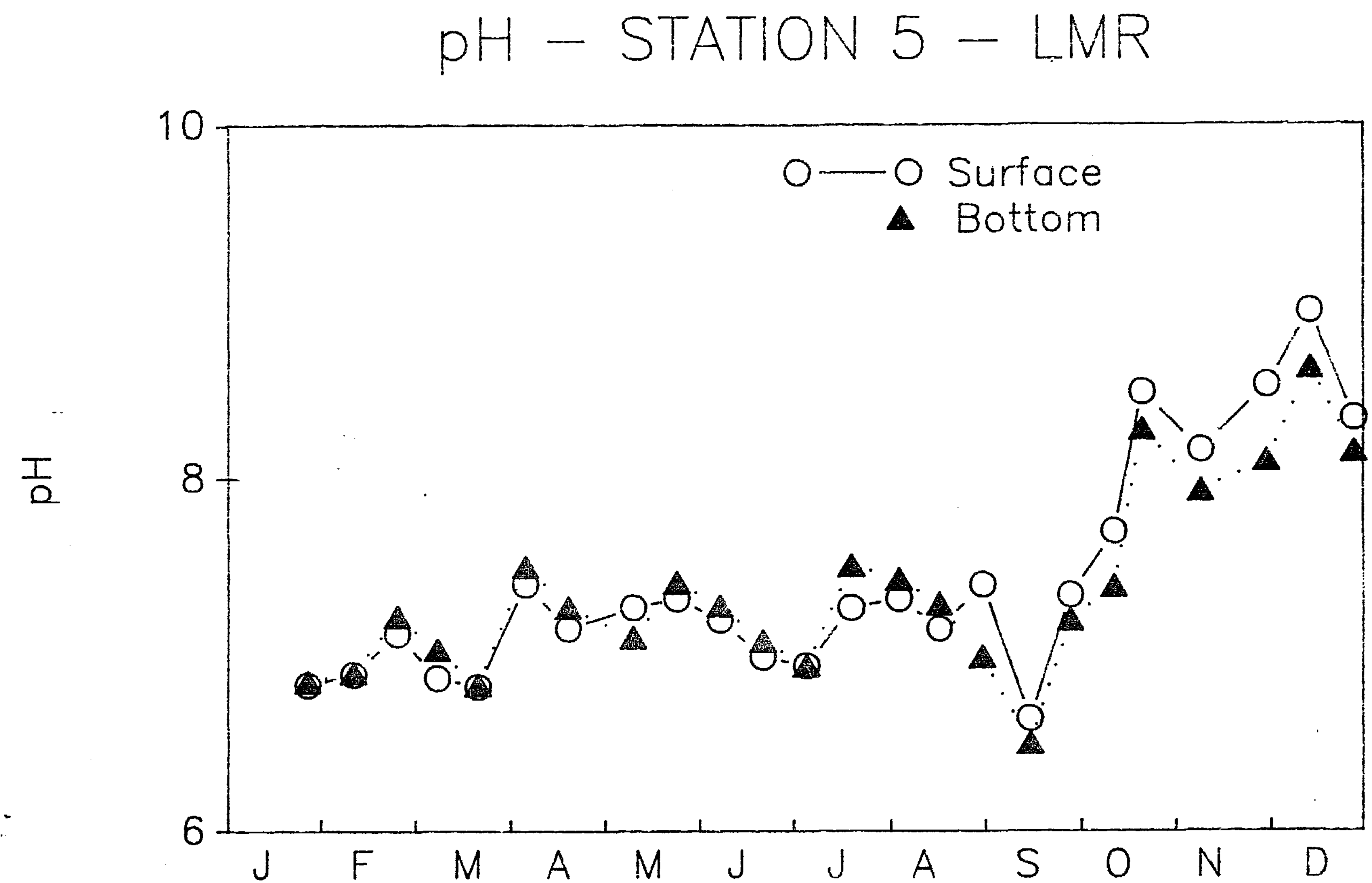
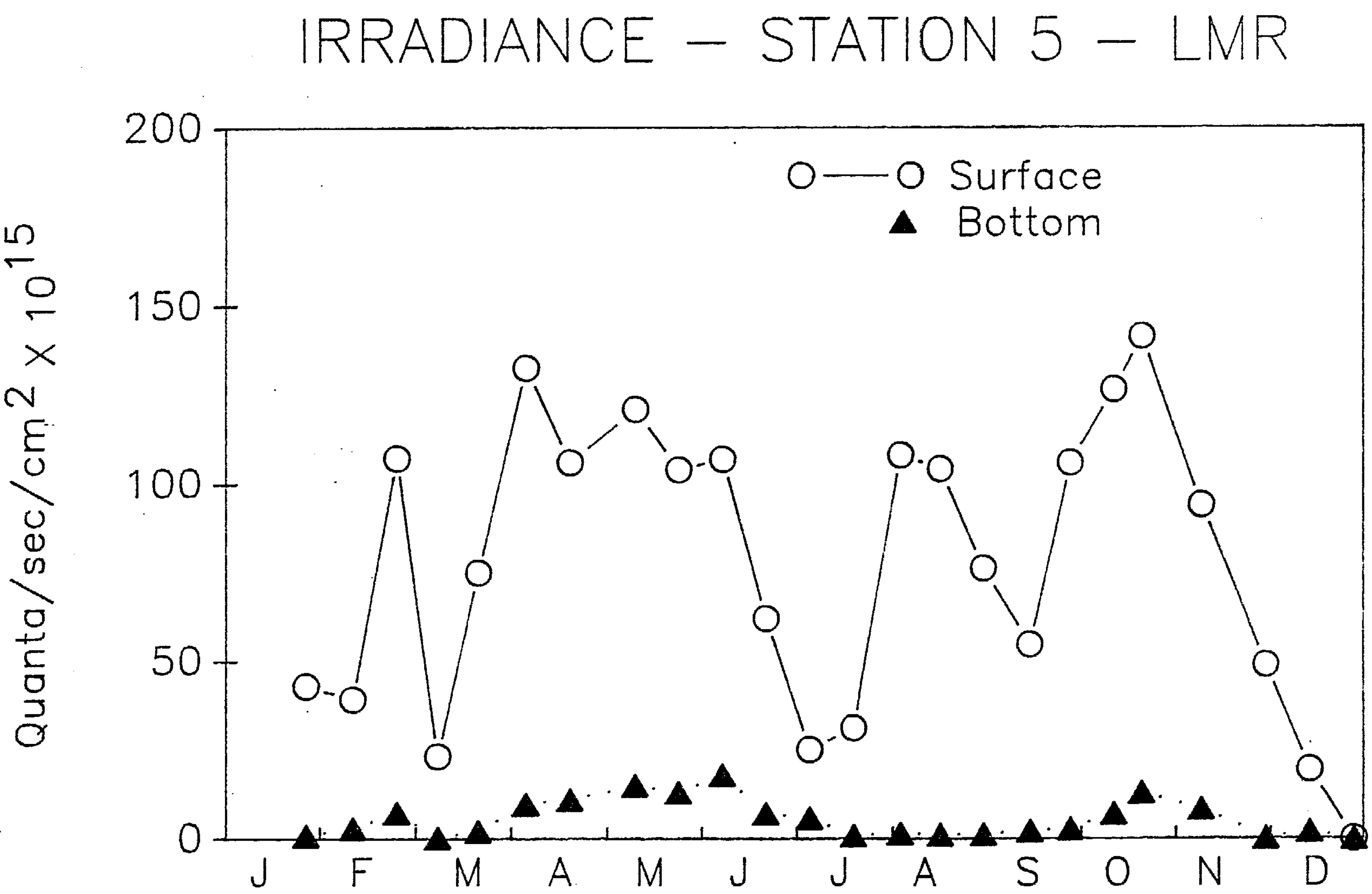


Figure 14d



IRRADIANCE – STATION 5 – LMR
Surface
Bottom
Quanta/sec/cm^2 X 10^{15}
200
150
100
50
0
J F M A M J J A S O N D

Figure 14e

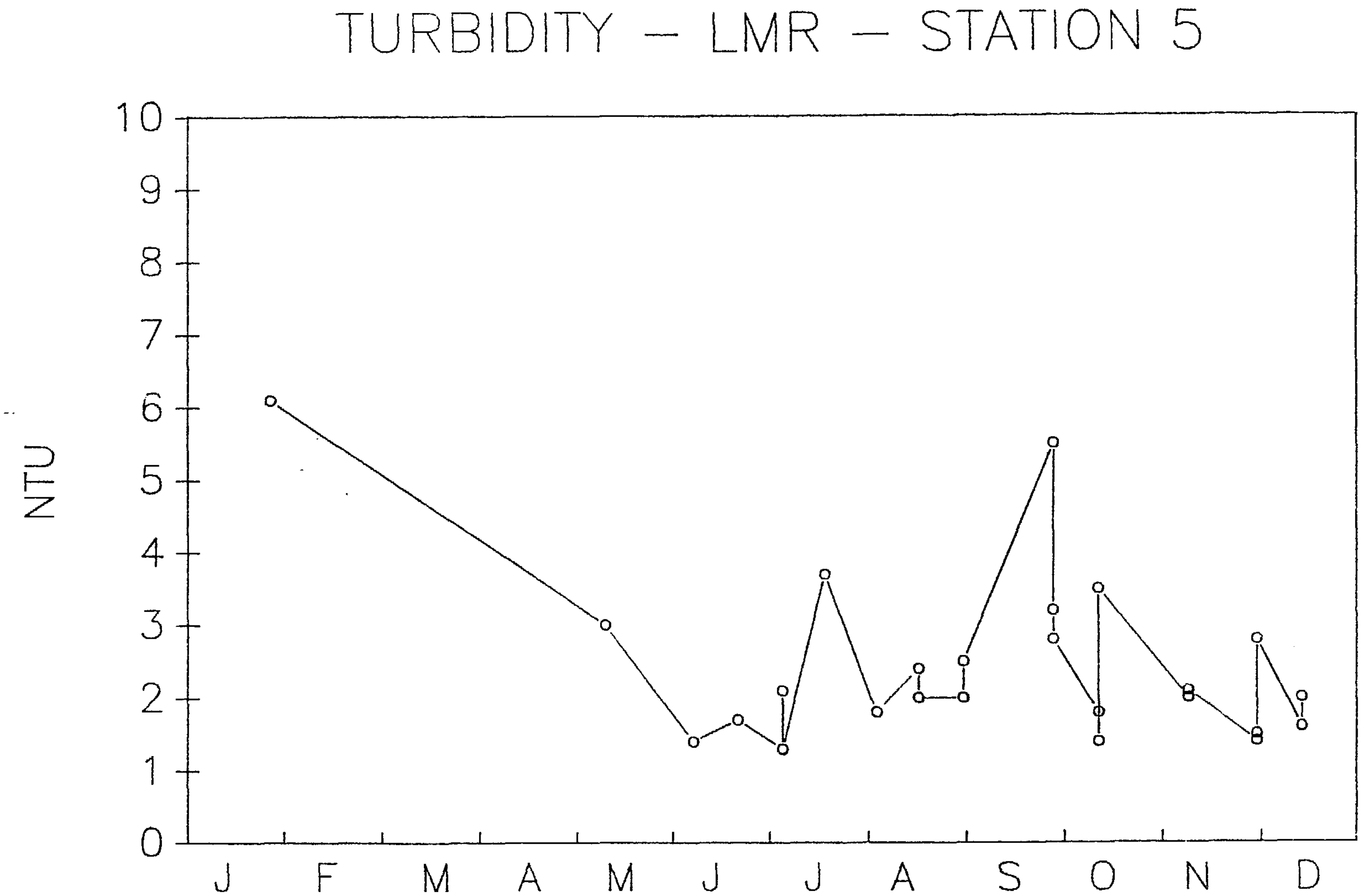
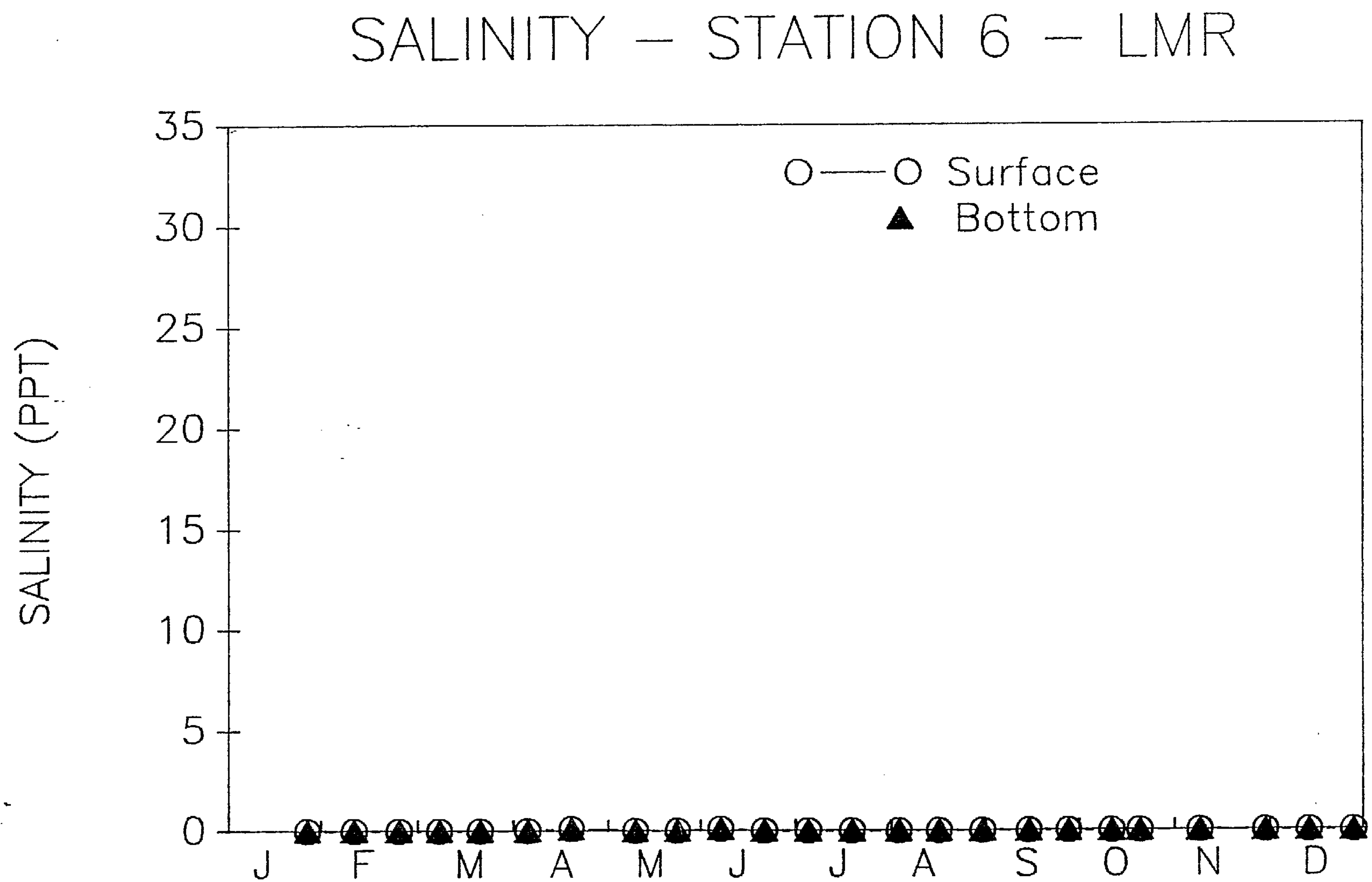


Figure 14f



SALINITY - STATION 6 - LMR
O——O Surface
▲ Bottom
SALINITY (PPT)
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 15a

TEMPERATURE - STATION 6 - LMR

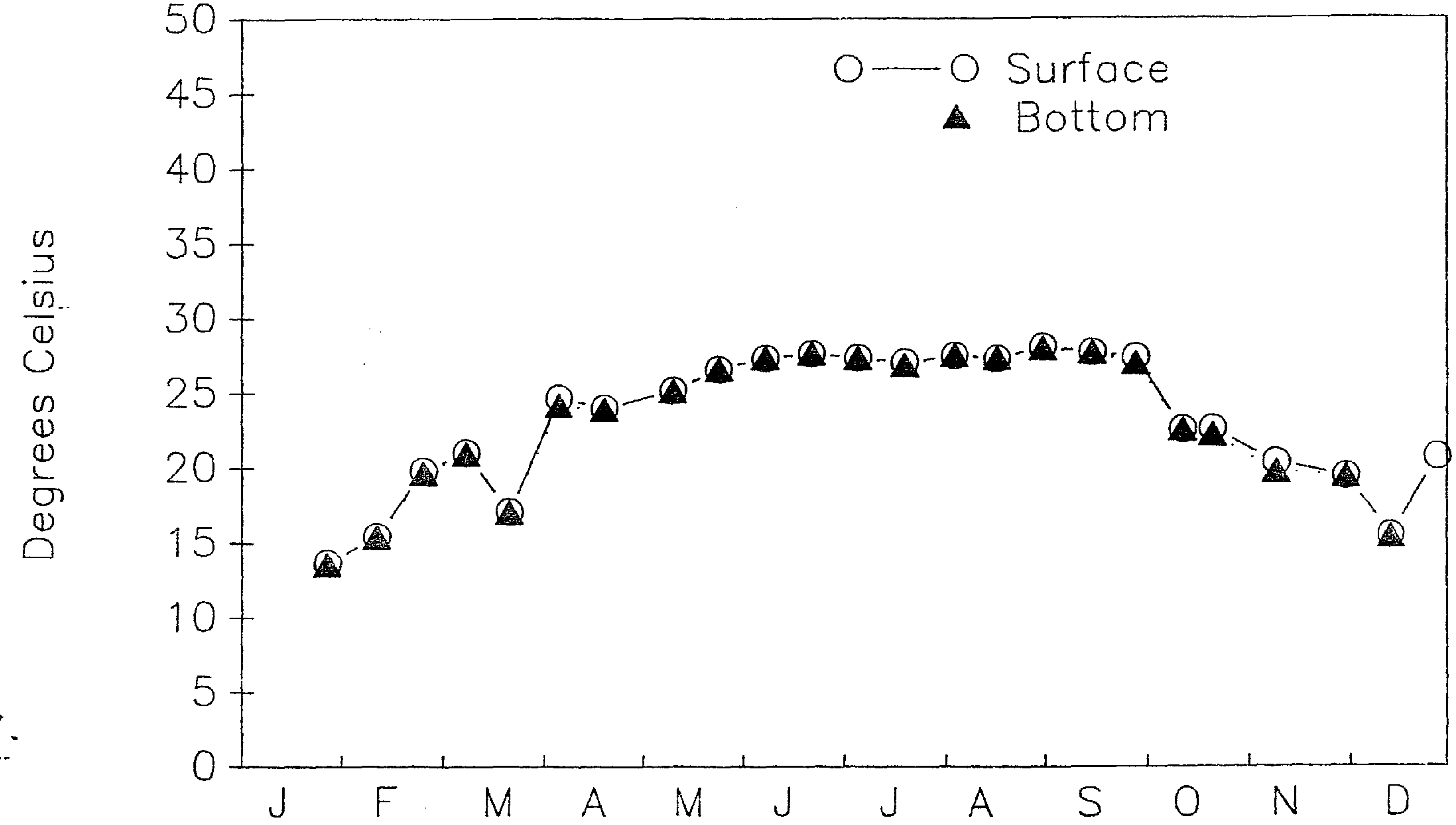


Figure 15b

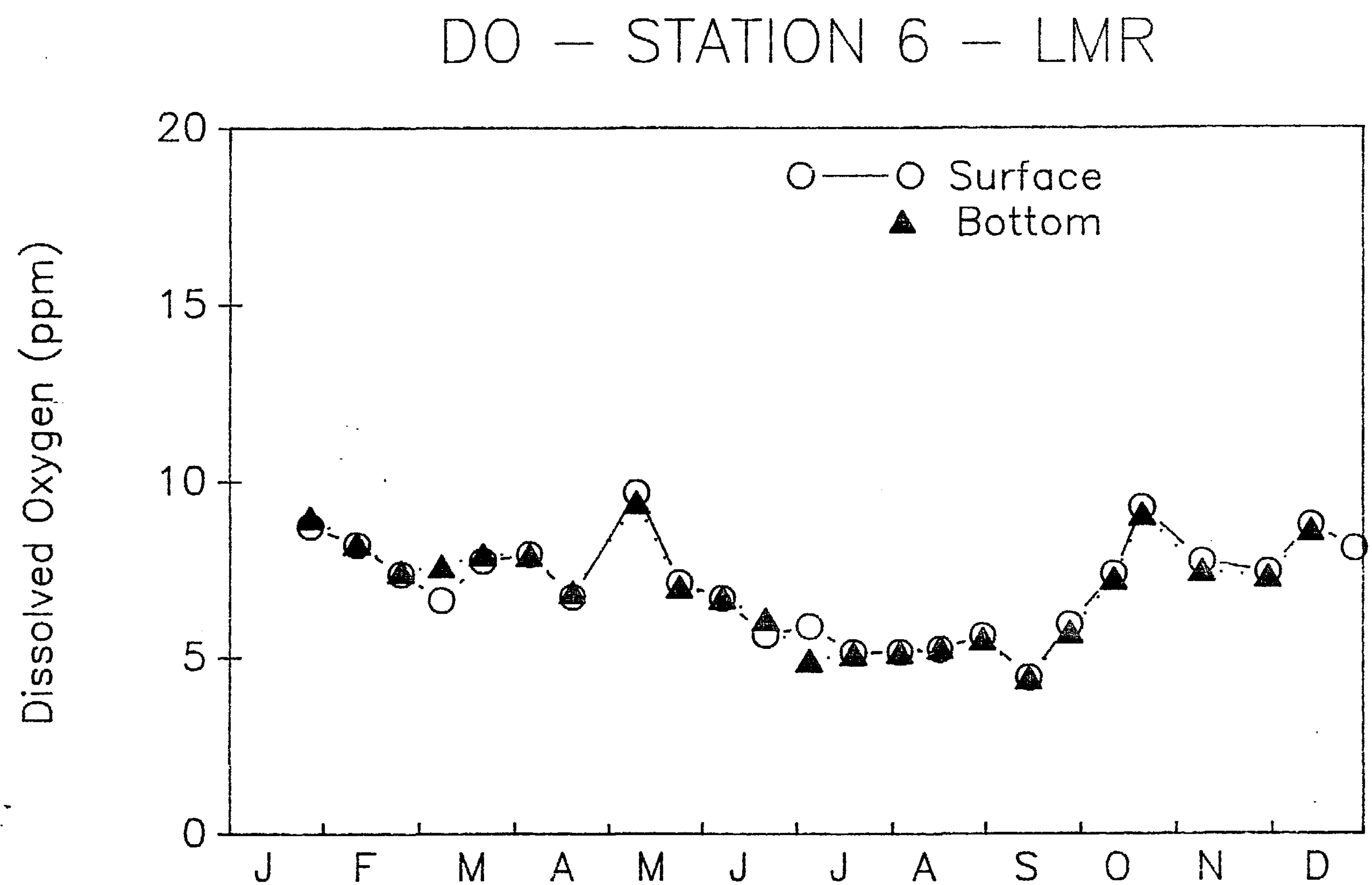

DO — STATION 6 — LMR
Surface
Bottom
Dissolved Oxygen (ppm)
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 15c

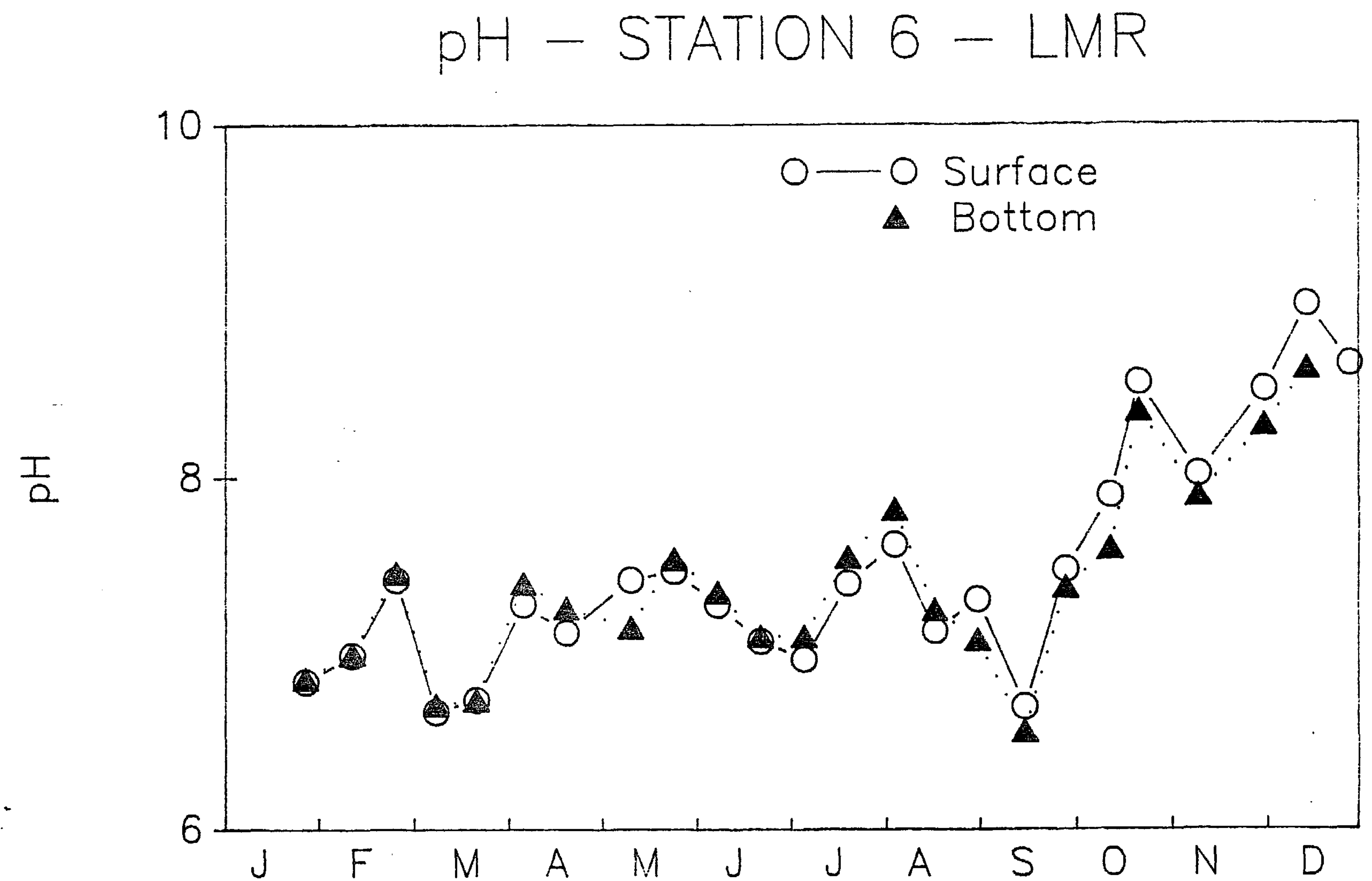


Figure 15d

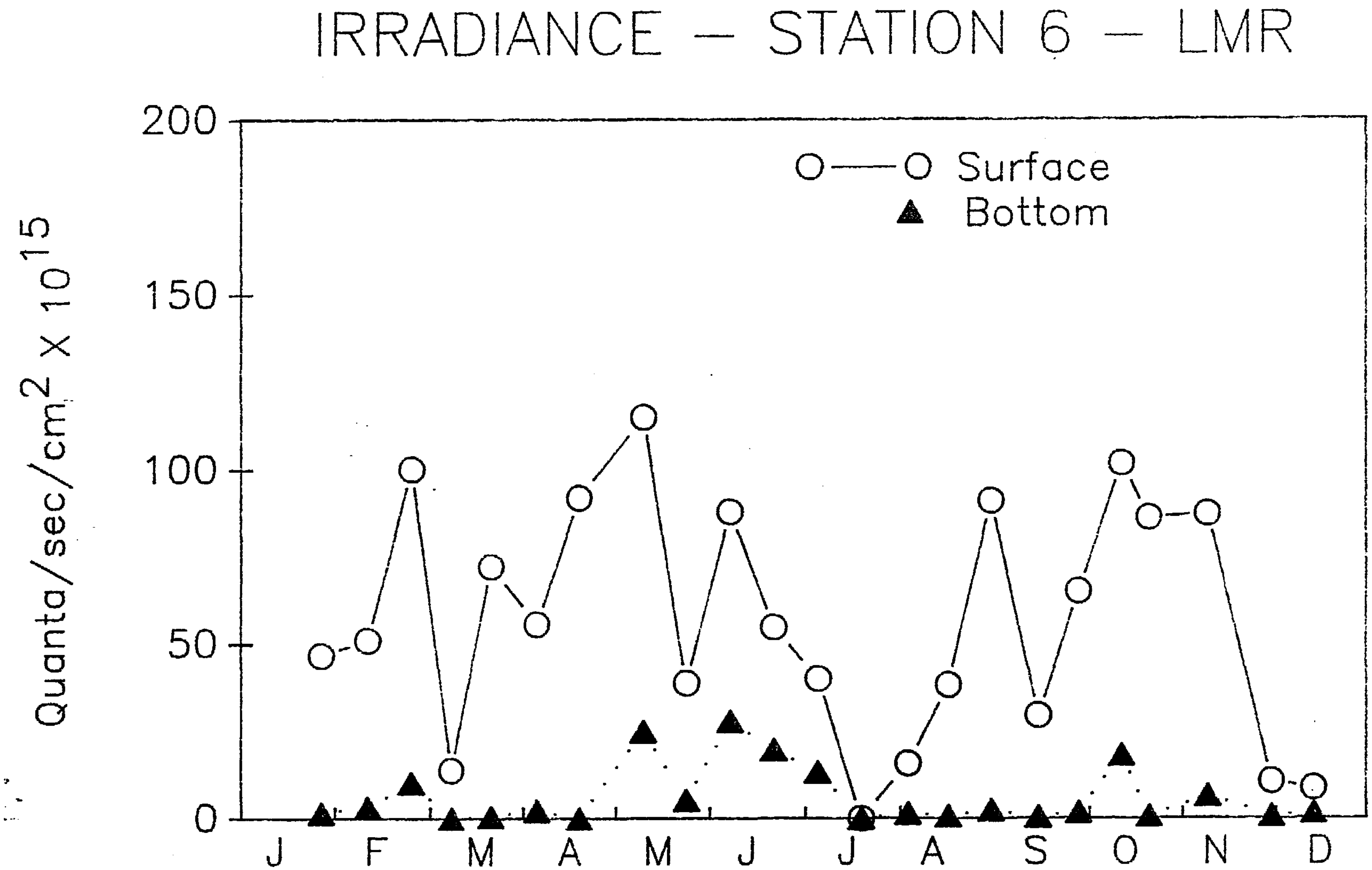

IRRADIANCE – STATION 6 – LMR
Surface
Bottom
Quanta/sec/cm2 X 1015
200
150
100
50
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 15e

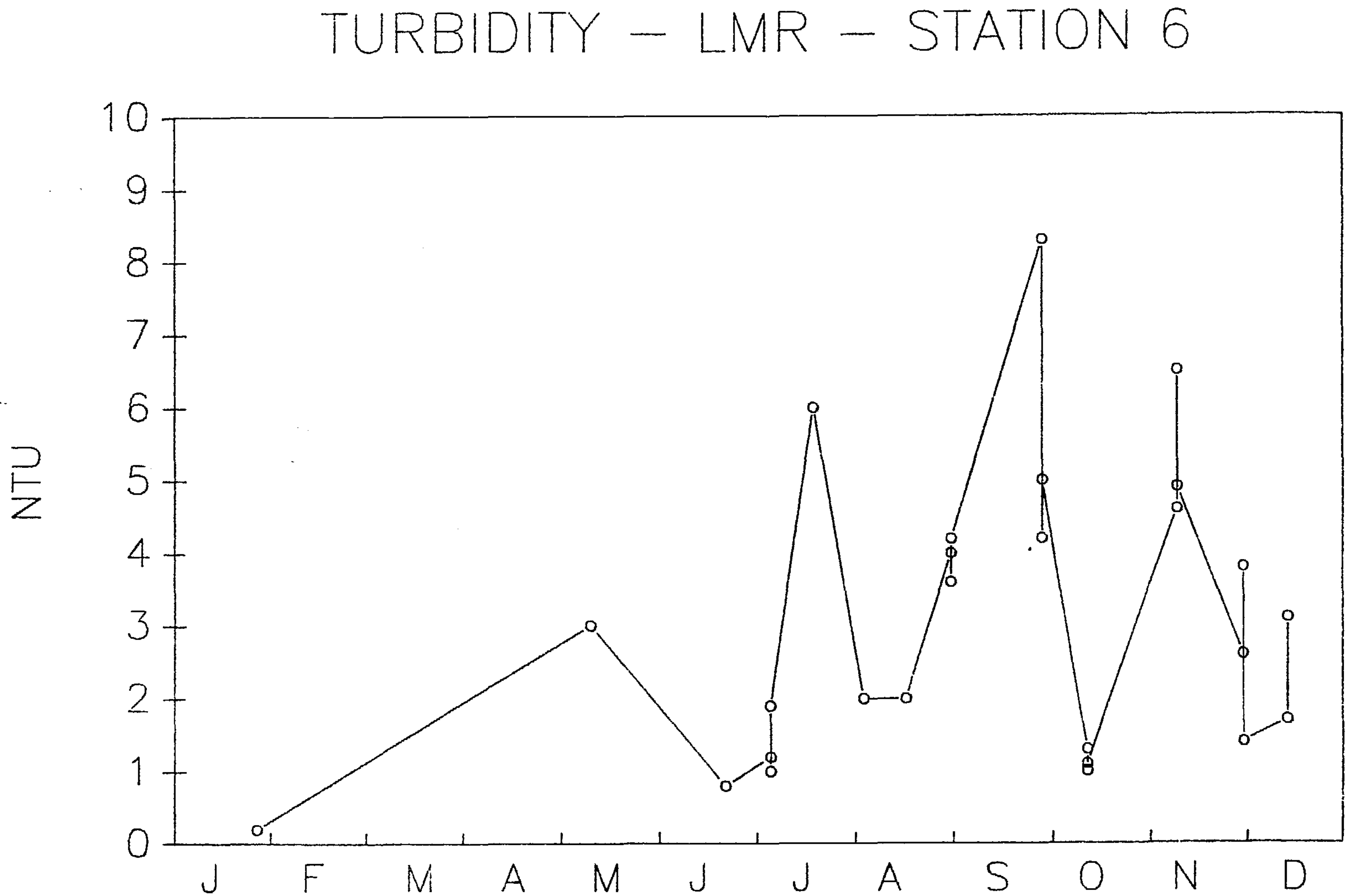
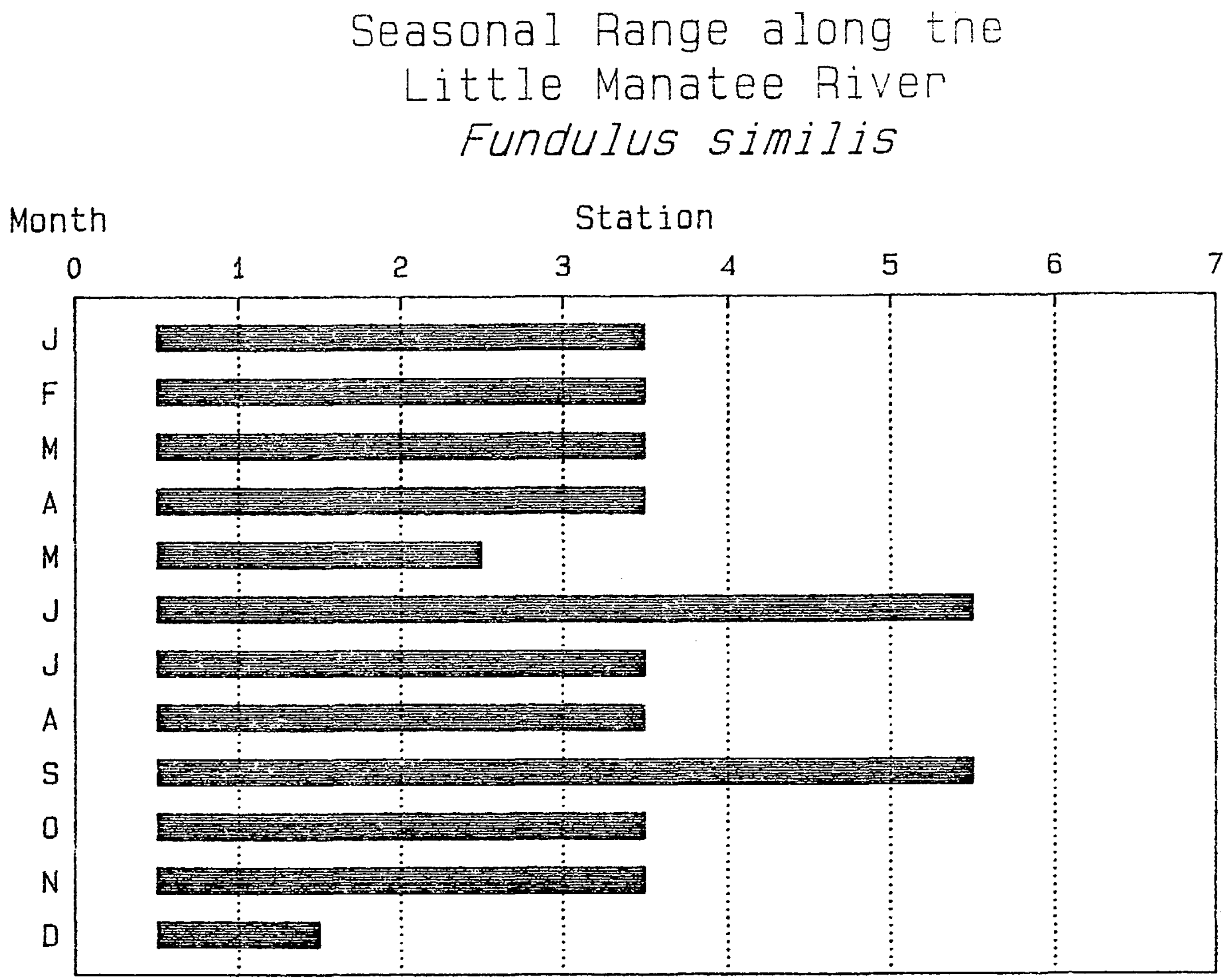


Figure 15f



Seasonal Range along the
Little Manatee River
Fundulus similis
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 16

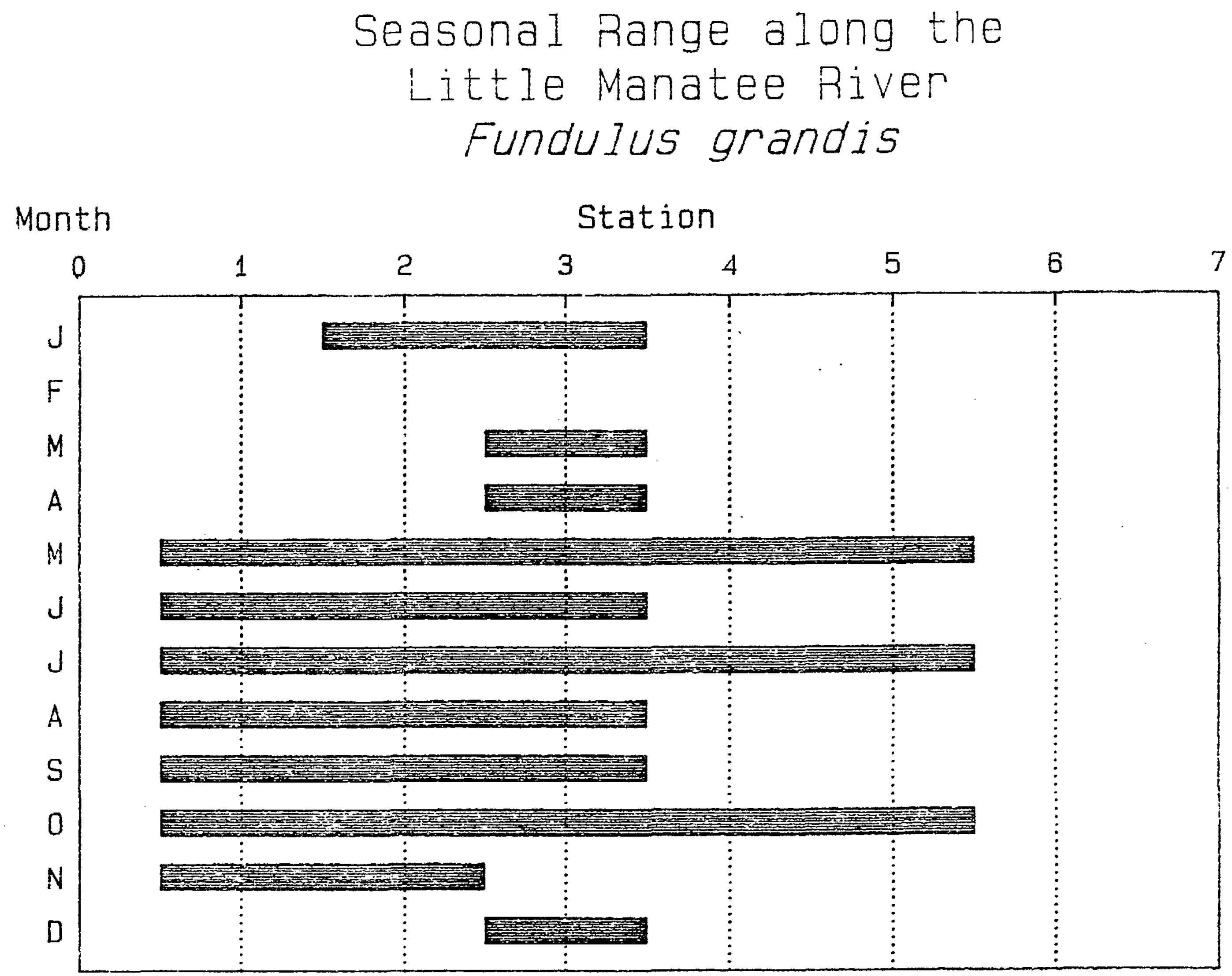
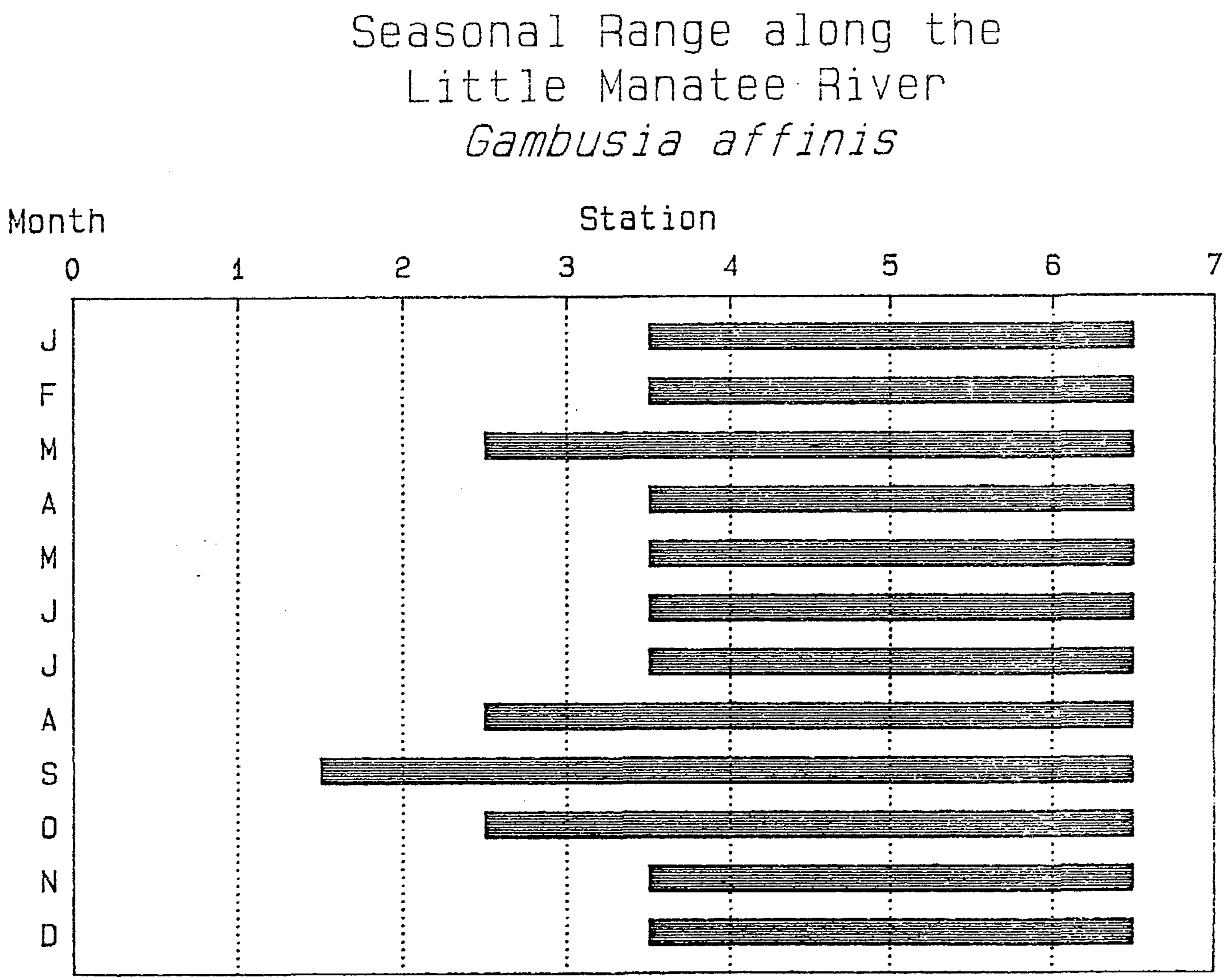

Seasonal Range along the
Little Manatee River
Fundulus grandis
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 17



Seasonal Range along the
Little Manatee River
Gambusia affinis
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 18

Seasonal Range along the Little Manatee River
Labidesthes sicculus

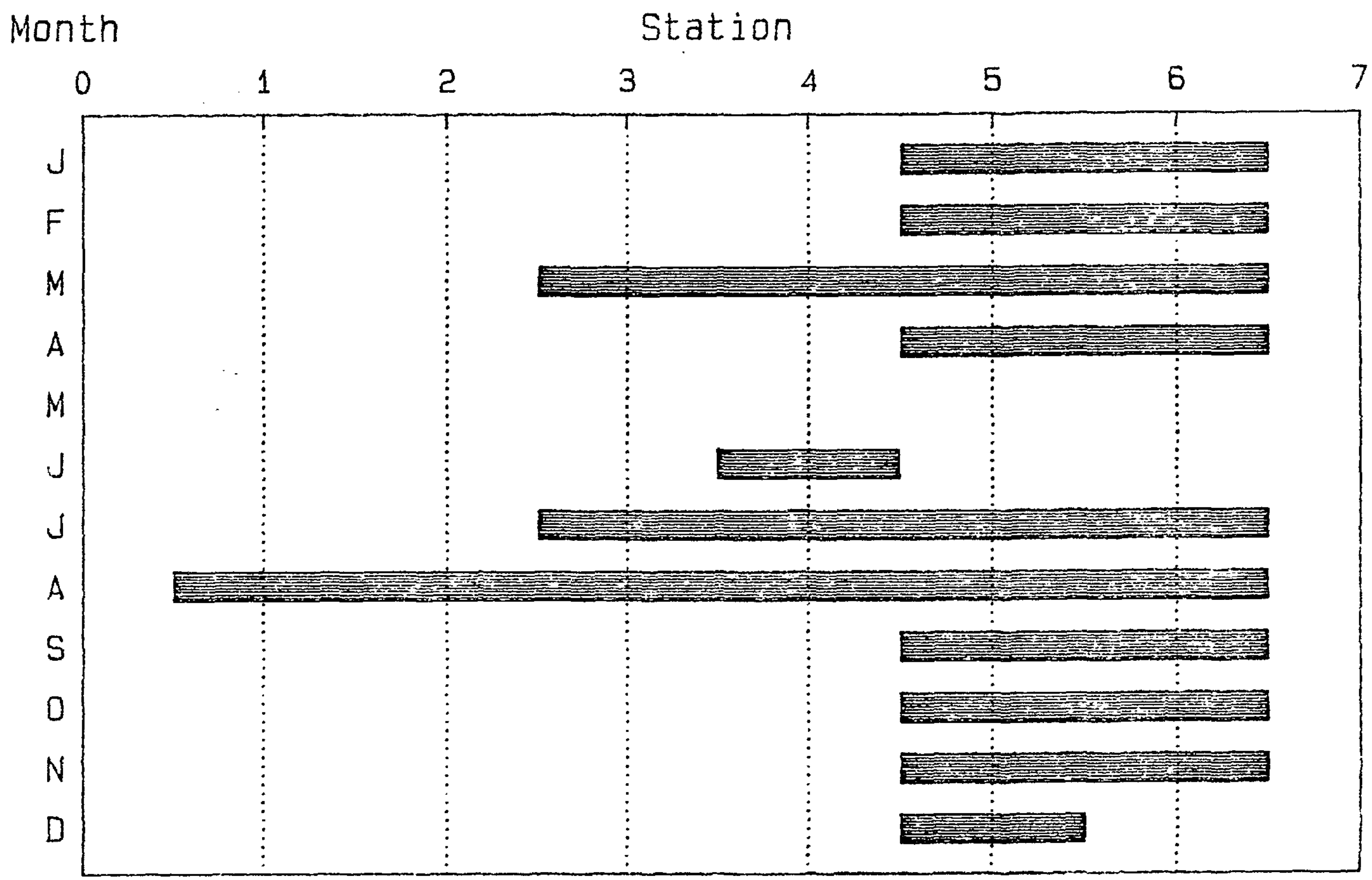


Figure 19

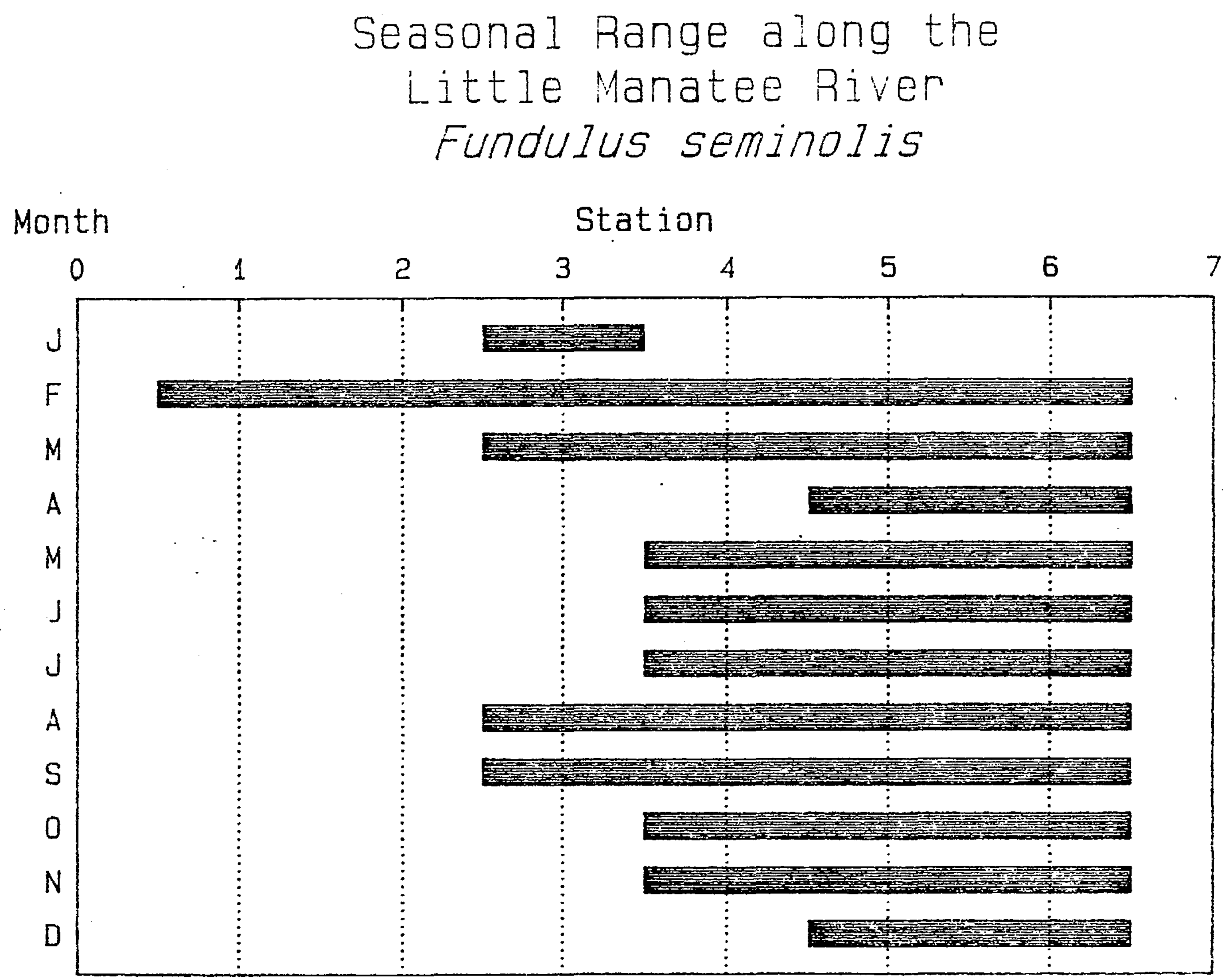

Seasonal Range along the
Little Manatee River
Fundulus seminolis
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 20

Seasonal Range along the
Little Manatee River
Bairdiella chrysoura

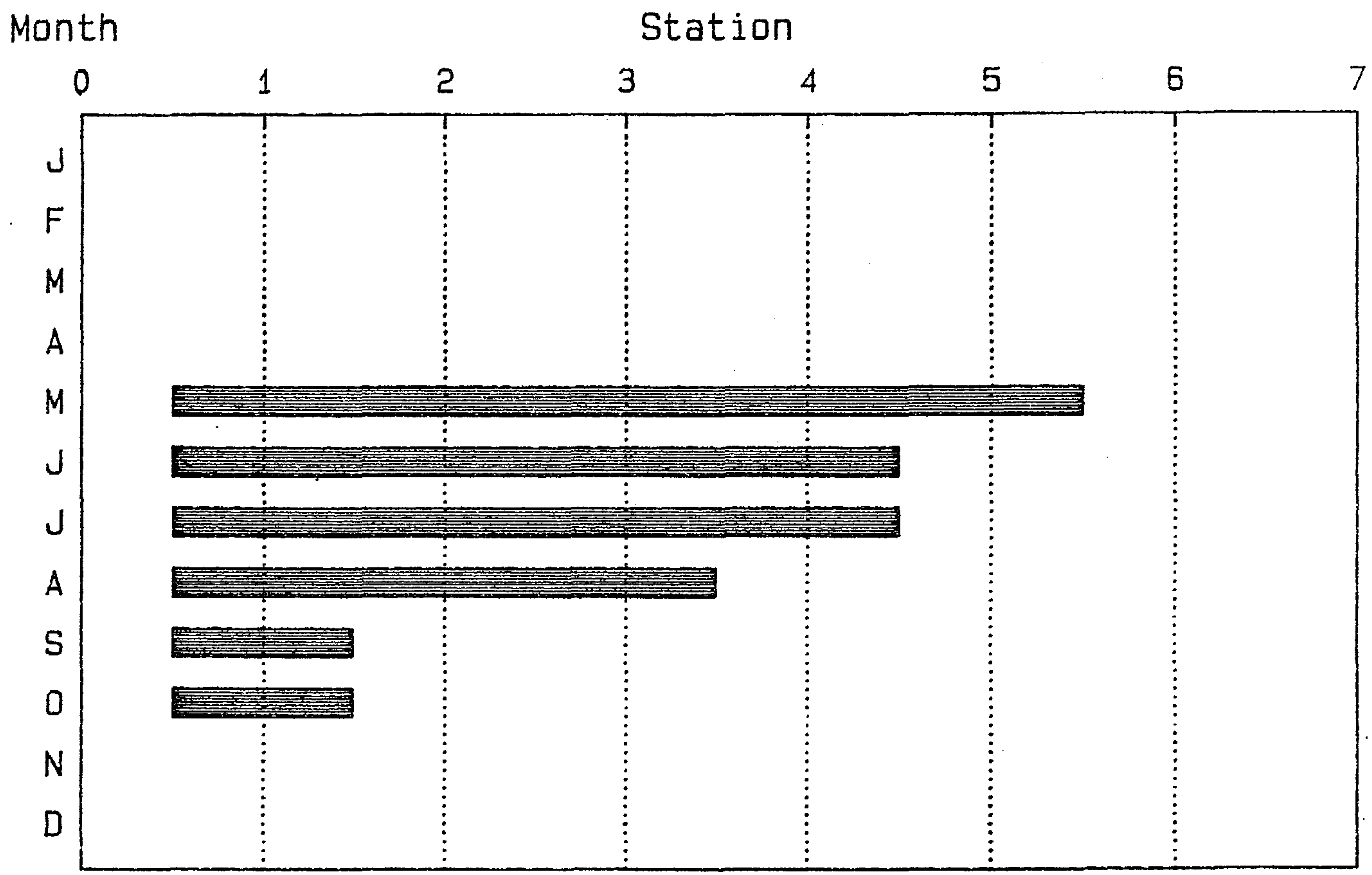
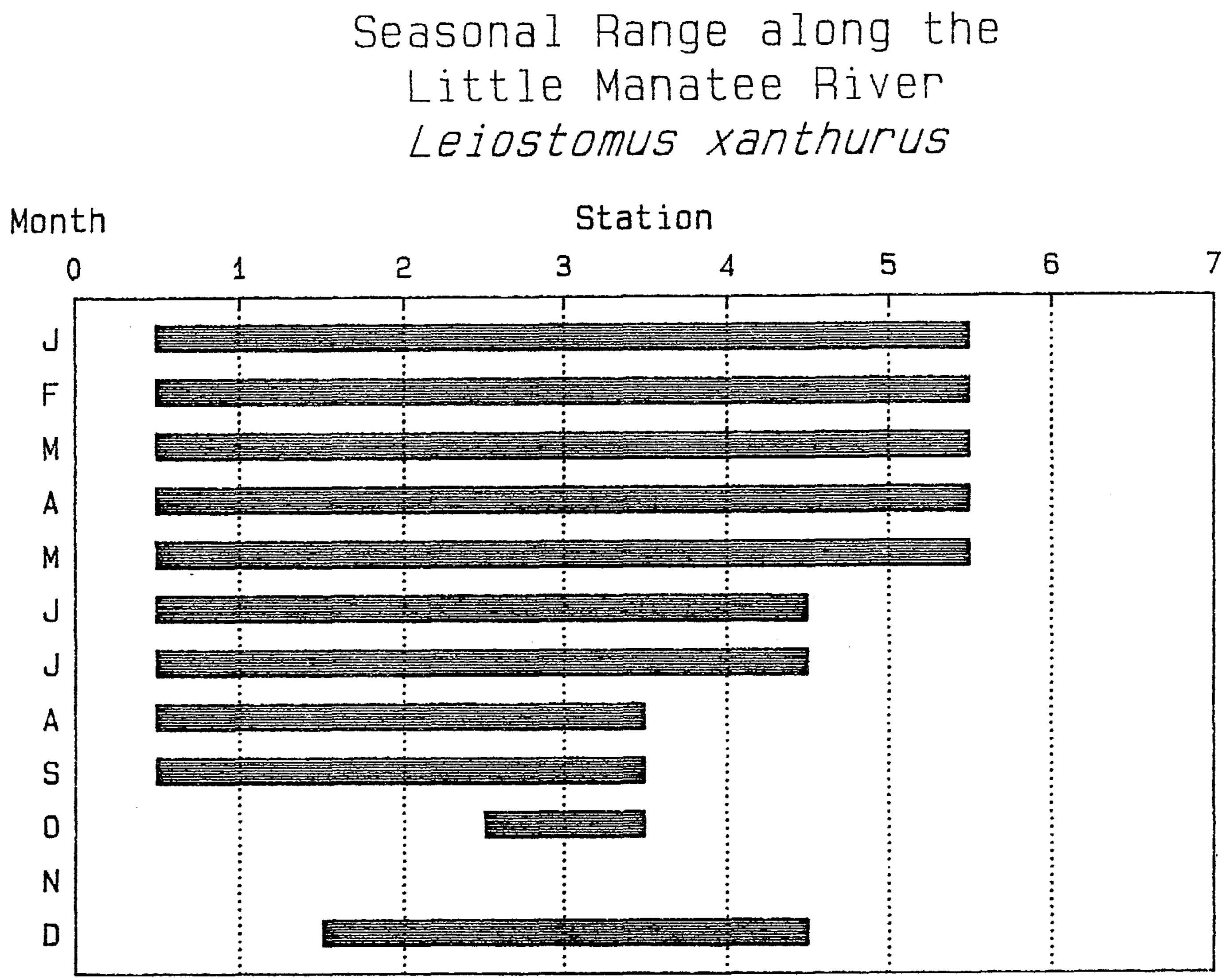


Figure 21



Seasonal Range along the
Little Manatee River
Leiostomus xanthurus
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 22

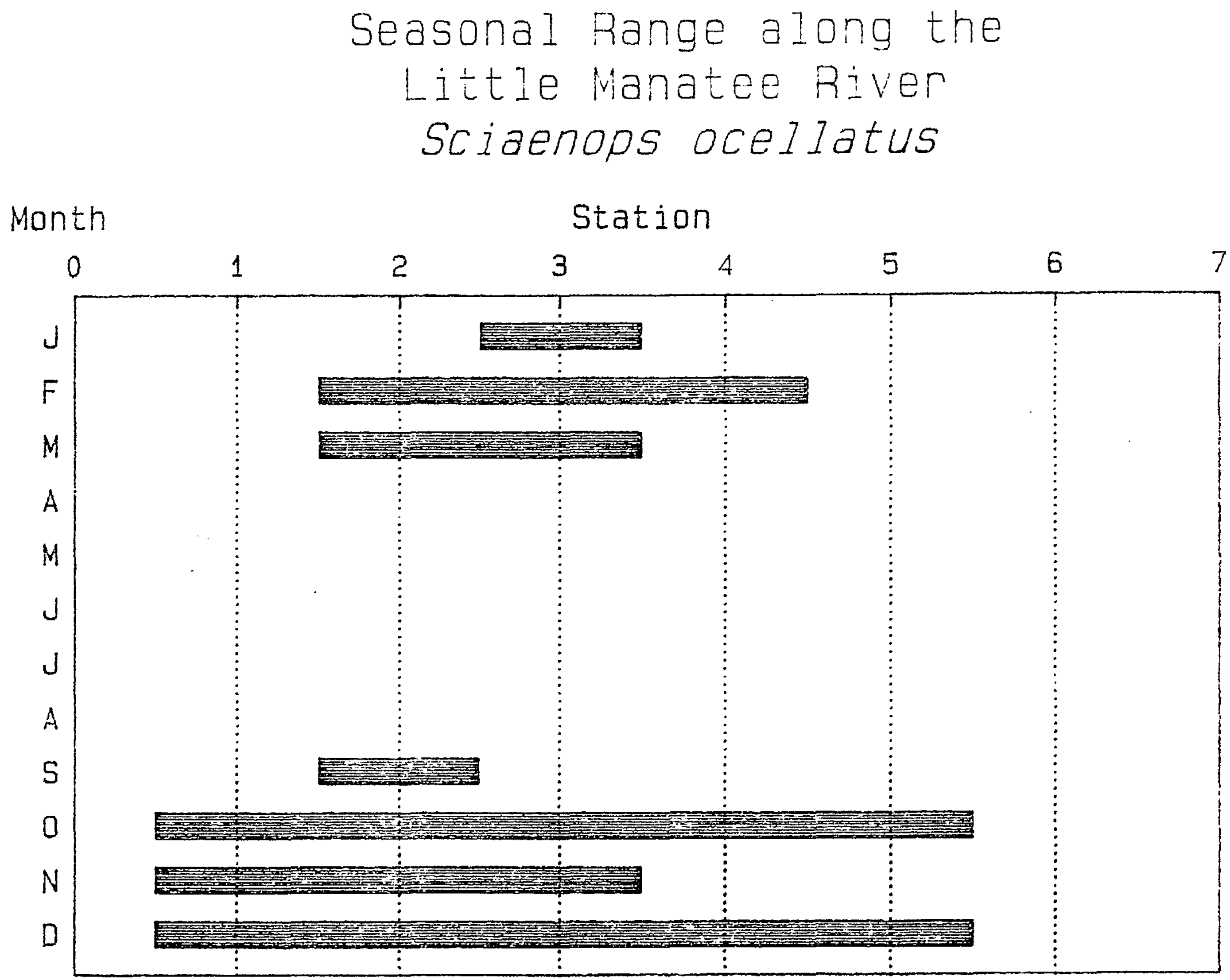

Seasonal Range along the
Little Manatee River
Sciaenops ocellatus
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 23

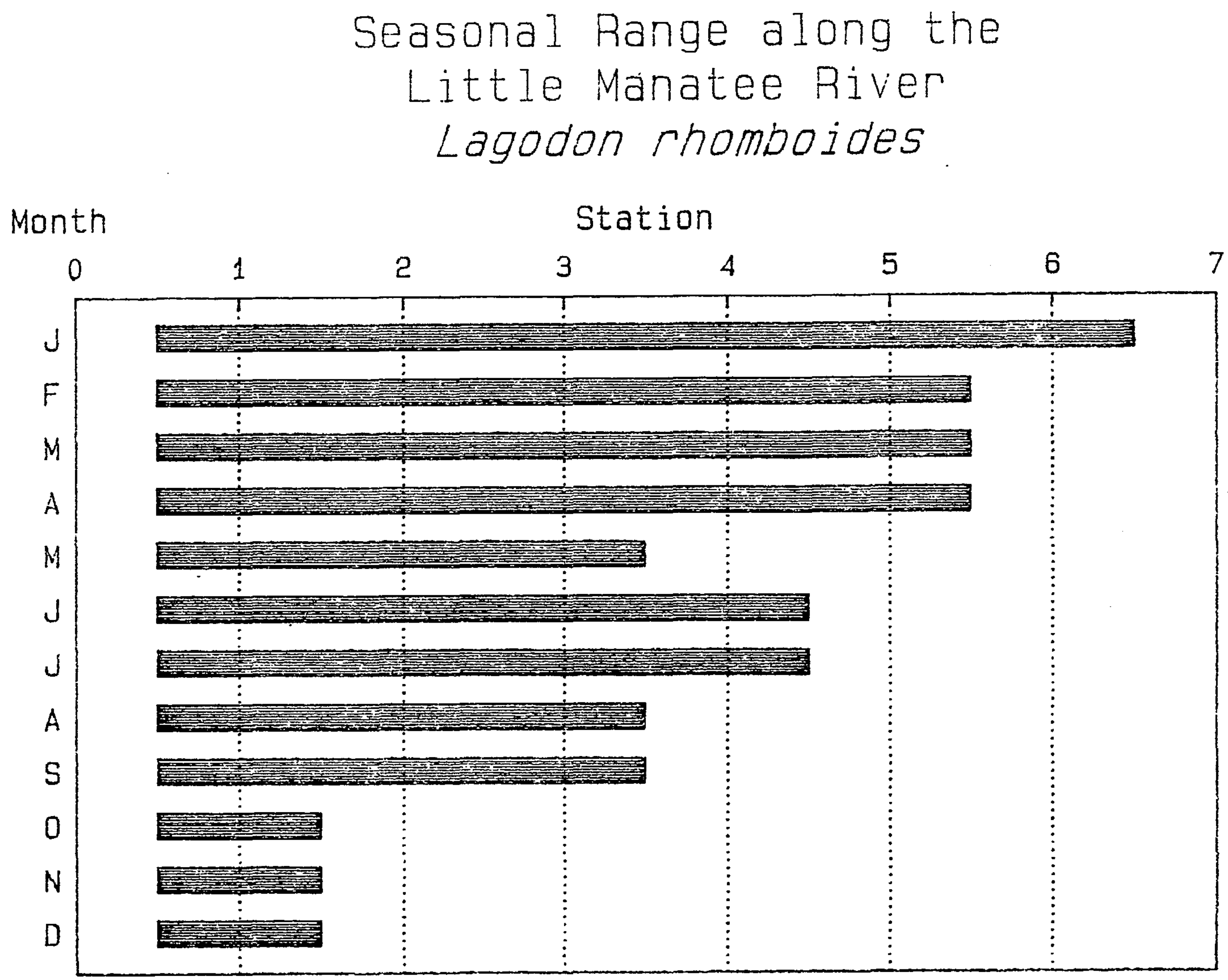

Seasonal Range along the
Little Manatee River
Lagodon rhomboides
Month
Station
0
1
2
3
4
5
6
7
J
F
M
A
M
J
J
A
S
O
N
D

Figure 24

TASK 4: JUVENILE HABITAT UTILIZATION

In this task, density and movement data were used to describe some aspects of the population dynamics of juvenile red drum in a small canal. Red drum, Sciaenops oscellatus, spawn principally in bay mouths or in near offshore waters. Larvae migrate into the lower salinity estuarine waters where juveniles remain for several years. In the Tampa Bay area primary habitat for small juveniles is characterized by low to moderate salinity, muddy bottoms, and slow moving water. A few studies have done work on age and growth, food habits, and habitat selection of small juveniles. However, many aspects of population dynamics of these young fish have not been examined.

The objective of task 4, was to determine the population dynamics of red drum in a localized estuarine habitat in Tampa Bay and to monitor changes in these variables when the population is augmented. Specific objectives were to: 1) determine the standing crop of juvenile red drum in a canal through time; 2) determine residency time for red drum within the canal 3) and to determine movement into and out of the canal.

A small dead end canal located about 2 km from the mouth of the Alafia River, Tampa Bay, FL was selected as the study site. The canal is a straight, naturalized, man-made canal covering approximately 3/4 of a hectare. Water depth normally ranges from about Ø.5 to 1.5 meters. Higher water levels are associated with large rain falls coinciding with high tides. Extremely low water occurs during the winter with the approach of cold fronts and north wind which blows the water out of the bay. The canal is undeveloped and will probably remain undeveloped due to the high tension power lines which run over the canal . The bottom of the canal consists of mud/sand to mud with no rooted vegetation. There is some terrestrial vegetation which at mid and high tides can reach into the water. This canal was selected as the study site because red drum have been collected here previously and this type of habitat is where the majority of red drum have been found in previous Tampa Bay studies. Also, the canal has only one entrance/exit which simplifies monitoring fish movements.

Fish were collected with a 21 m, 3 mm mesh bag seine. The net was deployed from the stern of a boat and was set in a semi-circle with both ends on the bank. Each net set encompassed 71 m2. Generally the net took in half of the width of the canal.

The canal was stratified by distance from the mouth and by bank and was randomly sampled within each strata. Twelve to sixteen hauls were made during each sampling trip. Weekly seining was done in the canal except during periods of low red drum abundance when bi-weekly seining was done. All fish collected were measured and released.

Standing crop estimates were made by two methods, one by mark-recapture and the other by expanding the number of fish collected per m2 to the whole area. Fish that were to be marked were collected and returned to the lab and held for three days, they were then marked using air-injected fluorescent pigment. Fish were maintained for three additional days and then randomly released throughout the canal. They were given 24 hours to disperse through out the canal before the canal was seined. Marking was done at 6.3 kg/cm2 at a spraying distance of just under a meter. The three day lag periods provided fish with recovery time between stressful events. Numerous marking exercises were run to develop this technique which yielded 100 % mark retention which could only be detected under ultra-violet light. Survival rate of marked fish was over 95%.

In order to estimate standing crop by fish per m2, net efficiency had to be calculated. A number of exercises were run where marked fish were placed within the scope of the net before retrieval. Mean recapture rate was 83 %. This correction factor (1.2) was included in the standing crop estimates.

Weekly seining data was pooled to plot monthly length frequencies (Fig. 1). Standard lengths are shown along the X axis; percentage along the Y. Juveniles are first apparent in the canal at about 15 mm in October of all years. Recruitment into the canal continued through December. Cohorts could be followed through spring into summer where few fish were collected. Growth rates are similar to rates published from fish collected in other parts of Tampa Bay; about 1/2 mm per day. Largest fish collected were about 300 mm collected in summer and fall.

Standing crop estimates were plotted monthly for each year

(Fig. 2). Months are shown along the X-axis and standing crop (number of fish times 100) is shown on Y-axis. These values are mean values calculated from two to four bi-weekly or weekly seining trips. Standard errors were omitted from the figure for clarity. However standard error ranged from about 300 for the larger estimates down to single digits for the smaller estimates. Standing crop values increased starting in October. with the arrival of new recruits. Maximum values were reached in January at about 2000 fish. Values decreased rapidly to less than 100 by May.

During this last year (1987-88) the study site was to be "stocked" with hatchery reared red drum. However, the newly constructed Florida hatchery did not produce red drum last fall or winter, so wild fish were collected from another location on the Alafia River. There were 365 red drum marked and released in the canal in January. 1988. Figure 2 shows the two lines reflecting standing crop estimates for the total stock (Top) and for the natural stock (Bottom). Far fewer individuals were present this year as compared to the two previous years, however both the natural and introduced populations showed similar trends to other years and to each other. The steep decay rate in early spring is evident in all years. The number of fish naturally occurring and the number of fish introduced were so below the numbers in previous years that this was probably a poor year to run this exercise. This portion of the exercise will be repeated next fall or winter with, hopefully higher natural and introduced numbers.

The standing crop estimates made using mark-recapture data are similar to those estimated from density values. These estimates are shown on Figure 2 as the independent points, no lines are connecting them. These estimates are single point estimates made using Chapman's method. Far fewer estimates could be made using mark-recapture because of the amount of time involved and the availability of only a few marking colors. Both methods yielded similar values indicating standing crop estimates probably reflect actual abundance in the canal.

Residency time in the canal could be monitored (Fig. 3) by utilizing the marked fish in the canal. Figure 3 shows the "time at large" for two different years (1985-86 on top and 1986-87 the bottom half). Each histogram represents a group of released fish. The left side of each histogram is the date that the marked fish were released into the canal. The right side is the date that the color was last collected. The number to the right is the number of days at large. All but one marked fish was gone from the canal by mid-May. That one was collected in August and had been marked for 217 days. The second to the last fish collected from that group was in mid-April; illustrated by the dotted line. Overall, marked fish were missing from the canal earlier in the spring in 1985-86 than in 1986-87. These data show that juvenile red drum which entered the canal in the fall overwintered there with the majority being gone by May; either from mortality or emigration.

To monitor red drum movement into or out of the canal, a series of stop nets were established at the canal entrance. These nets collected fishes trying to enter or exit the canal. Nets were set up for 24 or 48 hours weekly or bi-weekly depending on time of year. The nets were emptied on every tidal change and at mid-tide. This worked out to about every three hours. All fish collected were measured, checked for marks, and released in the direction they were heading.

Mean sizes of fishes collected in the stop nets were not significantly different from the mean size of fish collected by seining in the canal during the same time period. Variability in individual (three hour hauls) was great; ranging from empty to 289 red drum.

Figure 4 shows mean fish movement per haul into and out of the canal (on the Y axis) by month (on the X axis). The top portion is inward movement and the lower half is outward. Greatest movement (both inward and outward) was during the time of greatest abundance in the canal (January). The expected results from the movement data was to see an influx of fish in the fall and early winter and then an overall outward movement in the early spring. Neither of these trends was apparent. Movement was highly correlated with the coldest temperatures and the lowest water levels in the canal. Cold temperatures and low tides are a common combination during winter cold fronts in west central FL. The large majority (85 %) of the fish collected by the stop net were collected moving with the current. Possibly, the fish are oscillating with the tide between the river and the canal. This is supported by the collecting of a number of marked fish moving back into the canal. This oscillation could be masking any true net movement.

In conclusion, red drum first recruit to the canal in October at about 15 mm. They remain in the canal throughout the winter with the majority being gone by late spring. Maximum standing crop is in the winter at about 2000 fish. Growth rates are similar to published rates for that region (1/2 mm per day). Stocking was at such a small scale that no effect could be detected. Additional stocking work will be done this fall and winter.

FIGURE 1

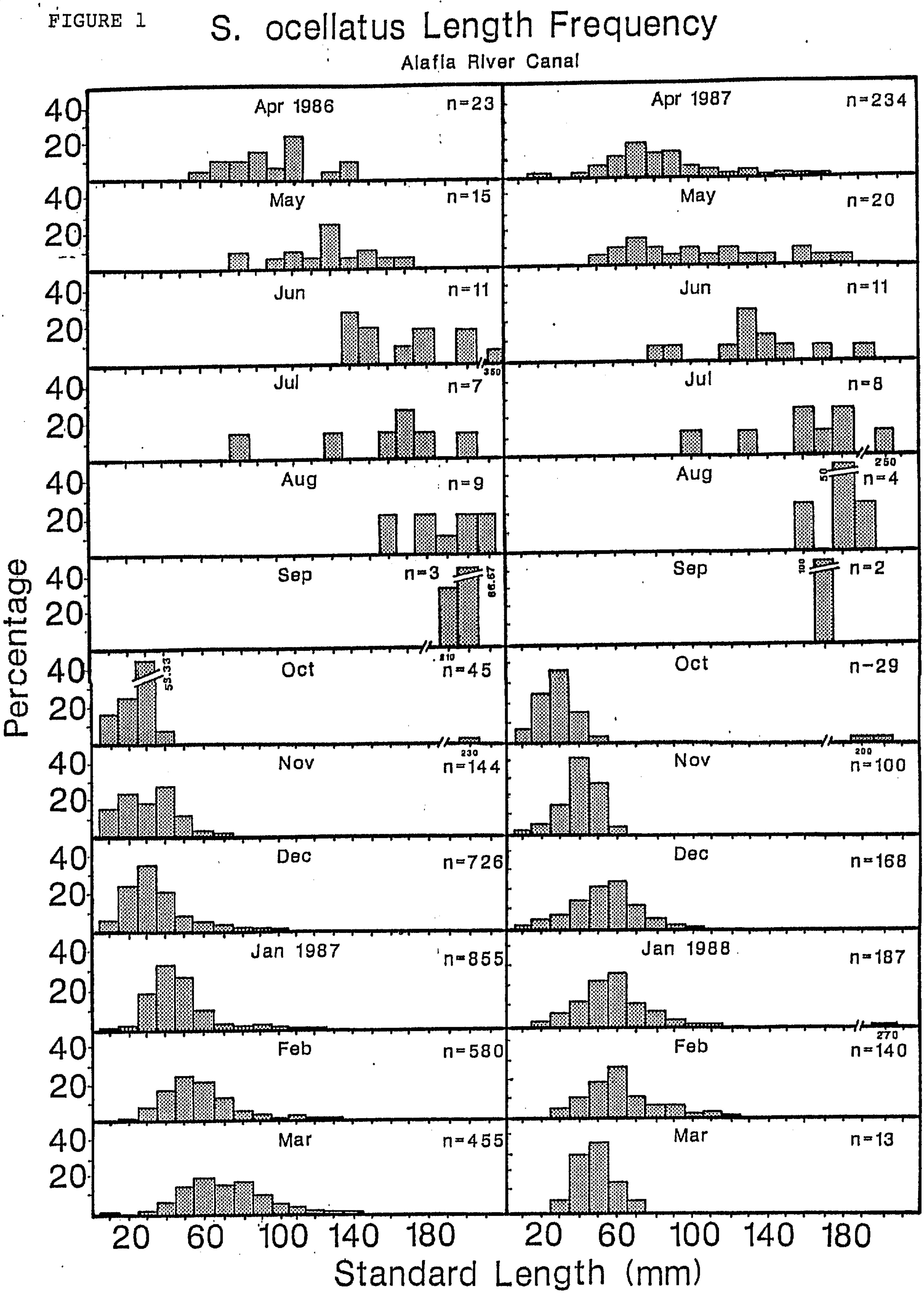

S. ocellatus Length Frequency
Alafia River Canal
Apr 1986
n=23
Apr 1987
n=234
May
n=15
May
n=20
Jun
n=11
Jun
n=11
Jul
n=7
Jul
n=8
Aug
n=9
Aug
n=4
Sep
n=3
Sep
n=2
Oct
n=45
Oct
n=29
Nov
n=144
Nov
n=100
Dec
n=726
Dec
n=168
Jan 1987
n=855
Jan 1988
n=187
Feb
n=580
Feb
n=140
Mar
n=455
Mar
n=13
Percentage
Standard Length (mm)

FIGURE 2

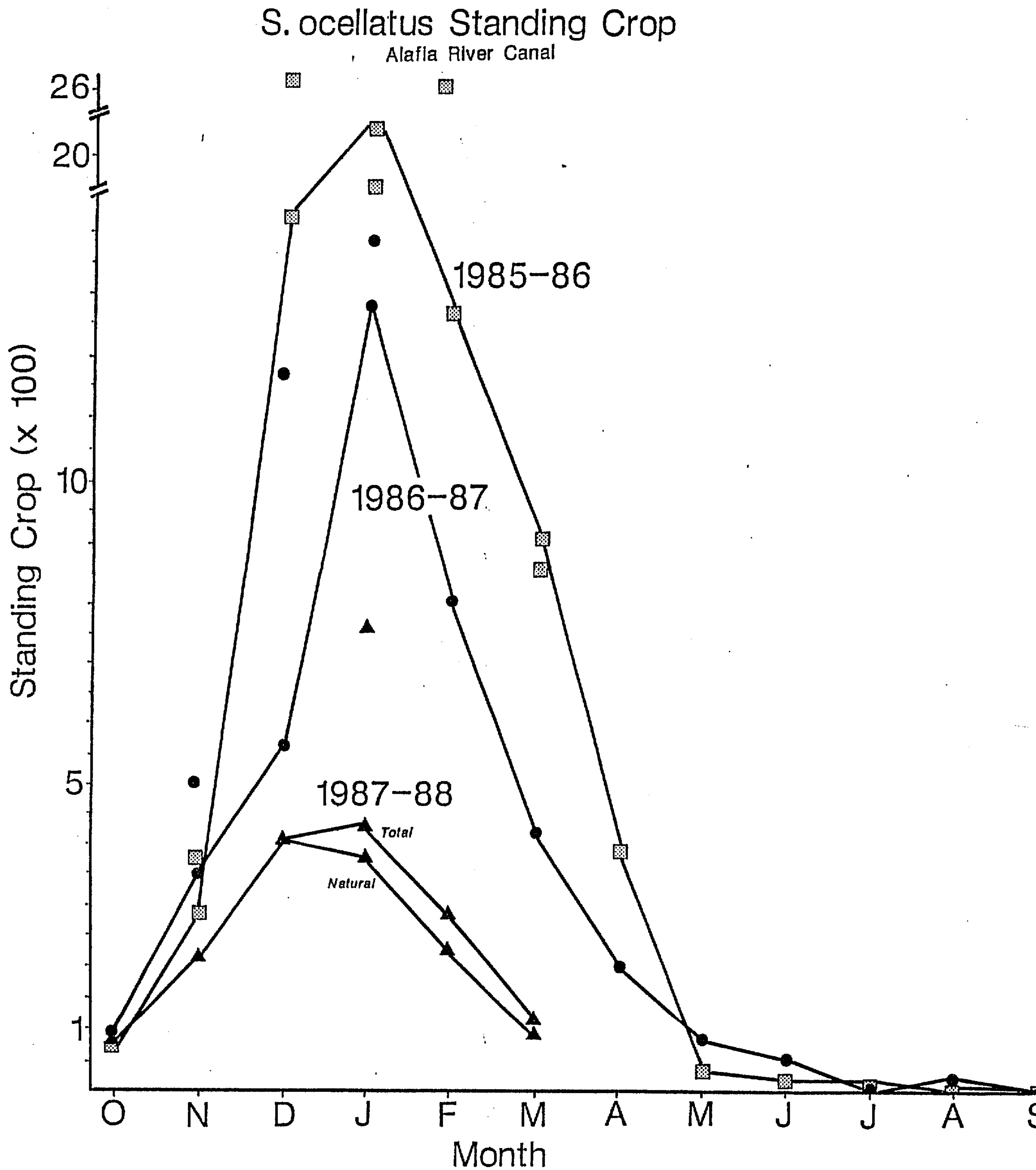

S. ocellatus Standing Crop
Alafia River Canal
Standing Crop (x 100)
26
20
10
5
1
1985-86
1986-87
1987-88
Total
Natural
O
N
D
J
F
M
A
M
J
J
A
S
Month

FIGURE 3

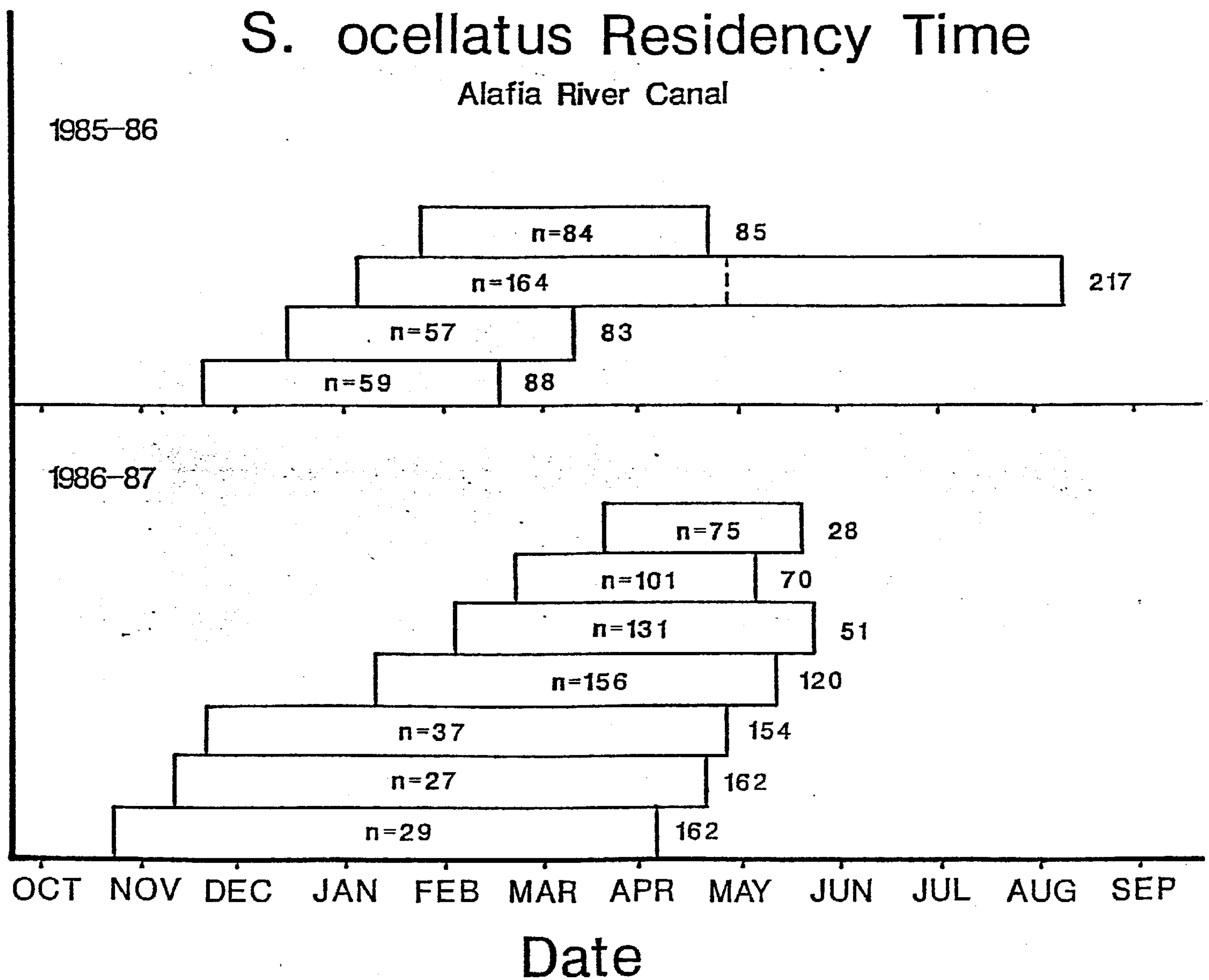
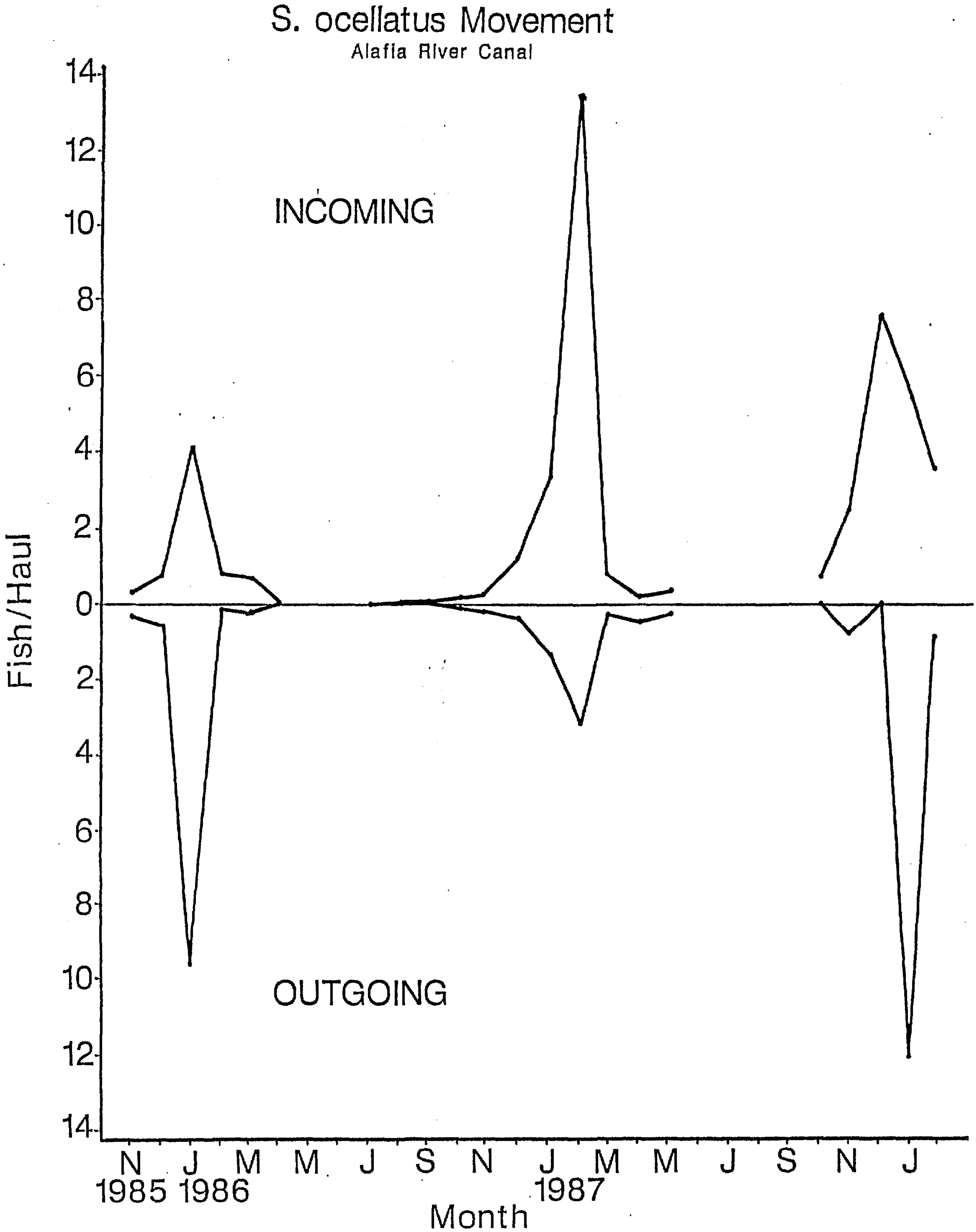

S. ocellatus Residency Time
Alafia River Canal
1985-86
n=84
85
n=164
217
n=57
83
n=59
88
1986-87
n=75
28
n=101
70
n=131
51
n=156
120
n=37
154
n=27
162
n=29
162
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Date

FIGURE 4



S. ocellatus Movement
Alafia River Canal
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
Fish/Haul
INCOMING
OUTGOING
N J M M J S N J M M J S N J
1985 1986 1987
Month

TASK #5

Public Information Regarding Coastal Wetlands and Coral Reefs

Efforts of Task #5 focus on production and distribution of educational brochures concerning our marine habitat. During the fourth quarter of 1988, an approximate total of 40,351 CZM brochures was distributed. The brochures were requested by approximately 154 organizations and 97 individuals. (See attached list A.)

A mailing data base was established in April 1988. A form letter was mailed and received by approximately 290 organizations. (See attached letter.) Requests from 117 organizations have been received and 150,376 brochures have been distributed.

25,000 Coral Reefs brochures have been printed at a cost of $1,429.00 and delivered in September 1988.

	General Distribution	Mass Mailing	Total
Coral Reefs	2,110	7,150	9,260
Estuaries	1,626	6,100	7,726
Mangroves	1,682	6,252	7,934
Salt Marsh	1,580	6,175	7,755
Sea Grasses	1,551	6,125	7,676
Total	8,549	31,802	40,351

A total of 40,351 CZM brochures was mailed in the fourth quarter of 1988. These numbers do not reflect the additional brochures distributed by lab personnel or those taken from our reception area.

State of Florida
DEPARTMENT OF NATURAL RESOURCES

Marjory Stoneman Douglas Building
3900 Commonwealth Boulevard
Tallahassee, Florida 32399

TOM GARDNER
Executive Director

REPLY TO:

Division of Marine Resources
Research Laboratories
100 Eighth Avenue S.E.
St. Petersburg, Florida 33701-5095

BOB MARTINEZ
Governor
JIM SMITH
Secretary of State
BOB BUTTERWORTH
Attorney General
GERALD LEWIS
State Comptroller
BILL GUNTER
State Treasurer
DOYLE CONNER
Commissioner of Agriculture
BETTY CASTOR
Commissioner of Education

Phone: (813) 896-8626
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7 April 1988

Mrs. Donna Strickland
Supervisor of Science
Dept. Education, Environmental Education
620 E. University Ave.
Gainesville,, FL 32601-5498

Dear Mrs. Strickland,

The Bureau of Marine Research, through a grant from the Office of Ocean and Coastal Resources Management, NOAA, provided by the Department of Environmental Regulation, Office of Coastal Management, announces the availability of educational brochures concerning Florida's coastal habitats and coral reef communities.

Samples of the full color brochures titled, "The Underwater World of Florida's Seagrasses", "Florida's Mangroves - Walking Trees", "Florida's Coral Reefs", Florida Salt Marshes", "Estuaries - The Cradle of the Ocean", are enclosed. The brochures are available in quantites of up to 500 each upon request to the St. Petersburg address listed on the letterhead.

The Bureau has also published numerous scientific papers and educational literature covering a wide range of topics all of which are available upon request, as long as they are in print.

We hope you take advantage of the availability of the above literature and assist us in disseminating information about our marine resources.

Education Is Our Future.

Sincerely,

DIVISION OF MARINE RESOURCES

Jamie L. Serino
Information Specialist III
Bureau of Marine Research

JLS/scb
Enclosures

LIST A

Florida Welcome Station	Yulee, Fl 32097
St. Pete Beach Area C of C	6990 Gulf Blvd 33736
Dr. Julian Bruce/St. George Island State Park	P.O. Box 62 St. George Island 32328
St. Marks Wildlife Refuge	P.O. Box 68 St. Marks 32355
Pasco District School Board	P.O. Box 190 Port Richey 34673
Charlotte County C of C	Port Charlotte, Fl 33952
Indian River Community College	Ft. Pierce, Fl 33454-9003
School District of Flagler County	Bunnell, Fl 32010
Cedar Key C of C	Cedar Key, Fl 32625
Palm Beach Soil and Water Conservation District	Green Acres, Fl 33463
DNR/Collier Seminole State Park	Naples, Fl 33961
Palm Beach County School Board	W. Palm Beach, Fl 33416-4690
Crystal River C of C	Crystal River, Fl 32629
Childrens Museum of Juno Beach	Juno Beach, Fl 33408
Key Colony Beach C of C	Key Colony Beach, Fl 33051
Cape Florida State Rec Area	Key Biscayne, Fl 33149
John Pennecamp State Park	Key Largo, Fl. 33037
Florida Park Service	Key Largo, Fl 33037
Alligator Harbor Aquatic Preserve	Sopchoppy, Fl 32358
Buchholz High School	Gainesville, Fl 32606
Palm Beach C of C	Palm Beach, Fl 33480
Superintendent of Schools Liberty Cnty	Bristol, Fl 32321
Florida Welcome Center	Tallahassee, Fl 32399-2000
Jupiter-Tequesta C of C	Jupiter, Fl 33477

LIST A (continued)

Dreher Park Zoo	West Palm Beach, Fl 33405
Orange County Library System	Orlando, Fl 32801
Bureau of Aquatic Preserves	Suwanee, Fl 32692
Dept. Environmental Resources	Miami, FL 33128-1971
Charlotte Harbor Aquatic Preserve	Bokeelia, Fl 33922
Sarasota Convention & Visitors Bureau	Sarasota, Fl 34236
Greater Boynton Beach C of C	Boynton Beach, Fl 33435
Palm Beach C of C	Palm Beach, Fl 33480
Safety Harbor C of C	Safety Harbor, Fl 34695
Key Largo Nat'l. Marine Sanctuary	Key Largo, Fl
Pineland Marina	Pineland, Fl 33945-0013
Pensacola Area C of C	Pensacola, Fl 32593
Osceola District Schools	Kissimmee, Fl 32741
Bahia Honda State Rec Area	Big Pine Key, Fl 33043
Hugh Taylor Birch State Rec Area	Ft. Lauderdale, Fl 33304
Environmental Study Area	Gonzalez, Fl 32560
Bureau of Aquatic Preserves	Tallahassee, Fl 32399
School Board of Manatee County	Bradenton, Fl 34206-9069
Greater Key West Chamber of Commerce	Key West, Fl 33040
District School Board/Madison County	Madison, Fl 32340
Everglades Area C of C	Everglades City, Fl 33929
Cocoa Beach Area Tourist Dev Council	Merritt Island, fl 32952
Fred Gannon Rocky BAyou SRA	Niceville, Fl 32578
Ft. Pierce Inlet SRA	Ft. Pierce, Fl 34949

LIST A (continued)

Washington County C of C	Chipley, Fl 32428
S.W. Florida C of C	Cape Coral, Fl 33904
Lee Island Coast	Ft. Myers, Fl 33901
Davie/Cooper City C of C	Davie, Fl Davie, Fl 33314
S. Hillsborough County C of C	Ruskin, Fl 33570
Lake Butler Middle School	Lake Butler, FL 32954
John Pennecamp Coral Reef State Park	Key Largo, Fl
Volusia County Schools	Daytona Beach, Fl 32015-1910
Bulow Plantation Ruins Stat Hist. Site	Bunnell, FL 32010
Apalachicola Bay C of C	Apalachicola, Fl 32310-1730
Greater Ft. Myers C of C	Ft. Myers Beach, Fl 33932
N. Miami Beach C of C	Miami Beach, Fl 33162
St. Lucie C of C	Ft. Pierce Fl 34982
N Palm Beaches C of C	Palm Beach Gardens, Fl 33408
Putnam County C of C	Palatka, Fl 32078
Environmental Studies Area	Gonzalez, Fl 32560
Greater Clearwater C of C	Clearwater, Fl 34617
DNR Ft. Clinch State Park	Fernandina Beach, Fl 32034
Greater Marathon C of C	Marathon, Fl 33050
Perry-Taylor C of C	Perry,Fl 32347
Panama City Beach-Bay County TDC	Panama City Beach, Fl 32407
DNR-Manatee Springs State Park	Chiefland, Fl 32626
Santa Rosa C of C	Milton, Fl 32570
DNR- Little Talbot Island State Park	Ft. George, Fl 32226
Greater S. Brevard C of C	Melbourne, Fl 32901

LIST A (continued)

Hobe Sound C of C	Hobe Sound, Fl 33475
St. Joseph Peninsula State Park	Port St. Joe, Fl 32456
Lower Keys Chamber of Commerce	Big Pine Key, Fl 33043
Putman County Public Schools	Palatka, Fl 32077
DNR District 8 Admin	Osprey, Fl 34229
Santa Fe High School	Alachua, Fl 32643
DNR-Apalachicola Reserve	Apalachicola, Fl 32320
Columbia County School System	Lake City, Fl 32055
School Board-St.Lucie County	Ft. Pierce, Fl 34950
Miami Beach C of C	Miami Beach, Fl 33139
Looe Key Marine Sanctuary	Big Pine Key, Fl 33043
Holmes District Schools	Bonifay, Fl 32425
Madiera Beach C of C	Madiera Beach, Fl 33708
Anna Maria Island Chamber of Commerce	Holmes Beach, FL 33509
Greater Pine Island C of C	Matlacha, Fl 33909
Hobe Sound C of C	Hobe Sound, Fl 33475
Belle Glade O of C	Belle Glade, Fl 33430
Bay City Public Libraries	Panama City, FL 33401
Miami Convention & Visitor Bureau	Miami, Fl 33137
Siesta Key C of C	Sarasota, Fl 34239
Treasure Island C of C	Treasure Island, Fl 33706
School Board of Levy County	Bronson, Fl 32621
Office of Instructional Services	Gulf County Court House/ Port St. Joe
Bay City Schools	Panama City, Fl 32402
Pasco DistrictSchool Board	Port Richey, Fl 34673

LIST A (continued)

Koreshan Stat Historical Site	Estero, Fl 33928
DNR-Big Lagoon State Rec Area	Pensacola, Fl 32507
DNR- Hobe Sound	Hobe Sound, Fl 33475
Greater Boca Raton C of C	Boca Raton, Fl 33432
Monroe County TDC	Key West, Fl 33041
Crystal River C of C	Crystal River, Fl 32629
Everglades Area C of C	Everglades City, 33939
Naples Area C of C	Naples, Fl 33940
State Library Document Section	Tallahassee, Fl 32399
Florida Welcome Center	Jennings Fl 32053
Florida Welcome Center	Yulee, Fl 32097
Florida Welcome Center	Campbelltown, Fl 32426
Florida Welcome Center	Pensacola, Fl 32505
Capitol Welcome Center	Tallahassee, Fl 32399
Florida Division of Tourism	Tallahassee, Fl 32399
School Board of Seminole County	Sanford, Fl 32771
School Board of Jackson County	Marianna, Fl 32446
School Board of Sarasota County	Sarasota, Fl 33577
Duval County Public Schools	Jacksonville, Fl 32207

LIST A

Bay Point Elementary School	St. Petersburg
Clerk of Courts-Punta Gorda	Punta Gorda, Fl
Pines Middle School	Pembroke Pines, Fl 33024
Florida Marine Science Educators	St. Petersburg, Fl 33701
National Marine Fisheries-Coast Guard	St. Petersburg
Office of Communications	Tallahassee
Charlotte County Chamber of Commerce	Punta Gorda, Fl
Ruskin Fair	Ruskin, Fl
Hobe Sound Nature Center, Inc	Hobe Sound, Fl
Winter Park High School	Winter Park, Fl
Department of Tourism	Tallahassee, Fl
Patricia Vanossi	Middle School-Ft. Lauderdale, Fl
St. Petersburg High School	St. Petersburg, Fl
Wink T.V.	Ft.Myers, Fl
Coast Guard Course/Walt Jaap	St. Petersburg, Fl
Brian Carr-High School	Morristown, NJ
Dunedin High School	Dunedin, Fl
Bay Point Middle School	St. Petersburg, Fl
Norwood Elementary	St. Petersburg, FL
MSUS Marine Science Under Sail	Hollywood, Fl
NCNBank Newcomer Dept	Ft. Lauderdale, Fl
Environmental Study Center	Ft.Pierce, Fl
Swiftmud	St.Petersburg, Fl
Sarasota Christian Day School	Sarasota, Fl

LIST A First Quarter, 1988

Aurora Environmental	Tampa, Florida
Charlotte Harbor Aquatic Preserve	Bokeelia, Florida
Cogen (Bill Welch)	Erie, Pennsylvania
DER	Ft. Myers, florida
DNR, Office of Communications	Tallahassee
FLorida Oceanographic Society	Stuart, Florida
Hampton Pines Park	North Lauderdale, Florida
Key Largo Chamber of Commerce	Key Largo, Florida
LEEF Conference	Lake Wales, Florida
Lower Dauphin Sr. High School	Hummelston, Pennsylvania
Sarasota Family Medical Clinic	Sarasota, Florida
SWIFTMUD (SWIM)	St. Petersburg, Florida
U.S. Dept Interior Canaveral Nat"l Seashore	New Smyrna, Florida
Tony Lozon, Florida Environmental Preservation Association	St. Petersburg, Florida

LIST A

The Pier Aquarium	St. Petersburg, FL 33701
Florida Keys Welcome Center	Key Largo, FL 33037
AAA Automobile Club of Butler County	Cranberry Township, PA 16033-2235
Miami-Dade Public Library System	Miami, FL 33189
Long Key State Recreation Area	Long Key, FL 33001
Lignumvitae Key State Botanical Site	Isla Morada, FL 33036
Hobe Sound Nature Trail	Hobe Sound, FL
Terra Ceia Aquatic Preserve	Ellenton, FL 34222
Heritage Private School Systems, Inc.	Seminole, FL 34642
Department of Environmental Management	Clearwater, FL 34616
Florida Cooperative Extension Service	Seffner, FL 33584
Fruit & Spice Park	Homestead, FL 33031
D.O.T.	Lake City, FL 32055

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