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IMPACT OF FRESHWATER DISCHARGE FROM CAPE CORAL WATERWAYS INTO MATLACHA PASS AQUATIC PRESERVE

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Final Report

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EXECUTIVE SUMMARY

The Cape Coral canal system has altered the natural sheet flow of freshwater into Matlacha Pass Aquatic Preserve (Lee County, Florida). In an attempt to mitigate the potential environmental problems caused by this development, the Florida Department of Environmental Regulation (DER) required the developer of Cape Coral, Gulf America Corporation, to construct a "spreader" or "interceptor" waterway system at the border of Matlacha Pass Aquatic Preserve and the Cape Coral canal system. The intended purpose of the Spreader system was to re-establish, as best as possible, the natural sheet flow of water through the saline wetlands of MPAP. This sheet flow would facilitate the gradual, widespread mixing of fresh and saltwater. It would also help filter pollutants. The Spreader system has been identified as a sensitive area of particular concern with regard to water quality by the Charlotte Harbor Management Plan.

The little information available on the effectiveness of the Spreader system indicates that it is not functioning as intended. An engineering study found "breaks" or "breaches" along the Spreader-wetland boundary which cause channelized flow of water. The extent of the Spreader system problems, and the potential environmental impacts on MPAP, have not been thoroughly investigated.

The Environmental Resources Division of the City of Cape Coral has designed a long-term project to evaluate the function of the Spreader system, to investigate potential environmental impacts of discharge from Cape Coral into MPAP, and to develop and implement improvements of the Spreader system. The overall goal is to minimize the environmental impacts of discharge from Cape Coral waterways into MPAP.

The objectives of the initial stage of the project are to evaluate the effectiveness of the Spreader system and locate breaks in the system; to determine the extent and impact of channelized discharge from Cape Coral on the Matlacha ecosystem; and, to establish baseline data which will be used to evaluate the effectiveness of measures implemented to improve the Spreader system. This initial phase includes water quality monitoring, investigating cattail invasion of the mangrove ecosystem, and vegetational and fisheries surveys of seagrass beds. This phase, initiated in October 1988, is the subject of this report. The study period covered in this report is October 1988 through December 1989.

A total of 13 breaks, ranging from 1.5 to 14 m wide and 0.3 to 1.5 m deep, were found in the north and south Spreader rim canal. Substantial volumes of brackish to freshwater flow through these breaks into Matlacha Pass Aquatic Preserve (MPAP). This channelized flow reaches the receiving waters virtually unmixed and unfiltered in the wet season. This input affects the physiochemical habitat of the wetlands and receiving waters of MPAP. Because the upland area of the Spreader system is <10% developed, only small quantities of pollutants (e.g., excessive nutrients, petroleum hydrocarbons) are entering MPAP. Pollutant loading will increase with increasing development.

Salinity is an important factor affecting seagrass and seaweed distribution, abundance, and seasonality in Matlacha Pass. It is difficult to assess the effect of freshwater or low salinity channelized discharge through Spreader breaks on seagrass and seaweed distribution and abundance in MPAP because there are insufficient data previous to this study. We believe that channelized discharge may inhibit or affect seagrass and seaweed growth in the immediate receiving waters and perhaps at nearshore areas on the tidal flow path from the receiving waters.

Cattails have invaded MPAP saline wetlands through breaks and along channelized flow paths. At most breaks this invasion is minor; however, Typha invasion through NB-2, the break with the highest discharge rate, is extensive. It appears that Typha has opportunistically colonized habitat newly created or altered, physically and chemically, by the channelized discharge from the Spreader. Although there are little or not data previous to our study, we doubt that Typha was present along the tidal creek before NB-2 and the resultant Spreader discharge via the creek existed.

Typha abundance varied seasonally at the mangrove-cattail study sites. Typha die-back in the dry season likely reduces its rate of invasion into the saline wetlands. The red mangrove, Rhizophora mangle, exhibited little seasonality. The 3-4 months of low Typha abundance are apparently insufficient time for a substantial increase in abundance of the slower growing Rhizophora. Repair of the breaks and elimination of channelized freshwater discharge would inhibit Typha invasion and enhance re-establishment of wetland vegetation.

We could not conclusively determine if reduced salinity had a negative impact on fish abundance in nearshore seagrass beds in Matlacha Pass. Many factors, in addition to salinity, can influence the abundance of juvenile fish in seagrass beds.

The breaks must be repaired as soon as possible. The goal is to eliminate channelized discharge and re-establish sheet flow. An engineering project is underway to repair known breaks. Ecological monitoring must continue to assess the effectiveness of repairs to the spreader waterway; to determine changes (improvements) in the MPAP ecosystems following the anticipated reduction in channelized discharge from Cape Coral; and, to ascertain the need for additional management actions to restore damaged ecosystems. Additional breaks in the Spreader will likely occur in the future. Thus, a long term maintenance program for the Spreader needs to be instituted.

BACKGROUND

Matlacha Pass, in Lee County, is one of 40 State Aquatic Preserves in Florida (Figure 1). Aquatic preserves are state-owned submerged lands of special natural resource value which are intended to be maintained in an essentially natural condition. They are designated by acts of the Florida Legislature and administered by the Florida Department of Natural Resources (DNR). Matlacha Pass is identified as a sensitive area of particular concern within the Charlotte Harbor estuarine system because of its valuable natural resources, recreational value, hydrographic position, and vulnerability to upland development (1). Significant natural resources include extensive mangrove, seagrass, and marsh systems which serve as important juvenile and/or adult habitats for fisheries, the West Indian manatee, and other threatened and endangered species. These resources are potentially threatened by, among other factors, channelized discharge of fresh or brackish water from the adjacent Cape Coral waterway system.

The City of Cape Coral extends along and beyond the entire eastern border of Matlacha Pass. The City is transected by over 400 miles of man-made fresh and estuarine waterways (Figure 4). This extensive waterway system disrupted the natural sheet flow of water through the saline wetlands of Matlacha Pass Aquatic Preserve (MPAP). Channelized flow, caused by the Cape Coral system and Gator Slough Canal, results in rapid, high volume, point source of nearly freshwater during the rainy season into Matlacha Pass. Furthermore, pollutants (e.g., excessive inorganic nutrients, petrochemical products) from the canal system may be entering MPAP. These environmental impacts may have a negative effect on marine/estuarine flora, including mangroves and seagrasses, and fauna, especially juvenile states, in the Matlacha ecosystem. Many of these organisms have recreational and/or commercial value. Increased freshwater discharge into estuaries has adversely affected important fishery species elsewhere in Florida (2,3).

In an attempt to mitigate these potential environmental problems, the Florida Department of Environmental Regulation (DER) required the developer of Cape Coral, Gulf America Corporation, to construct a "spreader" or "interceptor" waterway system at the border of Matlacha Pass Aquatic Preserve and the Cape Coral canal system (Figure 2). The intended purpose of the Spreader system was to re-establish, as best as possible, the natural sheet flow of water through the saline wetlands of MPAP. This sheet flow would facilitate the gradual, widespread mixing of fresh and saltwater. It would also help filter pollutants. The Spreader system also serves as a retention and pollutant assimilation area for upland stormwater runoff. The Spreader system has been identified as a sensitive area of particular concern with regard to water quality by the Charlotte Harbor Management Plan (1).

The little information available on the effectiveness of the Spreader system indicates that it is not functioning as intended. An engineering study found "breaks" or "breaches" along the Spreader-wetland boundary which cause channelized flow of water (4). An unpublished U. S. Geological Survey study documented channelized flow of fresh or low salinity water through breaks in the north Spreader system into MPAP saline wetlands during the rainy season. This USGS study measured some water quality parameters, but it did not investigate the ecological impact of the freshwater intrusion.

The extent of the Spreader system problems, and the potential environmental impacts on MPAP, have not been thoroughly investigated. The Charlotte Harbor Management Plan states that there is insufficient water resource data to understand how the Spreader system operates or to identify any environmental problems in Matlacha, both current and future, caused by the Spreader system (1). It recommends further investigation into these problems. Cape Coral's population is currently at 15-20% of an anticipated build-out of 350,000. The area bordering MPAP is one of the fastest growing sections of the City. Therefore, the potential for additional impact on MPAP is high.

The Environmental Resources Division of the City of Cape Coral has designed a long-term project to evaluate the function of the Spreader system, to investigate potential environmental impacts of discharge from Cape Coral into MPAP, and to develop and implement improvements of the Spreader system. The overall goal is to minimize the environmental impacts of discharge from Cape Coral waterways into MPAP. This project is required by the City's Comprehensive Plan (5). This project will involve the City of Cape Coral, FDNR, FDER, and perhaps the South Florida Water Management District and USGS.

The objectives of the initial stage of the project are to evaluate the effectiveness of the Spreader system and locate breaks in the system; to determine the extent and impact of channelized discharge from Cape Coral on the Matlacha ecosystem; and, to establish baseline data which will be used to evaluate the effectiveness of measures implemented to improve the Spreader system. This initial phase includes water quality monitoring, investigating cattail invasion of the mangrove ecosystem, and vegetational and fisheries surveys of seagrass beds. This phase, initiated in October 1988, is the subject of this report. The study period covered in this report is October 1988 through December 1989.

The second phase of the program is an engineering project to fill in the breaks, attempting to reestablish sheet flow. This project, which is being conducted by the City's Engineering/Public Works Department, was initiated in September 1989. The project is currently in the design phase.

The third phase of the program is continued environmental monitoring of the Spreader system and the Matlacha ecosystem after repairs to the Spreader system. Data obtained in this phase will be compared to baseline data collected during the first phase. These data are essential to evaluate the effectiveness of repairs to the Spreader system; to determine changes in the seagrass and mangrove ecosystems in response to the anticipated reduction in channelized discharge from the Cape Coral canals; and, to ascertain the need for additional management actions, such as, restoration of damaged or destroyed plant communities as specified by the aquatic preserve management plan (1).

The Charlotte Harbor system is the least studied major estuary in Florida (6). This is especially true for the seagrass ecosystems in Matlacha Pass and Pine Island Sound. An additional objective of this study is to contribute to the understanding of seagrass population dynamics and seasonality in the Charlotte Harbor System.

Summary of Project Objectives:

1. Determine the number, size, and locations of breaks in the Spreader system that result in channelized low-salinity flow into the Matlacha wetlands.

2. Attempt to assess the impact of channelized low-salinity flow on Matlacha estuarine wetland and seagrass/seaweed ecosystems. (This objective is difficult to achieve because the lack of scientific data on these ecosystems before channelization occurred).

3. Obtain baseline scientific data which will be used to evaluate the effectiveness of repairs to the Spreader system.

4. Provide basic scientific data on the Charlotte estuarine system, especially the seagrass ecosystems in Matlacha Pass and Pine Island Sound.

STUDY AREA

The Charlotte Harbor estuarine system, located on the Gulf of Mexico in southwest Florida, includes Charlotte Harbor, Pine Island Sound, Matlacha Pass, San Carlos Bay, and the tidal Caloosahatchee, Peace, and Myakka Rivers (Figure 1). The system has a water surface area of 920 km^2. Pine Island Sound and Matlacha Pass are shallow; most of the subtidal area is <1.2 m deep (7).

The climate of the region is subtropical and humid. Climatological data for Fort Myers (17 km east of Matlacha Pass) are given in Tables 1 and 2. The mean annual temperature is 23.3°C (1959-1988). Rainfall averages 136.5 cm (53.7 inches) annually (1959-1988). There are definite wet (mid-June through September) and dry (November through May) seasons. About 64% of the annual rain fall occurs during the wet season.

Benthic vegetation, seagrasses and seaweeds, covered about 237 km in the Charlotte Harbor estuarine system in 1982 (8). Most of the seagrass beds occur in Pine Island Sound, Matlacha Pass, and San Carlos Bay. The tropical seagrasses *Thalassia testudinum* and *Halodule wrightii* and subtropical red seaweeds are the predominate benthic vegetation. Unvegetated sandy bottom and seagrass meadows are the most common benthic habitats in Matlacha Pass and Pine Island Sound.

The north and south Spreader waterway systems are a part of the 650 km of man-made canals and lakes in Cape Coral. The brackish water Spreader systems are the most westerly canal systems in Cape Coral (Figure 4). They are adjacent to Matlacha Pass Aquatic Preserve. The south and north systems are separated by several km on both sides of Pine Island Road. Each system consists of the outer rim Spreader canal, the western bank of which borders MPAP, and a network of finger canals proceeding landward to Burnt Store Road (north) and Chiquita Boulevard (south). The systems are separated from adjacent freshwater canals by a series of weirs (dams) along these roads. They are also separated from the estuarine canals by dams with a boat lift (north) and boat lock (south).

The north system has a direct drainage basin of km², and the south of km². Both systems receive discharge over the weirs from the adjacent freshwater canals to the east. The area of the Cape Coral freshwater canals draining into the north Spreader is greater than that in the south. Furthermore, the north Spreader receives all of the discharge from Gator Slough Canal, which drains a large area outside of the City. Thus, the north Spreader system receives more freshwater inflow than the south Spreader; however, the actual volumes are not known. Water is discharged into the Spreader system from the adjacent freshwater system at least months of the year.

Specific study sites are described in the Methods section.

METHODS

Locating Breaks in Spreader System

Surveys of the north and south Spreader canal were conducted in October 1988, the first month of the study, to determine the number and magnitude of breaks or breaches in the Spreader berm. Additional surveys were made in late August and early September 1989, the period of peak water level. Also during this period water flow rate measurements were taken by a U.S. Geological Survey hydrologist at the largest break in the north and south system. These measurements were made one to two hours before low tide.

Water Quality Monitoring

Water quality data were taken throughout the Spreader system, especially at breaks; along channelized flow paths through Matlacha wetlands caused by the largest break in the south and north Spreader; in Matlacha Pass; and, in Pine Island Sound (PIS), which serves as the control for Matlacha sites because PIS receives little direct terrestrial runoff. Thus, a non-linear transect of water quality stations extending from the Spreader, along a break flow path, and into Matlacha Pass--was established in each section of the Spreader system. Figures 1,2,and 3 give the locations of water quality monitoring stations.

The following water quality parameters were sampled monthly at each station: temperature, salinity/conductivity, dissolved oxygen, pH, turbidity, ammonia, nitrate-nitrite, TKN, inorganic phosphorus, and organic phosphorus. Petroleum hydrocarbons were sampled periodically at selected stations. All analyses will be performed using standard methods (9, 10).

Benthic Vegetation (Seagrass/Seaweed) Surveys

The seagrass monitoring sites were selected based on their proximity to water quality stations, their position along the Spreader-break-Matlacha transect, and the need for sampling the three major seagrass species (*Thalassia testudinum*, *Halodule wrightii*, and *Ruppia maritima*) present along this transect. Major sites were sampled quarterly (December 1988, March, June and September-October 1989); other sites were sampled at the end of the dry (June) and wet (October) seasons. The sites are (see Figures 1,2,and 3):

MS-PBB: A seasonal macroalgal (seaweed) bed in Punta Blanca Bay near the point of discharge from the southern channelized break. Punta Blanca Bay is the receiving body for channelized discharge from the major break in the southern Spreader. Sampled quarterly.

MS-PBB-OC: A seasonal sparse *Halodule* and algal bed at the junction of Punta Blanca Bay and Oyster Creek. Oyster Creek is the major outflow from Punta Blanca Bay to Matlacha Pass. Sampled at end of dry (mid-June) and (early October) wet seasons.

MS-OCN-H: A *Halodule* bed in Matlacha Pass at the mouth of Oyster Creek. Approximate area: 600-800 m^2. Sampled quarterly.

MS-OCN-T: A *Thalassia* bed (area <750 m^2) adjacent to and west of MS-OCN-H in southern Matlacha Pass. Sampled quarterly.

MS-GK: A large *Thalassia* bed on the north side of Givney Key in central southern Matlacha Pass. Sampled quarterly.

MN-P1: A *Ruppia*-*Halodule* bed northeast of the Matlacha Bridge in north Matlacha Pass. This is the seagrass bed nearest the discharge point from the largest break in the north Spreader.

MN-Marker "63": A *Thalassia-Halodule* bed at navigational marker "63" in central northern Matlacha Pass. Sampled at end of dry (June) and wet (October) seasons.

PIS-2: A large *Thalassia* bed in Pine Island Sound several kilometers east of Captiva Pass and adjacent to Rocky Channel. This site was chosen as a control (little direct low-salinity or terrestrial input) to more accurately explain changes at Matlacha sites. Sampled quarterly.

PIS-1: A large *Thalassia* bed in Pine Island Sound 0.5 km south of Coon Key and 3.5 km east of southern Cayo Costa. This site is also a control which was sampled at end of dry (June) and wet (October) seasons.

Mean low water depth at all sites was <1.0 m.

Population and community structure data were collected at each site using 0.25 m^2 quadrats located randomly within the grass bed. Each quadrat was divided into four 0.0625 m^2 (1/16 m^2) sections and one of these was randomly selected for sampling. For *Thalassia*, all shoots and blades in the 0.0625 m^2 section were counted, and the lengths of 6-10 blades were recorded. When *Halodule* was sparse or moderate in abundance, all shoots in the 0.0625 m^2 section were counted. In *Ruppia* and dense *Halodule* beds, a 0.02 quadrat were haphazardly placed within each quadrat for shoot counts. After recording counts and lengths, all grass and algal biomass within the 0.0625 m^2 section was harvested at ground level and brought back to the lab where it was sorted, rinsed, epiphytes and epizoics removed, and widths of five blades from each sample were recorded. Seagrass and algal biomass samples were dried at 60 °C until a constant weight.

We were unable to obtain adequate aerial photographs to accurately determine long term (since 1975, when the Spreader was constructed) changes in seagrass area at the study sites.

Mangrove-Cattail Interactions

The invasion of cattail (Typha) into the mangrove system and mangrove-cattail interactions are being monitored at two locations along the north Spreader break flow path. Both locations are near water quality station MN-C2 on the banks of the tidal creek that conveys channelized discharge from the north Spreader (Figure 3). The sites are the farthest penetration of Typha into the saline wetlands. Site A is about 100m². About one-half of the area is Typha; the other half is spare mangrove seedlings (mainly red, a few white). The second location (total area: about 1200m²) is divided into two sites: Site B is mainly Typha (area: 600-700 m²); Site C (area: 400 m²) is composed of juvenile red mangroves (Rhizophora mangle) and cordgrass (Spartina alterniflora). An ecotone about 5 m wide exists between the Typha and Rhizophora-Spartina stands. Interstitial salinity (depth: 0.3 m) was taken from wells at locations in both study sites.

Population and community structure data were collected quarterly, in February, May, August, and November 1989, at each site. The number of shoots, shoot height, and live leaves per shoot for each species were recorded in randomly located quadrats. Five permanent 0.5m² quadrats at the ecotone between the mangroves and invading Typha have been established at each site. The number of shoots, shoot height, and live leaves per shoot for each species in these quadrats are sampled quarterly.

We were unable to obtain adequate aerial photographs to accurately assess Typha invasion and mangrove-Typha interactions on larger spatial and temporal scales.

Fisheries Surveys

Juvenile fish abundance in the seagrass study beds was assessed by seining. The following sites were sampled bimonthly from March 1989 to November 1989: MS-OCN-H, MS-OCN-T, and MS-GK in south Matlacha Pass; MN-P1 in north Matlacha Pass; and, PIS-2 in Pine Island Sound. We used a beach seine with a mesh size of 0.25 inches enabling us to capture juveniles as small as 10 mm. Before seining the grass bed was visually surveyed by snorkeling to determine its outer margins. Two people standing 8 m apart pulled the seine a marked distance of either 20 or 25 m; thus, each seine covered an area of either 160 or 200 m². Six to eight replicate tows were performed at each site, with each tow covering a different, undisturbed area. Sampling was conducted within two hours of high tide. In August, during the wet season, fish surveys were made at low and high tide to determine any differences with tide, and hence salinity, at OCN-H, OCN-T, MN-P1, and PIS-2. Fish captured were identified, enumerated, and measured on site, and then returned live to the water. After each seine, we made a qualitative estimate of benthic vegetation relative abundance in the area covered.

Statistical Procedures

The t-test or its nonparametric equivalent, the Mann-Whitney U test, was used to test for significant ($P<0.05$) difference between two groups of data. Analysis of variance (ANOVA) or its nonparametric equivalent, the Kruskal-Wallis test, was used to test for significant difference among more than two data groups. For the permanent quadrats, which were sampled repeatedly, in the *Typha*-mangrove study, a two-way ANOVA without replication was the statistical test used.

RESULTS AND DISCUSSION

Identification and Description of Breaks

Six breaks or breaches were found in the south Spreader system (Figure 5). A brief description of the south breaks (SB-#) follows:

SB-1: The largest break in the southern system. It is 13-14 m wide and has a maximum depth of 1.2 m in wet season. Water flows from the Spreader through this break throughout the year. The discharge rate in the wet season was 48 ft^3/s. The immediate area downstream of the break appears to be either a filled in canal or former road bed. Several hundred meters downstream from the origin of the tidal creek in an area of heavy mangrove growth, we observed sawed-off mangrove branches. Thus, human activity is inhibiting the mangrove from growing into the channelized flow path. The water from this area flows into a tidal creek which discharges into Punta Blanca Bay. Water quality monitoring was conducted in the channelized flow path originating at this break.

SB-2: About 6 m wide and 0.3 m deep.

SB-3: Also 6 m wide and 0.3 m deep.

SB-4: 3 m wide, 0.6 m deep. There is an obvious current through this break during the wet season. Aerial photographs and ground surveys reveal a remnant canal or road bed immediately down stream from SB-4. Water discharging through SB-4 flows seaward down this channel or path and then enters a culvert. We could not determine where the culvert terminates.

SB-5: 4.5 in wide and 0.3 m deep. Cattails growing in the break.

SB-6: 7.5 wide and 0.3 m deep. Cattails growing in the break.

There are seven breaks (NB-#) in the north Spreader system (Figure 6).

NB-1: 3 m wide and 0.3 m deep. This break results in channelized flow, at a relatively high velocity (wet season), around the west end of the boat lift into an estuarine canal which leads into Matlacha Pass. An elevation gradient accounts for the high velocity. Water from the Spreader system flows through this break year round.

NB-2: This is the largest break in the north Spreader system. It is nearly 8 m wide and has a maximum depth of 1.5 m. Sawed-off mangrove branches were observed at the break and several meters downstream into the channelized flow path. Again, this is evidence that man is inhibiting mangroves from growing into a break and flow path. Water flows from the Spreader through this break throughout the year. The discharge rate in the wet season was 95 ft^3/s, the greatest at any break. The break size, a large hydrostatic head, and an elevation gradient accounts for the high discharge rate. Water flowing through this break enters a tidal creek. The creek empties into a dredged channel that, in less than 100 m, opens into a back bay of Matlacha Pass. Water quality stations and the mangrove-cattail study sites were located along the channelized flow path originating at this break.

NB-3: This break is about 6 m wide and 1.5 m deep in the wet season. A slight current entering the break was detected. This break connects the Spreader canal with another extensive canal dredged in the wetlands but later abandoned when construction activities ceased. There is clear evidence that human activity contributes to maintaining the break opening.

NB-4: This break is about 6 m wide and 0.5 m deep in the wet season. An obvious current entering the break was observed. Water flowing through the break enters a partially filled canal which extends several hundred meters seaward into the wetlands before intersecting a deeper, more extensive canal which parallels the Spreader canal.

NB-5: A 1-1.5 m opening blocked with stone rubble. Beyond the break is a partially filled canal with emergent vegetation. This proceeds several hundred meters seaward into the wetlands and connects with a deeper extensive canal that parallels the Spreader canal.

NB-6: This is a shallow opening 1-1.5 m wide with cattails growing in it. It leads to a partially filled canal.

NB-7: A small break, 1-1.5 m wide, clogged with cattails. Appears to lead into a marsh.

Many of the breaks in the Spreader system occur at points where partially filled canals or old road beds intersect with the Spreader canal. They are remnants of the original dredging of the Cape Coral canal system. The breaks formed because these canals and road beds were not properly filled in when construction ceased and/or because of natural erosion and settling processes over the past 14 years. There is clear evidence that human activity (e.g., cutting of wetland vegetation, airboating, canoeing) help maintain the breaks. Human activity may even have caused some of the smaller breaks.

The discharge rate through breaks is generally greater in the north than the south Spreader. This is likely because more freshwater flows into the north Spreader due to input from Gator Slough canal. Also, the elevation gradient between the Spreader and Matlacha Pass is steeper in the north than south. Thus, there is likely a greater hydrostatic head in the north Spreader.

Discharge from the Spreader through SB-1 and NB-2 appears to greatly affect the physiography of the tidal creeks receiving the discharge. The surface sediment of the upper halves of the creeks is coarse sand, the same composition of the soils in the Spreader area of Cape Coral. During the wet season, sand banks form in the creeks which create habitat for wetland vegetation, alter the flow pattern of the creek, and limit tidal flushing in small embayments.

Water Quality

Precipitation and the resulting terrestrial runoff can greatly influence water quality. Precipitation during the 1989 wet season (June through September) was 92% that of the 30 yr mean (Table 1). However, rainfall in September and October 1989 was only 58% of the 30 yr mean. Hence, the duration of the 1989 wet season was shorter than usual, although total precipitation was near average. Precipitation from January 1988 through April 1989 was only 68% of the 30 yr mean. Rainfall in 1988 was the lowest for any year in 50 yr. Drought conditions existed for at least the first seven months of the study (October-May 1989).

A gradient of increasing salinity proceeding from the Spreader system through Matlacha wetlands and back bays, into Matlacha Pass, to Pine Island Sound existed throughout the study period (Table 3). Salinity in Matlacha Pass was equivalent to that in Pine Island Sound only in the latter part of the dry season (April to mid-June); and even then, only during high tide at stations adjacent to the mainland (MS-OCN, MN-P1). Pine Island Sound had the lowest annual salinity range (26-37 ppt). The receiving waters of channelized flow through the Spreader breaks, Punta Blanca Bay (MS-PBB) and MN-P1 in north Matlacha, had the highest annual range (Table 3).

Salinity in the Spreader system ranged from 0 to 17 ppt, classifying the system as oligohaline to mesohaline. There was a gradient of increasing salinity in the system proceeding from east, the points of freshwater inflow, to west, adjacent to saline wetlands. At any given time, salinity in the north Spreader rim canal was usually lower than in the south. As mentioned previously, the north system receives more freshwater input than the south. However, by the end of the 1989 dry season the surface salinity in both systems reached 14 ppt (Table 3). This is the highest salinity recorded in 3 yr of monitoring (11). The high salinity was undoubtedly a result of the 18 mo drought. The contributing factors were the influx of saline groundwater into surface waters, reduced direct and indirect freshwater input, and, in the south, possible input of saline surface water at extreme high tide.

The 1989 wet season began about June 18-20. Within 10 days, salinity dropped considerably in the Spreader systems, the channelized break flow paths, and the immediate receiving waters Punta Blanca Bay (MS-PBB) and a back bay in north Matlacha Pass (MN-C1) (Figures 7 and 8). Except for the later part of the dry season, the physiochemical characteristics (salinity, dissolved oxygen, pH, temperature) of the discharge water varied little along its channelized path from the Spreader to the immediate receiving waters. This is the antithesis of the intended function of the Spreader to promote sheet flow and gradual mixing.

The low salinity channelized flow also affected the physiochemical characteristics of Matlacha Pass proper. At MN-P1 on June 26, 1989, surface and bottom (0.5 m) salinities at low tide were 9 and 21 ppt, respectively; whereas, in early June surface and bottom salinities were 29 and 31 ppt, respectively. At the mouth of Oyster Creek in Matlacha Pass (MS-OCN) on July

11, surface and bottom (0.3 m) salinities at low tide were 11 and 16 ppt, respectively. In the two months before wet season onset, the lowest salinity recorded at MS-OCN was 27 ppt. FDNR scientists measured salinity at 9.5 ppt at MS-OCN during the 1988 wet season (Hesselman and Seagle, unpublished data). Ten minutes earlier salinity at Sword Point at the mouth of the Caloosahatchee River (see Figure 2), on an outgoing tide, was 16 ppt. This suggests that river discharge was an unlikely, or only minor, causative factor of the low salinity recorded at Oyster Creek.

These observations indicate that channelized low salinity or freshwater flow through the Spreader breaks has a substantial effect on the physiochemical characteristics of Matlacha wetland and benthic habitats, even early in the wet season.

It appears that "pollutants" are only occasionally discharged from the Spreader system through the breaks into MPAP. Total phosphorus concentration exceeded the minimum level indicative of eutrophication (>30 ug/L, 12) once at the south Spreader break (SP-4, Figure 9) and twice at the north Spreader break (MN-C4, Figure 10). None of the total inorganic nitrogen concentrations recorded during the study were at eutrophic levels (Figures 11 and 12). Petroleum hydrocarbon concentrations were within FDER standards.

Less than 10% of the upland area in the Spreader system is developed. At present, only small quantities of pollutants likely enter the Spreader canals via stormwater runoff. However, with increasing development pollutant loading will increase. These pollutants will rapidly enter MPAP unfiltered if the breaks are not repaired and the Spreader maintained.

Benthic vegetation (Seagrass/Seaweed)

MN-P1, the seagrass site in north Matlacha Pass that experienced the greatest salinity range, had the greatest seasonality in seagrass composition and abundance (Table 4). When first surveyed in November 1988 the site was a Ruppia maritima bed. Ruppia is a brackish-water plant that grows best at lower salinities. As the dry season progressed and salinity increased Ruppia abundance declined. At the end of the dry season, Ruppia was not encountered in our sampling at MN-P1. Between March and June, Halodule wrightii became established at MN-P1. Halodule abundance decreased during the wet season, with decreasing salinity. Ruppia was not observed in the sampling at the end of the wet season. Thalassia was not observed at MN-P1.

At marker 63 in central north Matlacha Pass, Thalassia abundance declined considerably during the wet season (mean shoots/m^2:June=215, October=66; $P<0.05$). Halodule abundance doubled between June and October ($P<0.05$).

Halodule abundance at Oyster Creek in south Matlacha Pass varied seasonally (Table 5). Abundance was greatest in the dry season (March and June). Halodule abundance was negatively affected late in the dry season (June sampling) by sting rays. The rays scoured numerous depressions (averaging over 0.5 m in diameter) in the Halodule bed, causing uprooting and destruction of Halodule. Halodule abundance declined substantially during the wet season.

Thalassia abundance in south Matlacha Pass varied seasonally (Table 6 and 7). Abundance was greatest in the dry season. Shoot density increased significantly from December 1988 to March 1989, but not from March to June 1989. However, blade length and blade to shoot ratio increased significantly from March to June. Biomass was greatest in June. Apparently, under favorable growing conditions, Thalassia channels most of its energy first into new shoot formation, and then into blade growth.

Thalassia in Pine Island Sound (PIS-1, PIS-2) varied seasonally (Table 8), but the pattern differed from Thalassia in Matlacha Pass. Thalassia abundance did not change significantly between December 1988 and March 1989 (in Matlacha Pass it increased). Abundance did increase from March to June in Pine Island Sound. However, Thalassia abundance did not decline significantly during the wet season as was the case in Matlacha Pass.

Nearly all seaweed biomass was drift macroalgae (i.e., not attached to the substrate). This is typical of seagrass communities in south Florida lagoons (13, 14). The most abundant genera were the red algae Gracilaria, Hypnea, and Acanthophara. Dictyota, a brown alga, was also common in Pine Island Sound. Macroalgae were more abundant in Matlacha Pass than in Pine Island Sound.

Seaweed biomass varied seasonally at all locations (Tables 4-8). Biomass was greater in the dry season than the wet season. In most locations, biomass was highest in the March sample. Similar seasonal patterns in drift algal abundance occur elsewhere in south Florida (13, 14).

Salinity is an important factor affecting seagrass and seaweed abundance, distribution, and seasonality in Matlacha Pass. In fact, it may have been the most important physiochemical factor affecting seasonality during the study. With increasing salinity, seagrass abundance increased from December to March even though temperature is lowest during this period. It should be noted that the 1989 winter was warmer than average (Table 2); however, seagrass abundance (and salinity) did not increase significantly from December to March in Pine Island Sound. Generally in south Florida, seagrass abundance is lowest in winter (February-March) (14, 15). Optimal salinity for Thalassia growth is 24 to 35 ppt (15). Salinity in Matlacha Pass, especially at nearshore sites, was below this range during most of the wet season (Table 3). Salinity in Pine Island Sound was always within this range. This could explain the decrease in seagrass during the wet season in Matlacha Pass, and the lack of decline in Pine Island Sound. In Matlacha Pass, Thalassia and Halodule appeared "healthiest" in the June sampling and "unhealthiest" in October 1989. Growth conditions, in terms of salinity, temperature, and irradiance, were optional in June.

It is difficult to assess the effect of freshwater or low salinity channelized discharge through spreader breaks on seagrass and seaweed distribution and abundance in MPAP because there are insufficient data previous to this study. We believe that channelized discharge may inhibit or affect seagrass and seaweed growth in the immediate receiving waters (Punta Blanca Bay, area round MN-C1) and perhaps at nearshore areas on the tidal flow path from the receiving waters (e.g., MN-P1). For example, the back bay area from MN-C1 to MN-P1 is suitable for seagrass growth; however, seagrass (Halodule) was observed there only late in the dry season. Only monitoring after the breaks are repaired and channelized flow is eliminated or reduced will confirm our speculation.

We were unable to obtain aerial photographs of sufficient quality to accurately assess any changes in seagrass area at the study sites since the dredging of the Spreader system. Harris et al. (8) estimate a 29% decline in seagrass acreage in the Charlotte Harbor system from 1945 to 1982. Over 50% of this estimated loss occurred in Pine Island Sound and Matlacha Pass areas. Seagrass losses were attributed to development, especially dredge and fill activities.

Mangrove-Cattail Interactions

In the south system, cattails have invaded MPAP saline wetlands a distance of <20 m at places where the Spreader bank is intact. In the north system there is another canal west of the Spreader (actually a series of unconnected canals that parallel the Spreader). Cattails grow in the disturbed area between this canal and the Spreader, but no farther west unless there are breaks in the western bank adjacent to MPAP saline wetlands.

Cattails have invaded MPAP saline wetlands through breaks and along channelized flow paths. At most breaks this invasion is minor; cattails extend <100 m into the break and only small stands occur. However, *Typha* invasion through NB-2, the study break in the north system is more extensive. The highest discharge rate occurs at this break. Several cattail stands occur along this break. The largest stand is about 25-30 m diameter. Cattails have invaded over half the distance down the break to the receiving waters. At present, invasion is restricted to the immediate vicinity of the banks of the channelized flow path. Sediment and surface water salinity increases moving away from the flow. Also, there is a shift in mangrove population structure from a predominance of seedlings and juvenile (<1 m shoot height) near the flow path to more mature, larger mangroves moving away from the flow path. Sediments in *Typha* stands are mainly sandy and are likely deposited by the channelized flow.

It appears that *Typha* has opportunistically colonized habitat newly created or altered, physically and chemically, by the channelized discharge from the Spreader. Although there are little or not data previous to our study, we doubt that *Typha* was present along the tidal creek before NB-2 and the resultant Spreader discharge via the creek existed.

Typha abundance varied seasonally at the mangrove-cattail study sites (Figures 13-15). In 1989, *Typha* decreased considerably during the dry season. This seasonal die-back likely reduces *Typha*'s rate of invasion into the saline wetlands. However, *Typha* abundance rapidly increased during the wet season. Maximum abundance occurred in November. During this period of re-establishment, *Typha* also spread farther into the mangrove and *Spartina* vegetation. *Typha* seasonality was most closely correlated with sediment salinity.

The red mangrove, *Rhizophora* mangle, exhibited little seasonality at the mangrove-cattail study sites (Figures 16 and 17). The 3-4 months of low *Typha* abundance are apparently insufficient time for a substantial increase in abundance of the slower growing *Rhizophora*.

Repair of the breaks and elimination of channelized freshwater discharge would inhibit Typha invasion and enhance re-establishment of wetland vegetation.

Fisheries Surveys

Fish abundance data collected in seagrass beds by seining are summarized in Tables 9-13. Table 14 lists all species collected.

We could not conclusively determine if reduced salinity had a negative impact on fish abundance in nearshore seagrass beds in Matlacha Pass. The data collected every two to three months at high tide indicate no significant difference in abundance between dry and wet season at OCN-H; that fish abundance was slightly higher ($P=0.058$) in the dry season than wet at MN-P1; and, that fish abundance at OCN-T was significantly ($P<0.05$) greater in the wet season. The high vs. low tide comparison data collected in August 1989 (wet season) revealed no significant difference between high (salinity: 22-24 ppt) and low (8-15 ppt) tides at MN-P1 and that fish abundance is significantly greater at high tide at OCN-H (high: 21-23 ppt, low: 16-19 ppt) and OCN-T (high: 22-24 ppt, low: 20-21 ppt).

Many factors, in addition to salinity, can influence the abundance of juvenile fish in seagrass beds. Fish breeding and recruitment in estuaries is affected more by temperature than salinity (16). Spawning along the Gulf coast is most common in spring and summer; at this time estuaries have the highest abundance of juveniles (3). Juvenile abundance is correlated with food availability (3). Fish densities in grass beds are influenced by grass standing crop, litter accumulation and water depth (17). Often the highest densities and greatest species richness occur during periods of peak drift algae abundance (15).

CONCLUSIONS AND RECOMMENDATIONS

1. A total of 13 breaks, ranging from 1.5 to 14 m wide and 0.3 to 1.5 m deep, were found in the north and south Spreader rim canal.

2. Substantial volumes of brackish to freshwater flow through these breaks into Matlacha Pass Aquatic Preserve (MPAP). This channelized flow reaches the receiving waters virtually unmixed and unfiltered in the wet season. This input affects the physiochemical habitat of the wetlands and receiving waters of MPAP.

3. Because the upland area of the Spreader system is <10% developed, only small quantities of pollutants (e.g., excessive nutrients, petroleum hydrocarbons) are entering MPAP. Pollutant loading will increase with increasing development.

4. Salinity is an important factor affecting seagrass and seaweed distribution, abundance, and seasonality in Matlacha Pass.

5. It is difficult to assess the effect of freshwater or low salinity channelized discharge through Spreader breaks on seagrass and seaweed distribution and abundance in MPAP because there are insufficient data previous to this study. We believe that channelized discharge may inhibit or affect seagrass and seaweed growth in the immediate receiving waters (Punta Blanca Bay, area round MN-C1) and perhaps at nearshore areas on the tidal flow path from the receiving waters (e.g. MN-P1).

6. Cattails have invaded MPAP saline wetlands through breaks and along channelized flow paths. At most breaks this invasion is minor; however, _Typha_ invasion through NB-2, the break with the highest discharge rate, is extensive. It appears that _Typha_ has opportunistically colonized habitat newly created or altered, physically and chemically, by the channelized discharge from the Spreader. Although there are little or not data previous to our study, we doubt that _Typha_ was present along the tidal creek before NB-2 and the resultant Spreader discharge via the creek existed.

7. _Typha_ abundance varied seasonally at the mangrove-cattail study sites. _Typha_ die-back in the dry season likely reduces its rate of invasion into the saline wetlands. The red mangrove, _Rhizophora_ mangle, exhibited little seasonality. The 3-4 months of low _Typha_ abundance are apparently insufficient time for a substantial increase in abundance of the slower growing _Rhizophora_.

8. Repair of the breaks and elimination of channelized freshwater discharge would inhibit _Typha_ invasion and enhance re-establishment of wetland vegetation.

9. We could not conclusively determine if reduced salinity had a negative impact on fish abundance in nearshore seagrass beds in Matlacha Pass. Many factors, in addition to salinity, can influence the abundance of juvenile fish in seagrass beds.

10. The breaks must be repaired as soon as possible. The goal is to eliminate channelized discharge and re-establish sheet flow. An engineering project is underway to repair known breaks.

11. Ecological monitoring must continue to assess the effectiveness of repairs to the spreader waterway; to determine changes (improvements) in the MPAP ecosystems following the anticipated reduction in channelized discharge from Cape Coral; and, to ascertain the need for additional management actions to restore damaged ecosystems.

12. Additional breaks in the Spreader will likely occur in the future. Thus, a long term maintenance program for the Spreader needs to be instituted.

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FIGURES

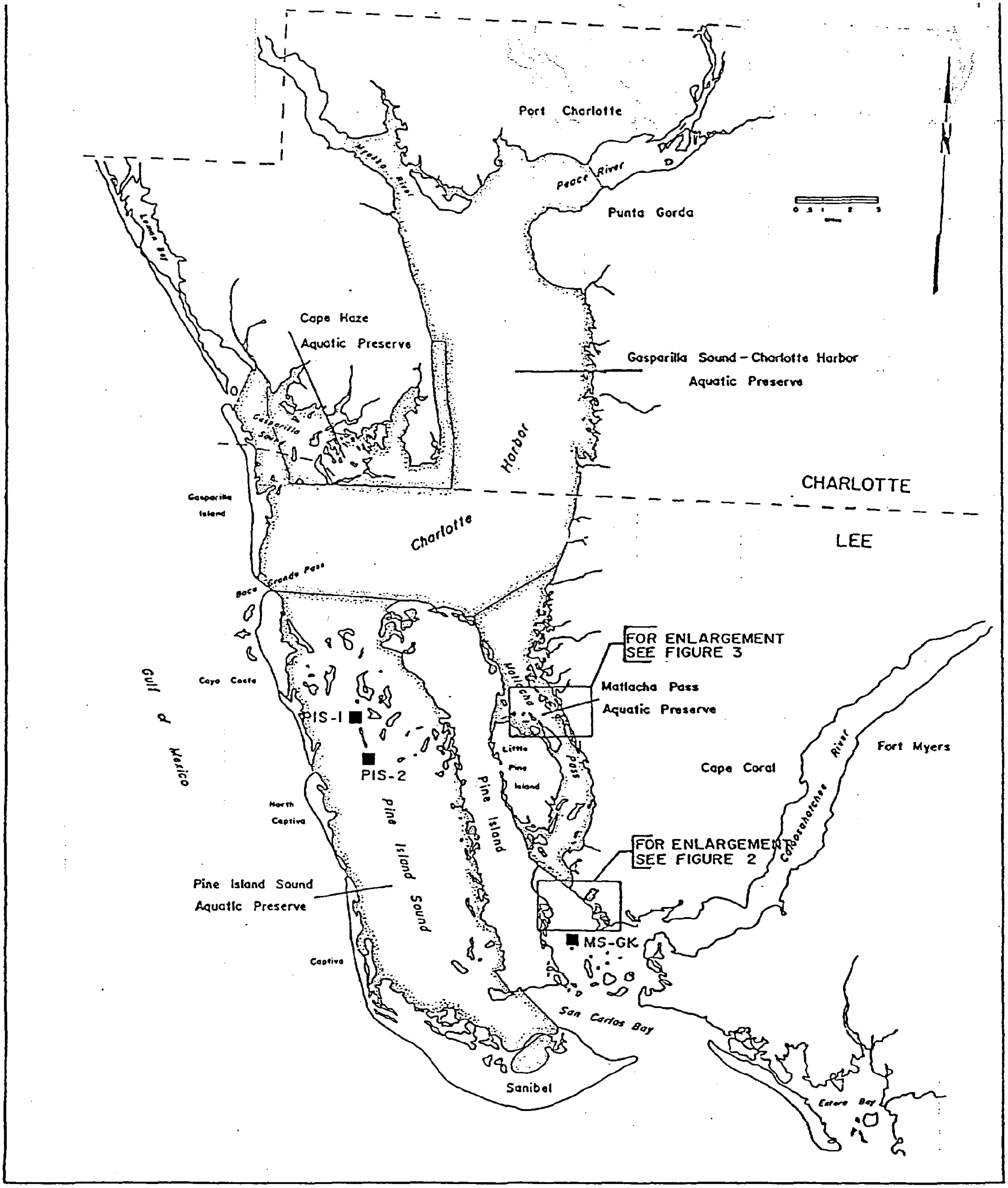

Figure 1. The Charlotte Harbor estuarine system including Matlacha Pass and Pine Island Sound. Also shown are water quality and benthic vegetation sampling sites MS-GK, PIS-1, and PIS-2.

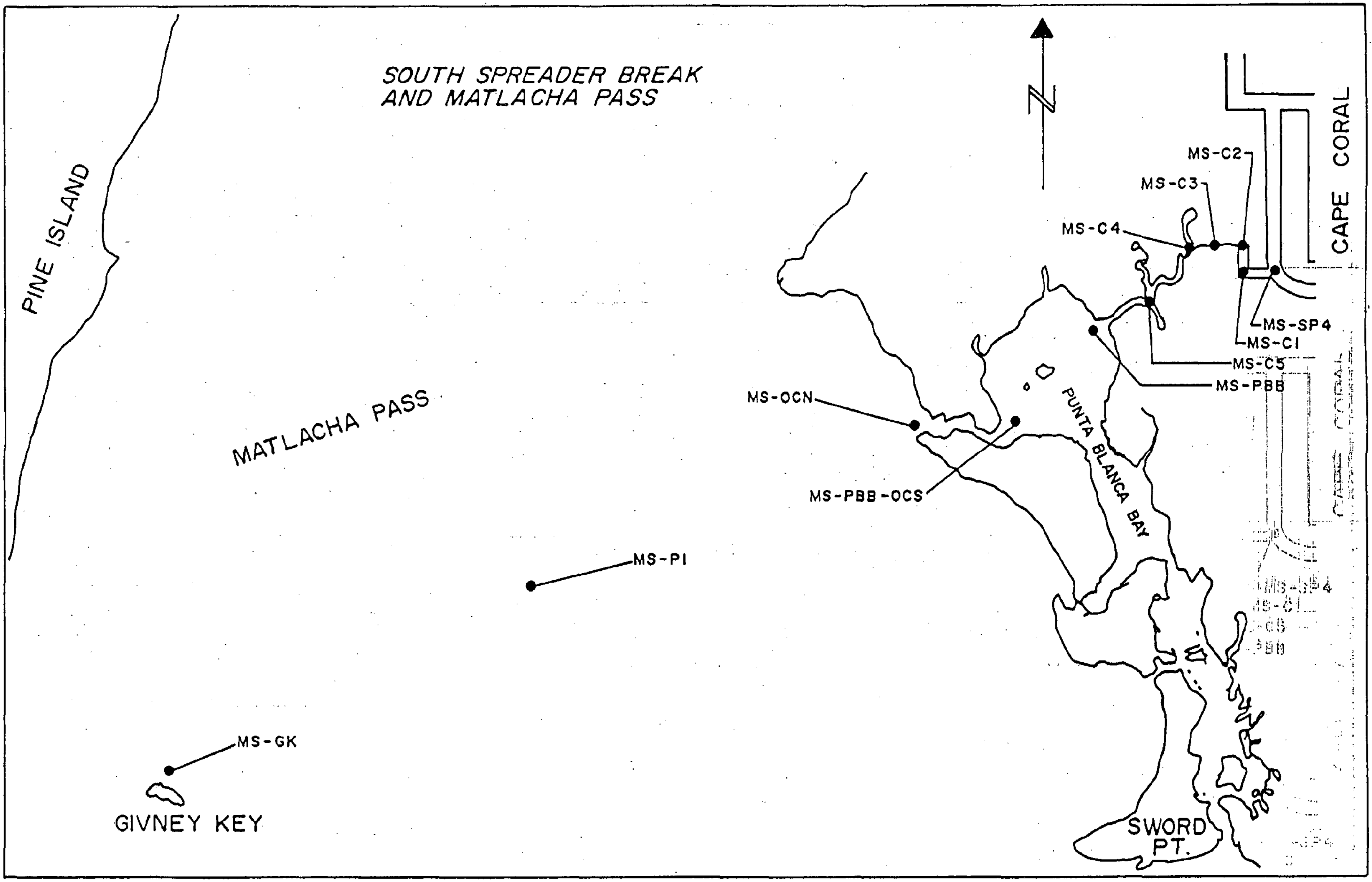

Figure 2. Location of water quality and benthic vegetation sampling stations on south Matlacha Pass and along the southern Spreader break transect.

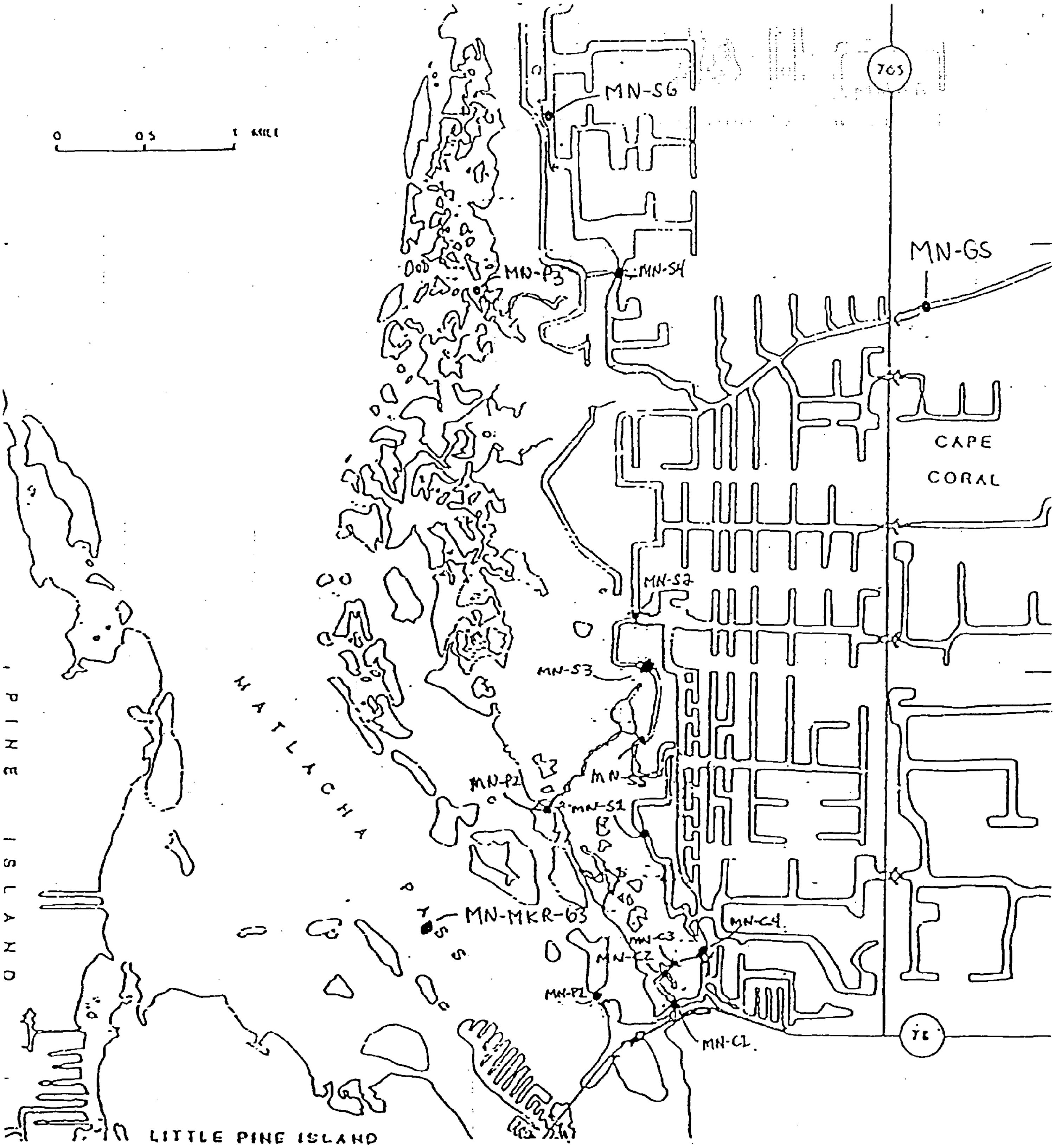

Figure 3. Locations of water quality and benthic vegetation sampling sites in north Matlacha Pass and north Spreader system.

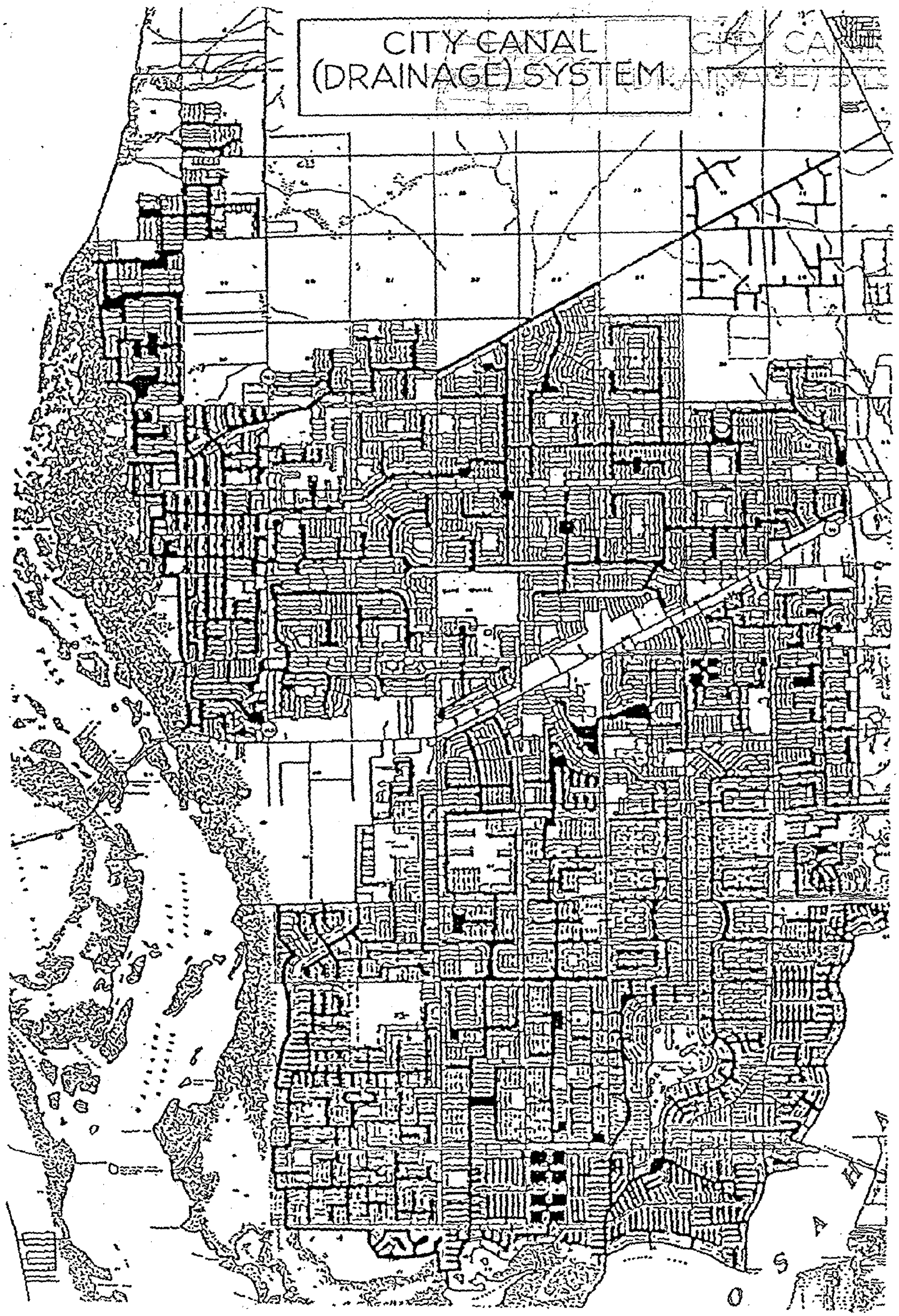

Figure 4. Cape Coral canal system, including the north and south Spreader systems which are adjacent to Matlacha Pass Aquatic Preserve.

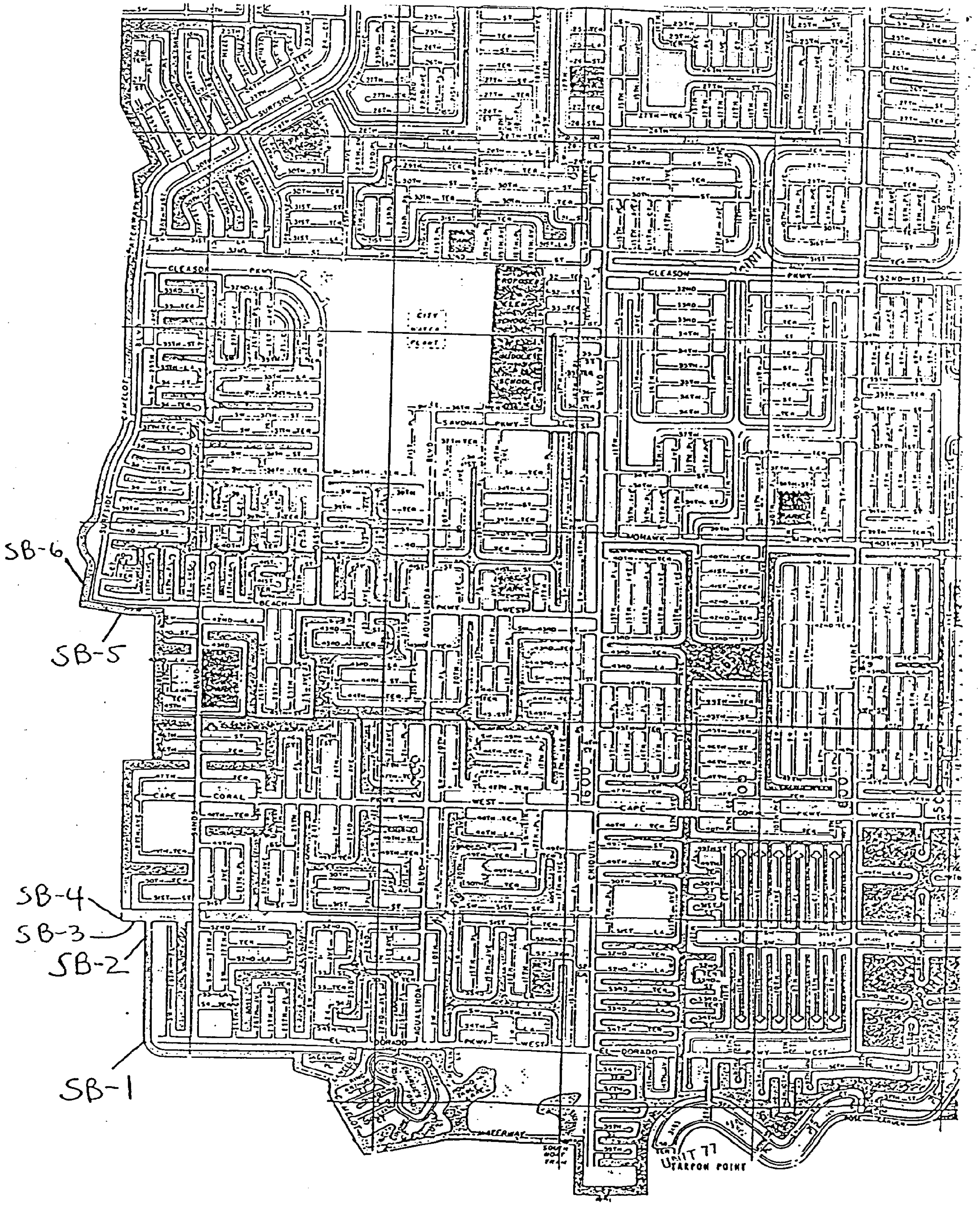

Figure 5. Location of breaks in the south Spreader canal.

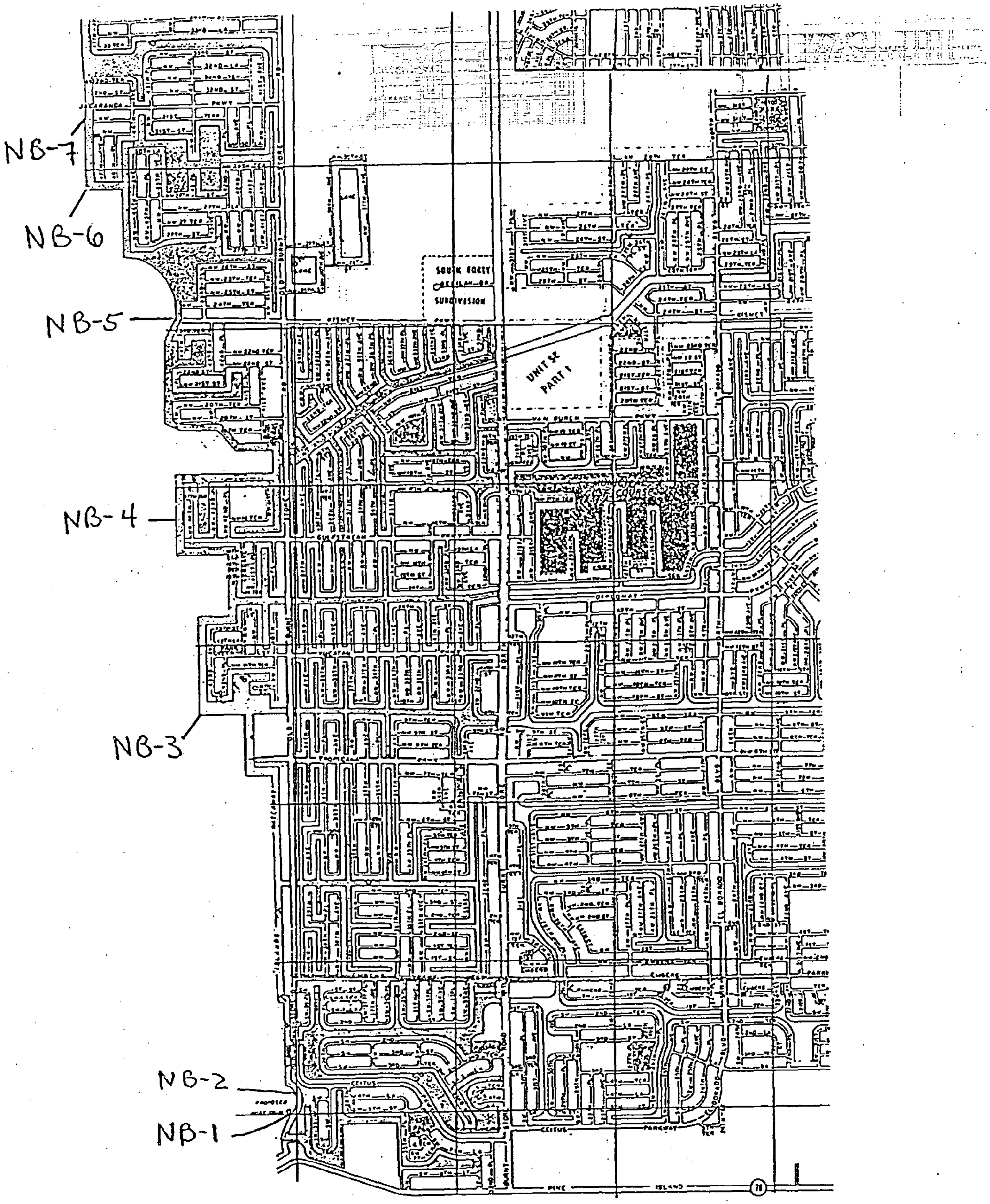

Figure 6. Location of breaks in the north Spreader canal.

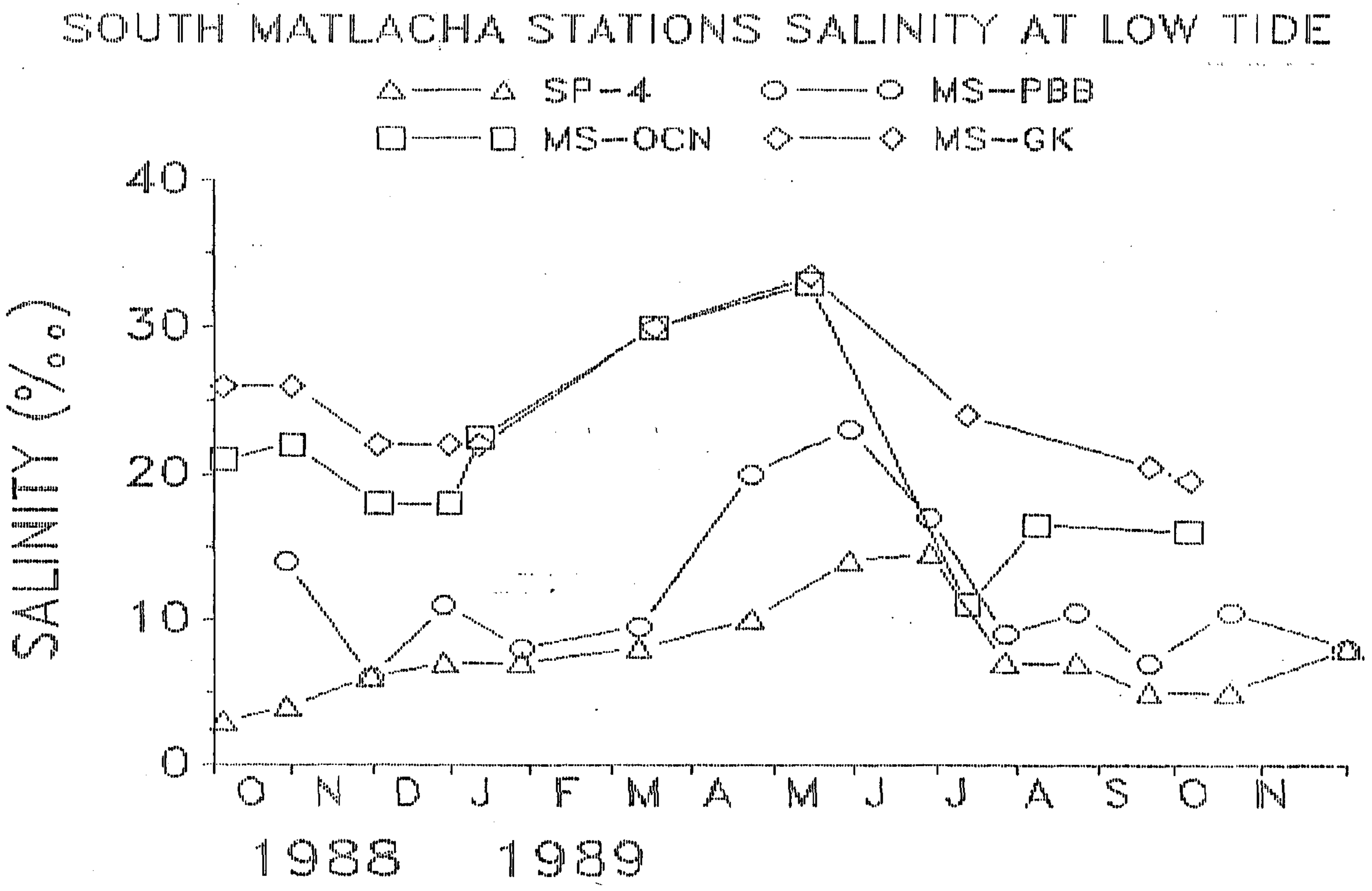

Figure 7. Salinity along the south Spreader (SP-4)--break (MS-PBB)--Matlacha Pass (MS-OCN, MS-GK) transect.

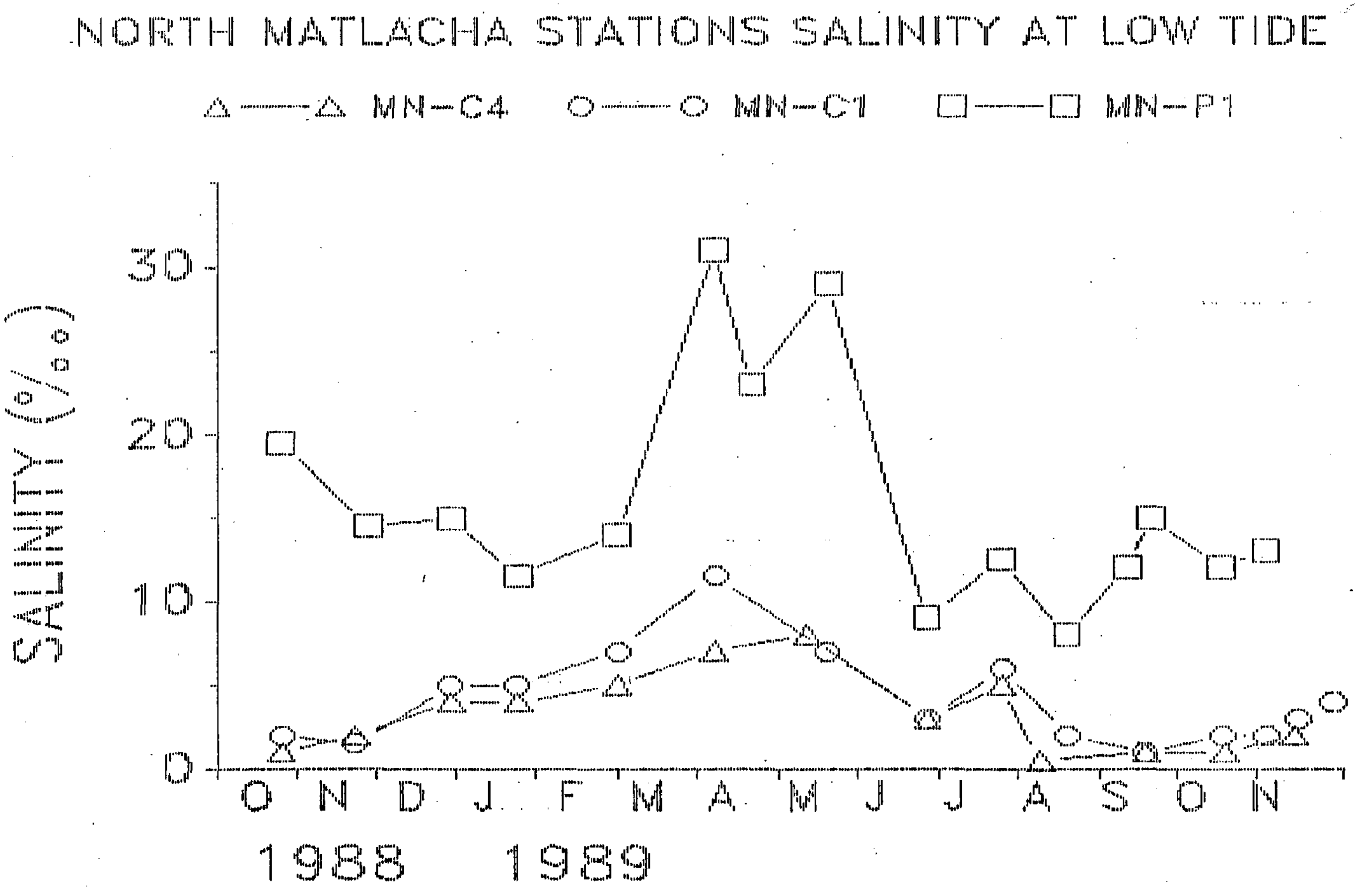

Figure 8. Salinity along the north Spreader (MN-C4)--break (MN-C1)--Matlacha Pass (MN-P1) transect.

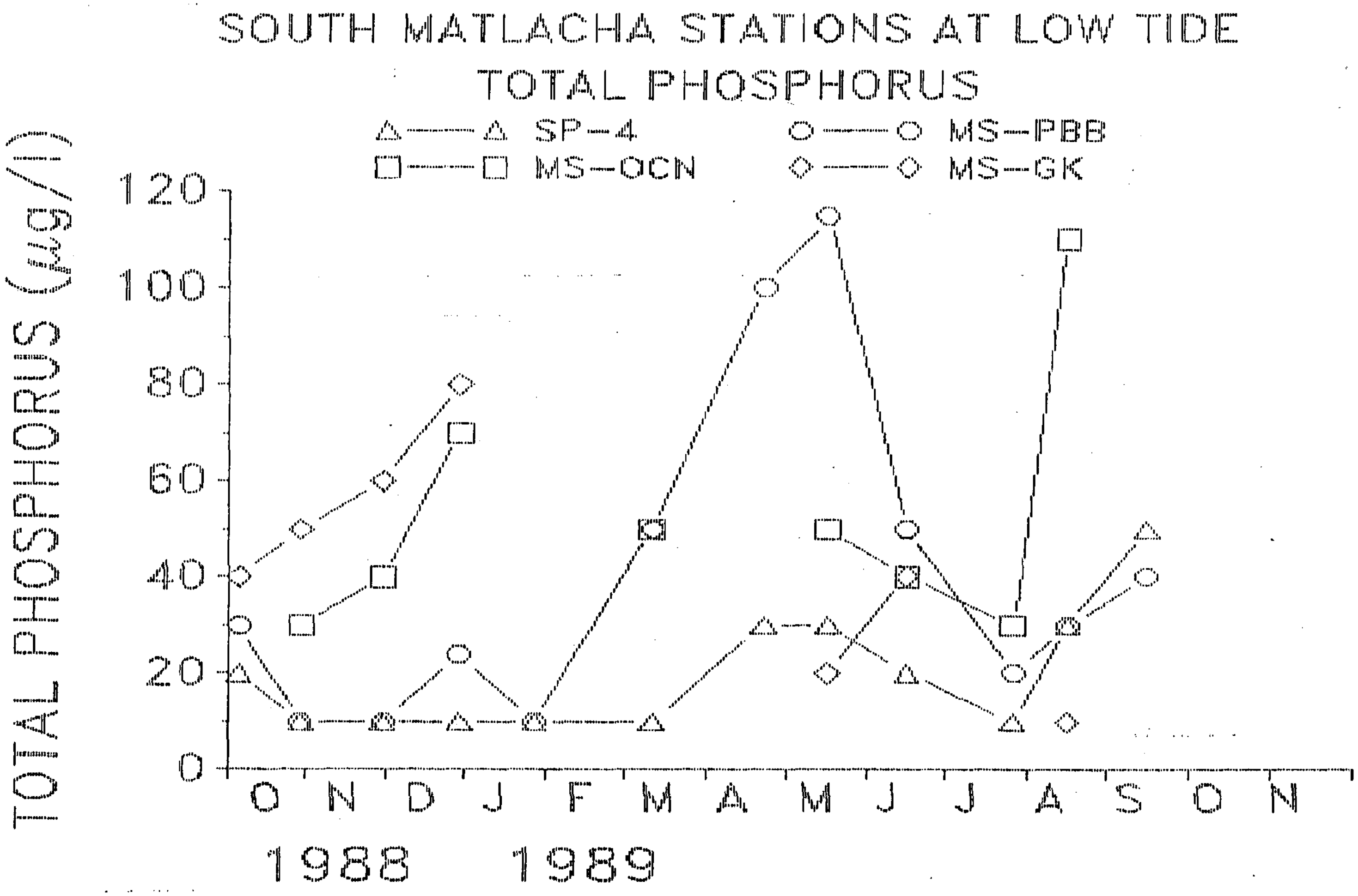

Figure 9. Total phosphorus concentrations along the south Spreader (SP-4)--break (MS-PBB)--Matlacha Pass (MS-OCN, MS-GK) transect.

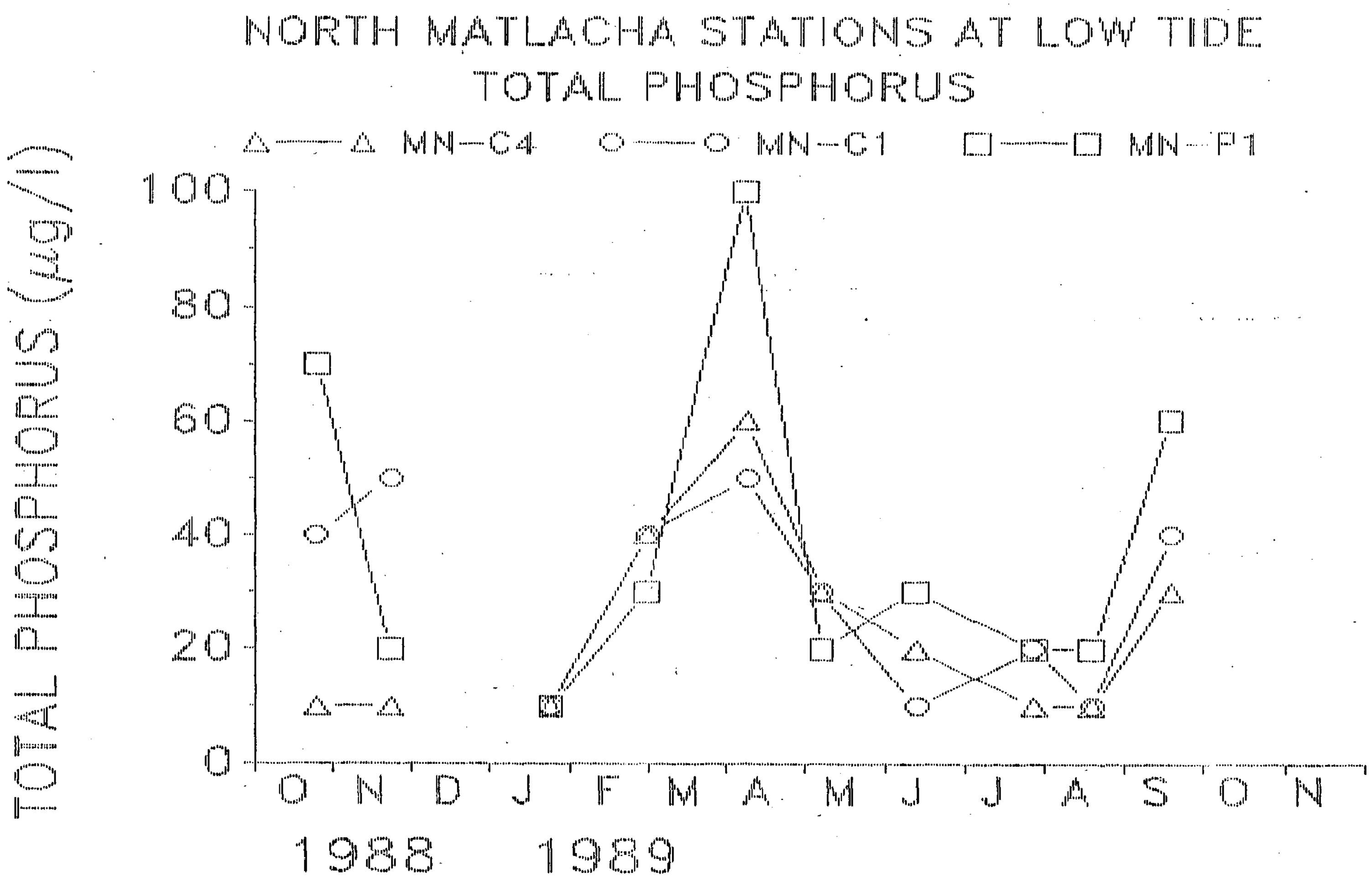

Figure 10. Total phosphorus concentrations along the north Spreader (MN-C4) break (MN-C1)--Matlacha Pass (MN-P1) transect.

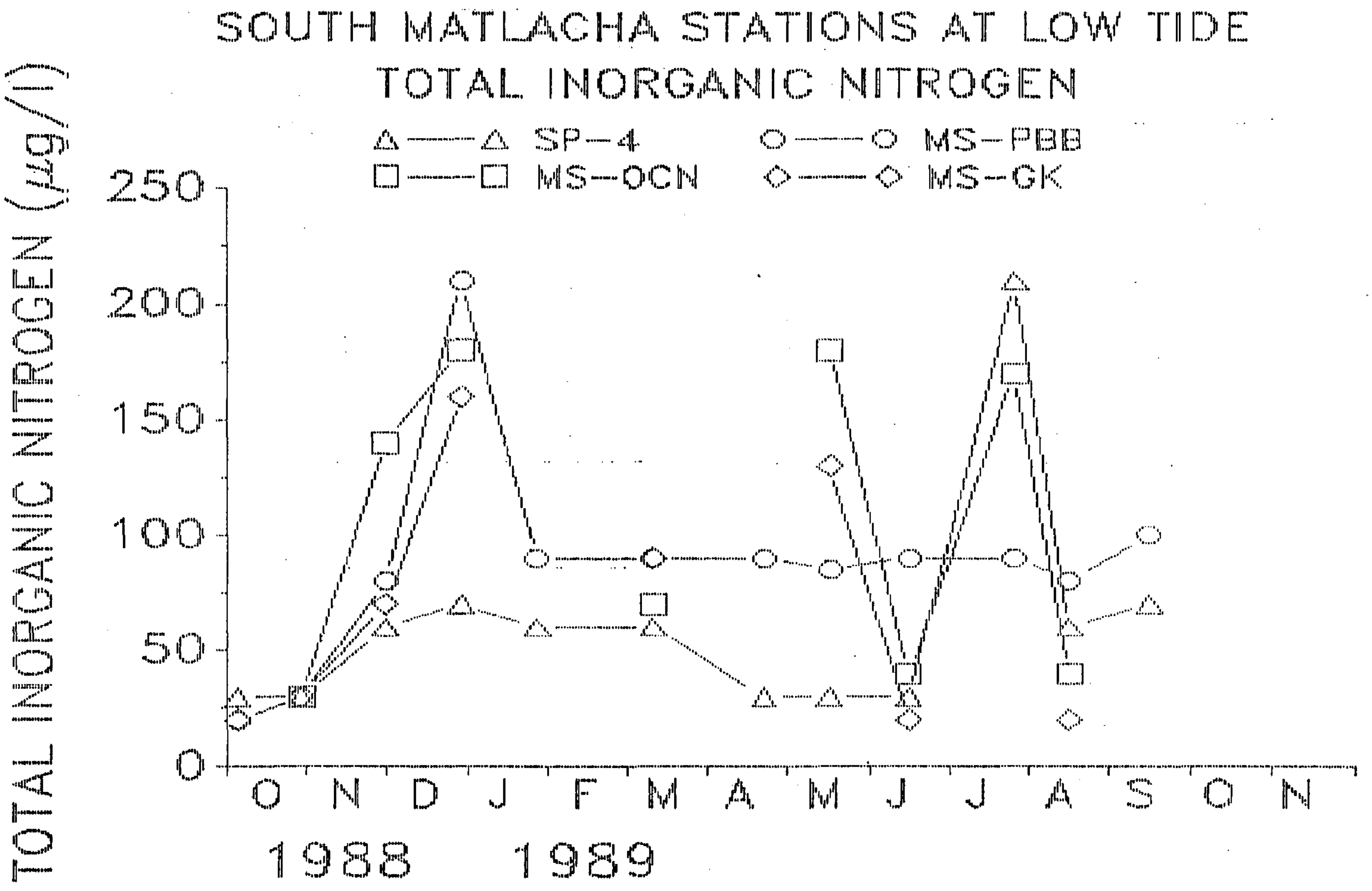

Figure 11. Total inorganic nitrogen concentrations along the south Spreader (SP-4)--break (MS-PBB)--Matlacha Pass (MS-OCN, MS-GK) transect.

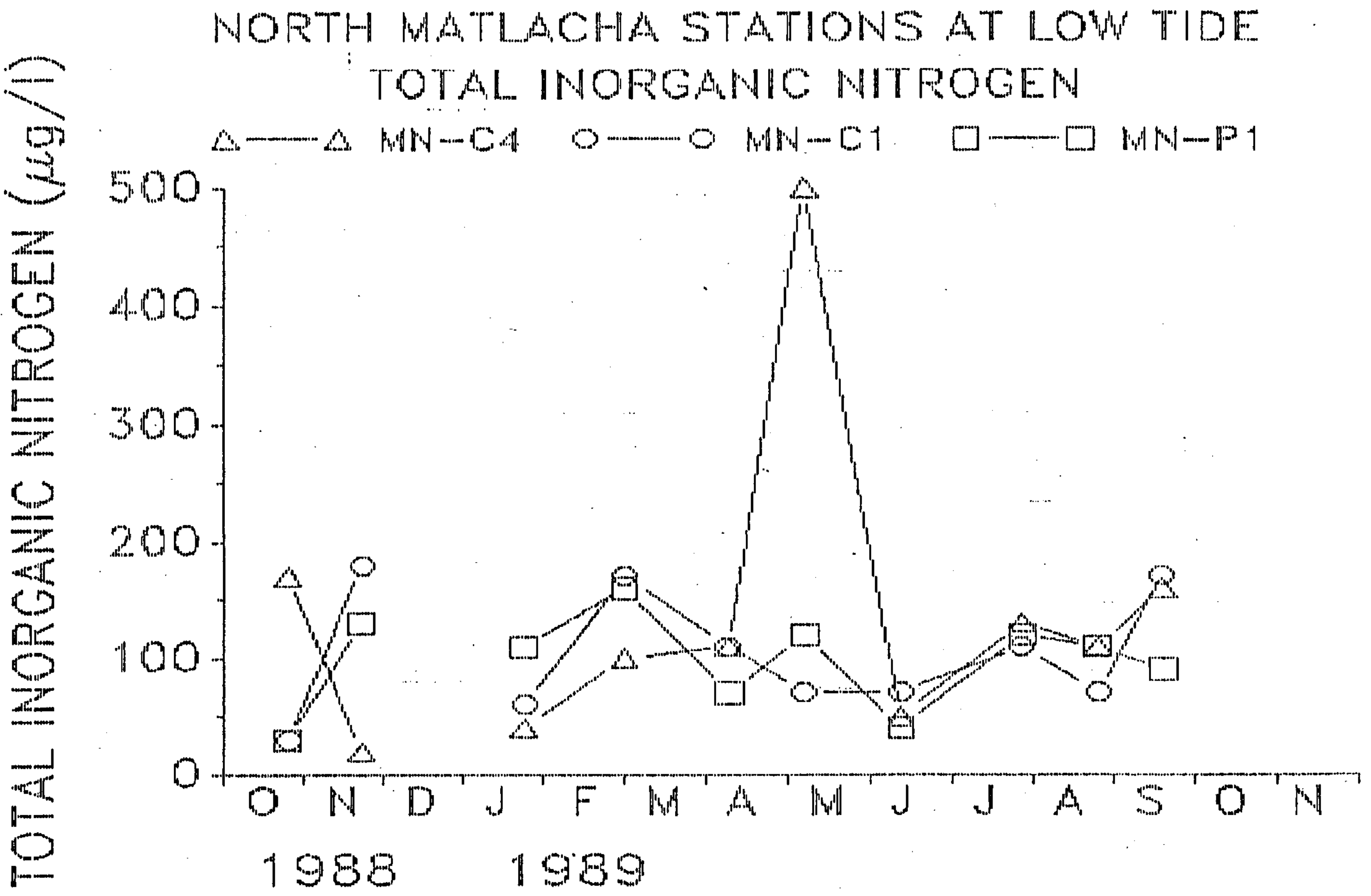

Figure 12. Total inorganic nitrogen concentrations along the north Spreader (MN-C4)--break (MN-C1)--Matlacha Pass (MN-P1) transect.

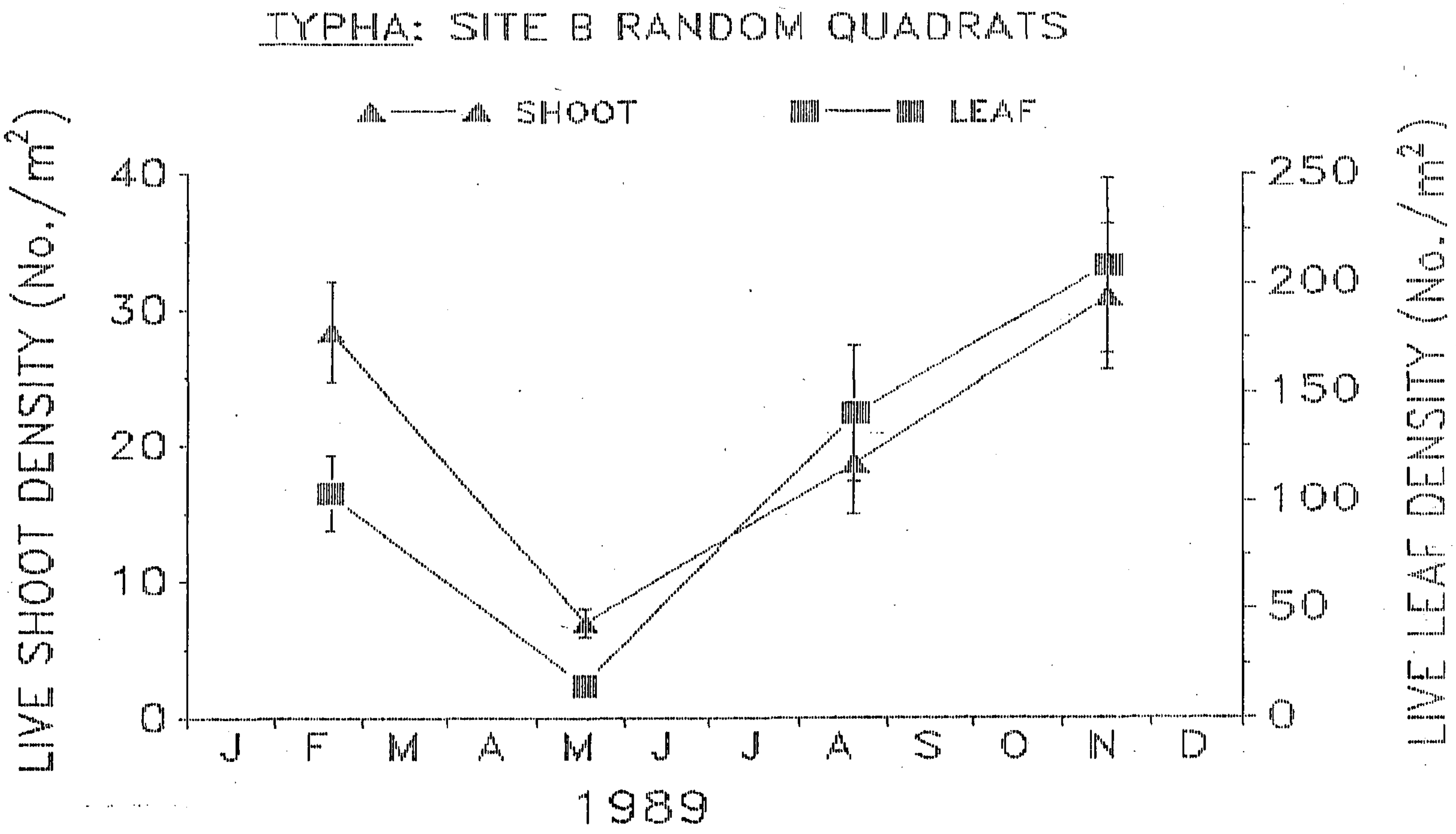

Figure 13. Live shoot and leaf densities of cattail (*Typha* sp.) from random sampling at mangrove--cattail Site B. Values are means ± SE (N=6).

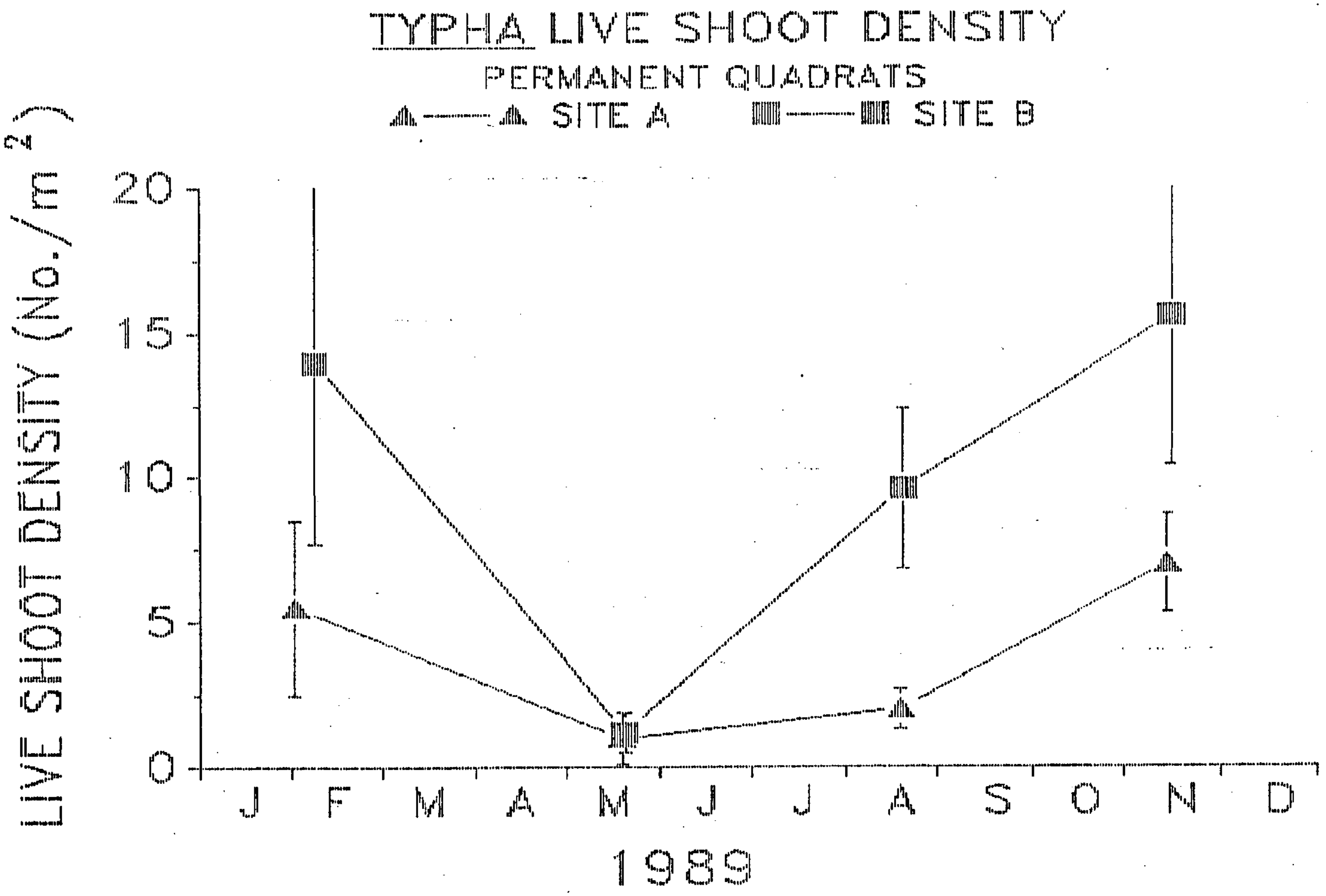

Figure 14. Live shoot densities of Typha in the permanent quadrats at mangrove-cattail Sites A and B. Values are means ± SE.

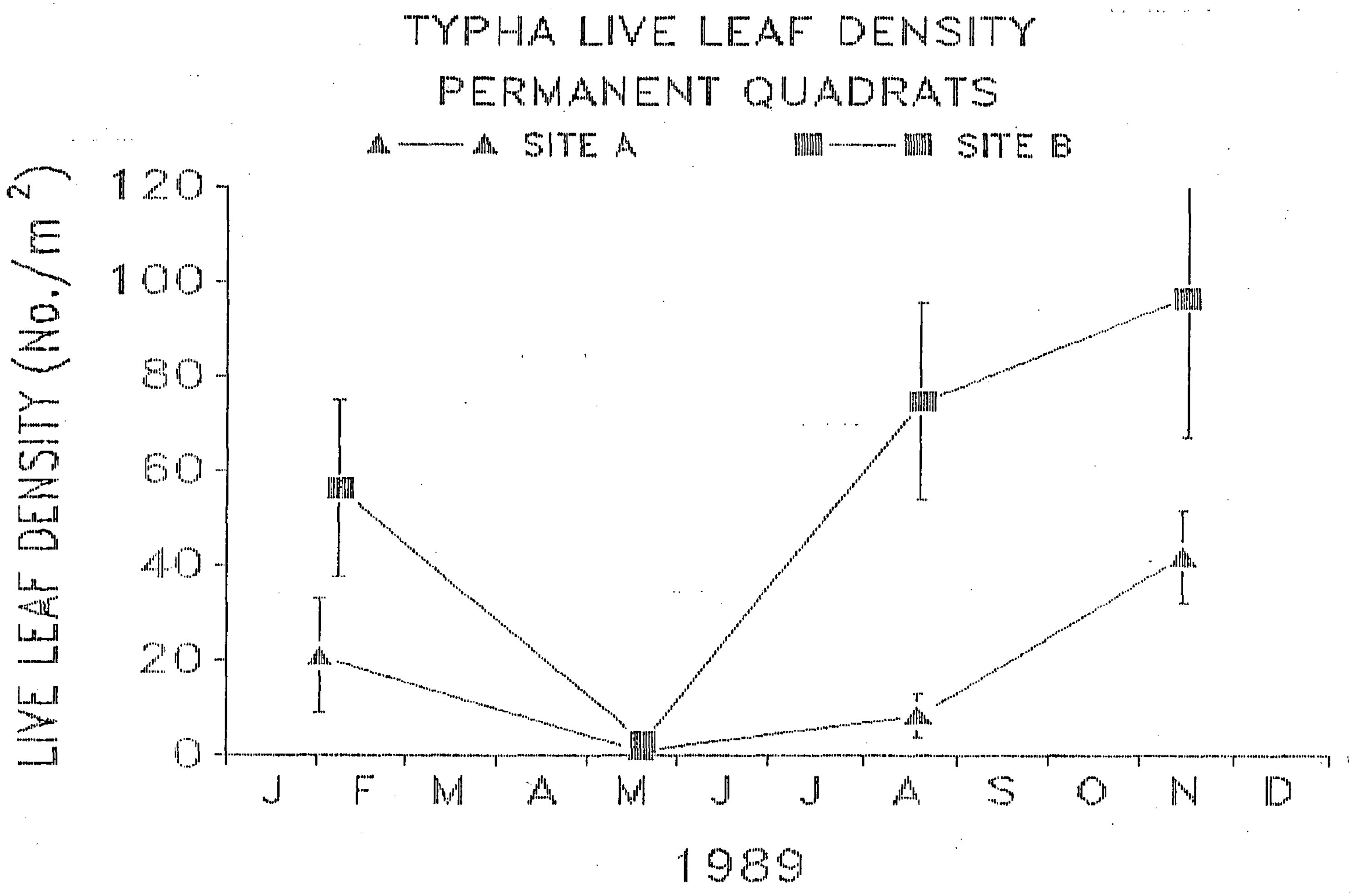

Figure 15. Live leaf densities of *Typha* in the permanent quadrats at mangrove-cattail Sites A and B. Values are means ± SE.

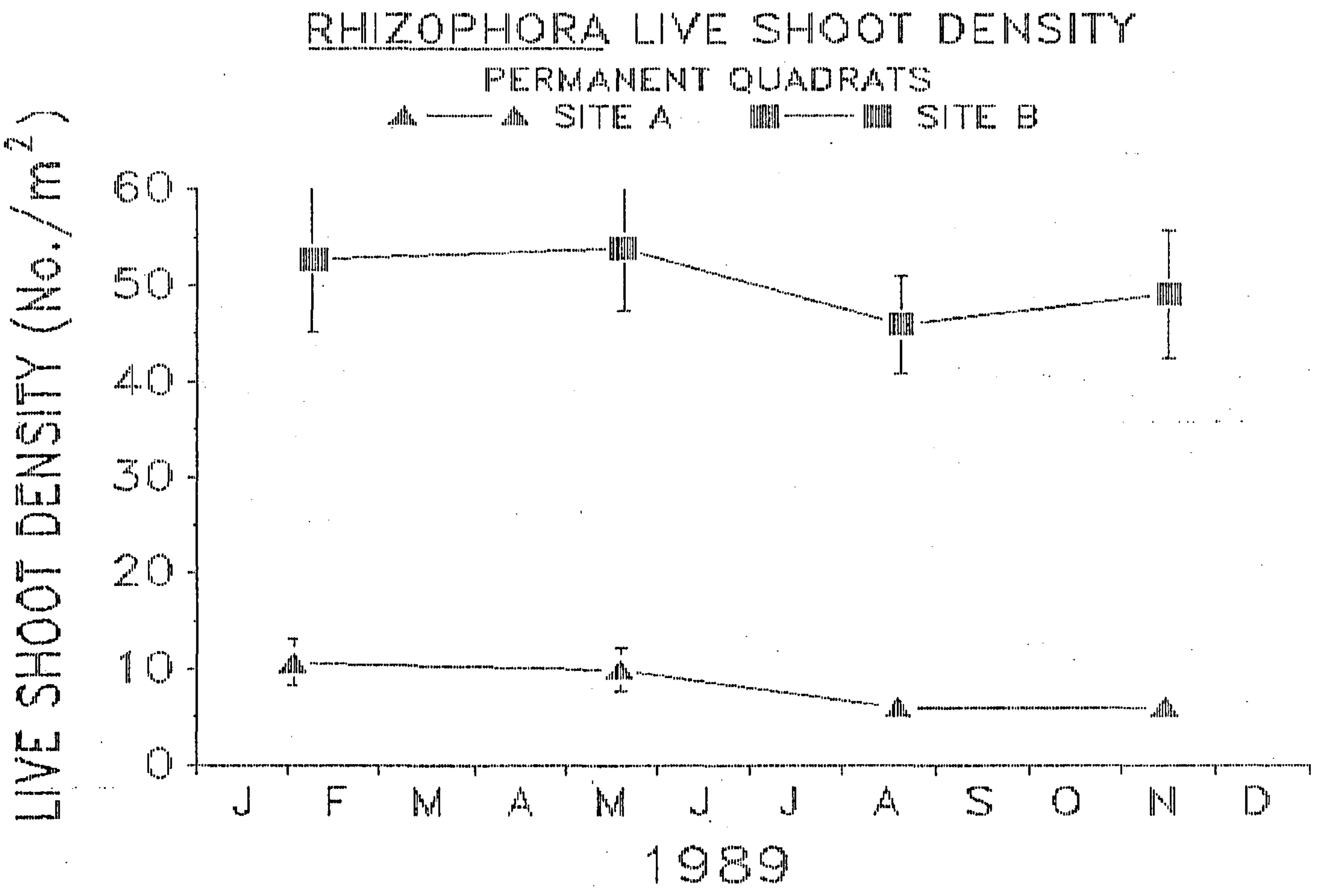

Figure 16. Live shoot densities of red mangrove (Rhizophora mangle) in the permanent quadrats at mangrove-cattail Sites A and B. Values are means ± SE.

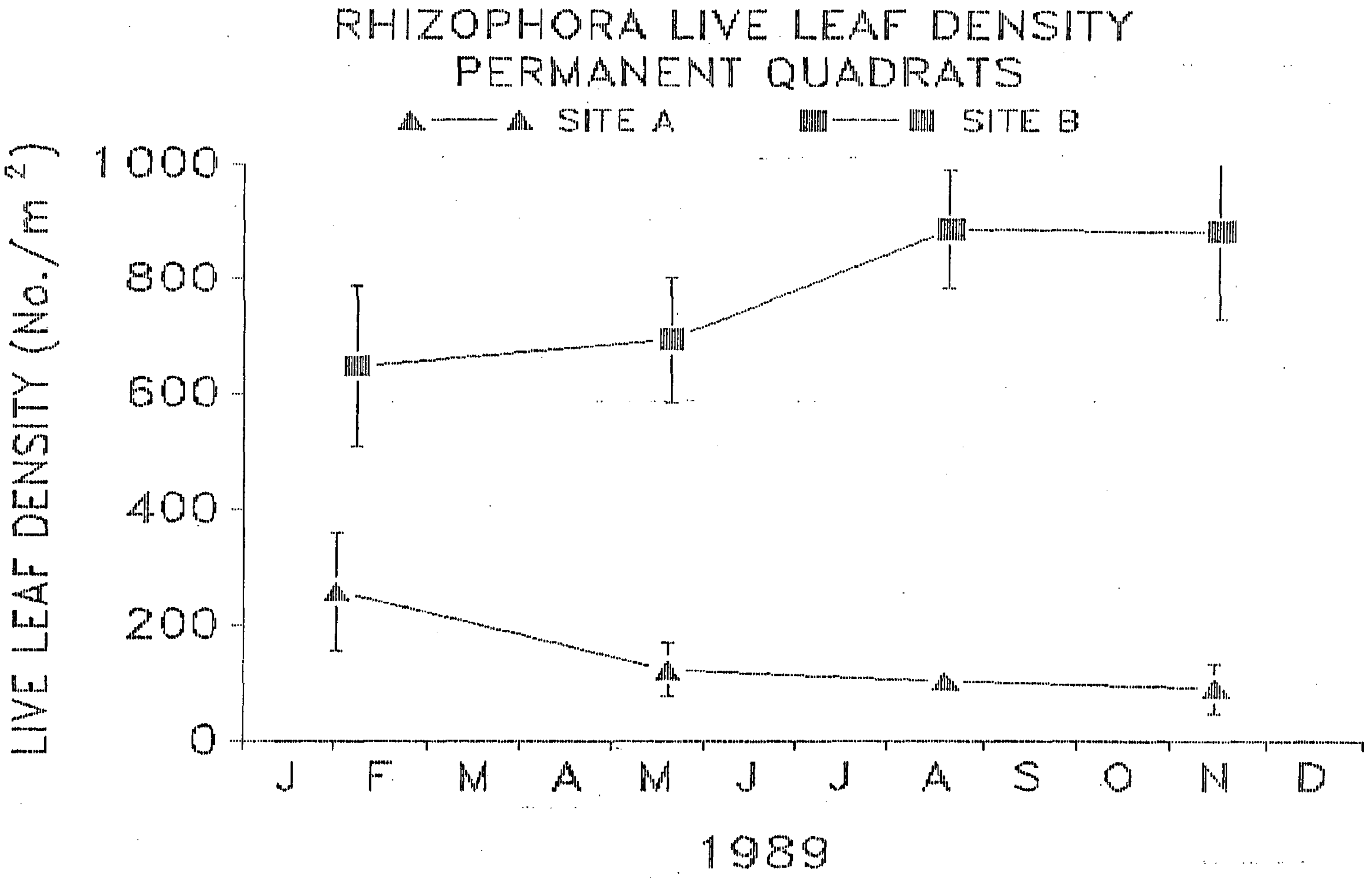

Figure 17. Live leaf densities of red mangrove (*Rhizophora mangle*) in the permanent quadrats at mangrove-cattail Sites A and B. Values are means ± SE.

TABLES

TABLE 1. Monthly precipitation (inches) at the National Weather Service station in Fort Myers (from NOAA 1989). Mean is based on the 30 year period 1959-1988.

MONTH	1988	1989	MEAN
January	2.19	1.65	1.66
February	1.47	0.36	2.14
March	2.44	2.89	2.66
April	1.36	0.36	1.89
May	0.62	8.05	3.93
June	7.16	8.67	9.19
July	5.13	9.05	8.73
August	9.21	8.82	8.31
September	1.93	5.18	8.43
October	0.40	1.95	3.91
November	2.83	0.20	1.45
December	0.26	2.29	1.42
TOTAL	35.00	49.47	53.74

Table 2. Monthly mean daily median temperature (°C) at the National Weather Service station in Fort Myers during the study period (Source: NOAA 1989).

MONTH	1988	1989	30 YR. MEAN (1959-1988)
January		21.1	17.8
February		19.9	18.4
March		22.0	20.7
April		24.0	22.9
May		26.9	25.4
June		29.0	27.3
July		28.0	28.0
August		28.4	28.2
September		28.1	27.6
October	25.1	25.0	24.8
November	23.3	21.9	21.1
December	19.2		18.7

Table 3. Salinity (ppt) ranges during the study at the water quality monitoring sites.

Location	October-December	January-March	April--mid-June	late June--September
Pine Island Sound (PIS-2)	28-33	30-34	33-37	26-35
Givney Key, Matlacha Pass (MS-GK)	22-26	22-32	32-35	19-27
Oyster Creek, Matlacha Pass (MS-OCN)	18-24	22-30	27-33	11-23
Punta Blanca Bay (MS-PBB)	5-24	8-28	20-31	7-21
South Spreader Break	3-19	7-24	9-29	5-18
South Spreader Waterway (SP-4)	3-7	7-12	10-14	5-11
North Matlacha Pass (MN-P1)	11-23	11-24	22-33	9-25
North Spreader Break	1-20	4-20	7-24	0.5-19
North Spreader Waterway (MN-C4)	1-4	4-6	7-14	0.5-7

Table 4. Benthic vegetation data at Station MN-P1. Values are Means ± SE (N).

	27 November 1988	13 March 1989	7 June 1989	28 September 1989	Significance Level
Ruppia					
Shoot Density (No/m^2)	2806 ± 211 (15)	930 ± 218 (17)	0 ± 0 (21)	0 ± 0 (24)	$P<0.05$
Biomass ($g[dw]/m^2$)	61.6 ± 5.5 (11)	10.9 ± 3.3 (17)	0 ± 0 (21)	0 ± 0 (24)	$P<0.05$
Halodule					
Shoot Density (No/m^2)	0 ± 0 (15)	0 ± 0 (17)	832 ± 158 (20)	511 ± 111 (24)	$P<0.05$
Biomass ($g[dw]/m^2$)	0 ± 0 (15)	0 ± 0 (17)	13.8 ± 3.3 (16)	4.4 ± 1.2 (17)	$P<0.05$
Algal Biomass ($g[dw]/m^2$)	2.9 ± 1.0 (12)	37.4 ± 10.1 (17)	36.4 ± 9.5 (16)	1.0 ± 0.6 (17)	$P<0.05$

Table 5. Benthic Vegetation Data for the Halodule Bed at Oyster Creek (OCN-H). Values are Means ± SE (N).

	5 December 1988	17 March 1989	13 June 1989	12 October 1989	Significance Level
Halodule					
Shoot Density (No/m^2)	1202 ± 123 (13)	1691 ± 130 (26)	1400 ± 176 (22)	424.4 ± 85.1 (28)	$P<0.05$
Biomass ($g[dw]/m^2$)	26.9 ± 6.6 (10)	31.4 ± 4.4 (14)	32.0 ± 5.0 (17)	5.1 ± 1.2 (19)	$P<0.05$
Algal Biomass ($g[dw]/m^2$)	30.0 ± 8.9 (10)	29.6 ± 4.6 (14)	15.0 ± 2.5 (17)	2.4 ± 1.6 (19)	$P<0.05$

Table 6. Benthic vegetation data for the *Thalassia* Bed at Oyster Creek (OCN-T). Values are Means ± SE (N).

	7 December 1989	20 March 1989	10 June 1989	13 October 1989	Significance Level
Thalassia					
Shoot Density (No/m^2)	556 ± 74 (12)	763 ± 51 (24)	801 ± 55 (19)	754 ± 51 (20)	$P=0.06$
Blade Density (No/m^2)	1453 ± 200 (12)	1891 ± 187 (15)	2506 ± 174 (16)	2251 ± 144 (20)	$P<0.05$
Blade: Shoot	2.6 ± 0.1 (12)	2.6 ± 0.1 (15)	3.2 ± 0.1 (16)	3.0 ± 0.1 (20)	$P<0.05$
Blade Length (cm)	17.6 ± 0.5 (9)	15.0 ± 1.2 (15)	23.8 ± 1.0 (17)	20.6 ± 0.9 (19)	$P<0.05$
Blade Width (mm)	5.7 ± 0.2 (12)	5.2 ± 0.1 (15)	5.1 ± 0.1 (15)	4.9 ± 0.1 (16)	
Biomass (g[dw]/m^2)	76.3 ± 11.5 (10)	81.7 ± 7.8 (15)	110.0 ± 10.3 (15)	80.2 ± 10.0 (16)	$P<0.05$
Halodule					
Shoot Density (No/m^2)	217 ± 90 (12)	104 ± 69 (24)	8 ± 6 (19)	35 ± 33 (16)	
Biomass (g[dw]/m^2)	1.7 ± 0.7 (10)		0.1 ± 0.1 (14)		
Algal Biomass (g[dw]/m^2)	5.4 ± 3.2 (10)	65.5 ± 8.1 (15)	12.8 ± 5.0 (15)	2.4 ± 0.9 (16)	$P<0.05$

Table 7. Benthic vegetation data at Givney Key Station MS-GK. Values are Means ± SE (N).

	21 November 1988	15 March 1989	8 June 1989	2 October 1989	Significance Level
Thalassia					
Shoot Density (No/m^2)	357 ± 32 (20)	713 ± 40 (15)	734 ± 35 (20)	548 ± 38 (19)	$P<0.05$
Blade Density (No/m^2)	891 ± 71 (20)	2028 ± 124 (15)	2286 ± 80 (17)	1314 ± 96 (19)	$P<0.05$
Blade: Shoot	2.6 ± 0.1 (20)	2.8 ± 0.1 (15)	3.0 ± 0.1 (17)	2.4 ± 0.1 (19)	$P<0.05$
Blade Length (cm)	25.5 ± 1.0 (15)	20.4 ± 0.6 (15)	35.4 ± 1.2 (16)	26.1 ± 1.8 (16)	$P<0.05$
Blade Width (mm)	5.5 ± 0.5 (11)	5.6 ± 0.1 (15)	5.3 ± 0.2 (19)	5.2 ± 0.2 (16)	$P>0.05$
Biomass ($g[dw]/m^2$)	68.5 ± 6.8 (15)	82.5 ± 8.1 (15)	144.9± 5.9 (16)	56.6 ± 4.5 (16)	$P<0.05$
Algal Biomass ($g[dw]/m^2$)	27.5 ± 6.8 (15)	23.8 ± 9.9 (15)	3.0 ± 1.2 (16)	7.4 ± 1.9 (16)	$P<0.05$

Table 8. Benthic vegetation data at Station PIS-2. Values are Means ± SE (N).

	4 December 1988	14 March 1989	12 June 1989	10 October 1989	Significance Level
Thalassia					
Shoot Density (No/m^2)	233 ± 17 (16)	245 ± 13 (20)	278 ± 16 (23)	292 ± 18 (21)	$P<0.05$
Blade Density (No/m^2)	607 ± 52 (16)	967 ± 50 (23)	967 ± 50 (23)	790 ± 53 (21)	$P<0.05$
Blade: Shoot	2.6 ± 0.1 (16)	3.0 ± 0.1 (20)	3.5 ± 0.1 (23)	2.7 ± 0.1 (21)	$P<0.05$
Blade Length (cm)	29.1 ± 1.0 (15)	23.4 ± 1.0 (16)	39.1 ± 1.7 (17)	40.4 ± 0.4 (17)	$P<0.05$
Blade Width (mm)	10.2 ± 0.2 (15)	11.1 ± 0.2 (20)	10.1 ± 0.2 (17)	9.8 ± 0.1 (18)	$P>0.05$
Biomass (g[dw]/m^2)	75.7 ± 8.0 (15)	89.0 ± 8.0 (20)	138.9± 10.4 (18)	93.8 ± 6.3 (17)	$P<0.05$
Algal Biomass (g[dw]/m^2)	0.0 ± 0.0 (15)	9.1 ± 1.5 (20)	0.9 ± 0.4 (18)	0.8 ± 0.4 (17)	$P<0.05$

Table 9. Total epibenthic fish abundance (No./200m²) and that of the five most common epibenthic species collected in the 1989 fisheries surveys at Station MN-P1. Values are means ± SE.

	APRIL N = 8	JUNE N = 7	AUGUST N = 7	SEPTEMBER N = 8	NOVEMBER N = 8
TOTAL (all epibenthic species)	162.3 ± 40.2	110.4 ± 11.8	87.7 ± 18.7	119.8 ± 14.1	159.5 ± 8.2
Gerreidae					
Eucinostomus spp.	6.3 ± 2.1	68.9 ± 14.3	75.9 ± 16.9	37.8 ± 5.5	66.6 ± 7.1
Sparidae					
Lagodon rhomboides	143.5 ± 39.1	26.1 ± 16.8	0.9 ± 0.9	2.0 ± 1.2	3.0 ± 1.0
Sciaenidae					
Bairdiella chrysura	0	0	0	36.3 ± 37.2	72.1 ± 4.0
Cyprinodontidae					
Lucania parva	0.2 ± 0.1	2.3 ± 1.1	0.3 ± 0.3	23.1 ± 4.9	4.8 ± 2.5
Gobiidae					
Gobiosoma robustum	6.1 ± 1.2	7.7 ± 2.4	0.3 ± 0.3	4.4 ± 1.1	8.4 ± 0.6

Table 10. Total epibenthic fish abundance (No./200m²) and that of the five most common epibenthic species collected in the 1989 fisheries surveys at Station MS-OCN-H. Values are means ± SE.

	JUNE N = 6	AUGUST N = 8	SEPTEMBER N = 5	NOVEMBER N = 8
TOTAL (All epibenthic species)	115.2 ± 6.0	177.6 ± 32.3	208.4 ± 57.4	121.6 ± 38.1
Gerreidae				
Eucinostomus spp.	63.7 ± 11.8	110.1 ± 16.4	45.6 ± 3.3	95.4 ± 29.9
Sciaenidae				
Bairdiella chrysura	32.3 ± 11.4	51.9 ± 36.2	145.2 ± 54.0	2.5 ± 1.5
Gobiidae				
Gobiosoma robustum	0	7.8 ± 2.9	2.2 ± 0.9	15.8 ± 6.6
Sparidae				
Lagodon rhomboides	11.8 ± 2.1	2.0 ± 0.6	2.2 ± 0.8	0
Sciaenidae				
Cynoscion nebulosus	0.5 ± 0.2	0.5 ± 0.4	6.4 ± 3.3	2.3 ± 1.3

Table 11. Total epibenthic fish abundance (No./200m^2) and that of the five most common epibenthic species collected in the 1989 fisheries surveys at Station MS-OCN-T. Values are means ± SE.

	APRIL N = 6	JUNE N = 8	AUGUST N = 8	SEPTEMBER N = 8	NOVEMBER N = 8
TOTAL (All epibenthic species)	73.3 ± 9.1	152.0 ± 7.0	1220.5 ± 303.8	237.4 ± 14.3	75.1 ± 9.3
Sciaenidae *Bairdiella chrysura*	8.8 ± 3.2	121.8 ± 28.6	1157.2 ± 313.8	123.0 ± 14.4	15.5 ± 9.8
Gerreidae *Eucinostomus* spp.	11.2 ± 3.6	8.9 ± 2.2	44.8 ± 14.0	92.9 ± 10.9	47.3 ± 3.6
Sparidae *Lagodon rhomboides*	48.3 ± 9.9	15.1 ± 2.1	7.8 ± 2.8	2.3 ± 0.9	0
Gobiidae *Gobiosoma robustum*	0	0.3 ± 0.3	1.5 ± 1.1	5.0 ± 1.2	2.1 ± 1.2
Sciaenidae *Cynoscion nebulosus*	0	0.4 ± 0.2	1.4 ± 0.6	9.3 ± 2.0	6.6 ± 1.4

Table 12. Total epibenthic fish abundance (No./200m^2) and that of the five most common epibenthic species collected in the 1989 fisheries surveys at Station MS-GK. Values are means ± SE.

	APRIL N = 8	JUNE N = 7	SEPTEMBER N = 8	NOVEMBER N = 8
TOTAL (All epibenthic species)	160.0 ± 35.9	170.6 ± 12.1	127.4 ± 16.6	122.5 ± 16.7
Sparidae				
Lagodon rhomboides	100.0 ± 19.5	77.9 ± 7.4	5.5 ± 0.8	0.5 ± 0.2
Gerreidae				
Eucinostomus spp.	1.5 ± 1.1	24.0 ± 4.4	48.9 ± 5.4	94.8 ± 15.8
Sciaenidae				
Bairdiella chrysura	15.6 ± 7.7	58.0 ± 5.4	67.1 ± 14.0	22.1 ± 11.7
Haemulidae				
Orthopristis chrysoptera	39.8 ± 13.1	0.9 ± 0.5	0	0
Syngnathidae				
Syngnathus scovelli	1.0 ± 0.4	1.7 ± 0.7	2.0 ± 0.3	1.9 ± 0.5

Table 13. Total epibenthic fish abundance (No./200m^2) and that of the five most common epibenthic species collected in the 1989 fisheries surveys at Station PIS-2. Values are means ± SE.

	APRIL N = 8	JUNE N = 8	AUGUST N = 6	SEPTEMBER N = 8	NOVEMBER N = 6
TOTAL (All epibenthic species)	216.8 ± 51.2	145.5 ± 8.0	59.7 ± 16.0	39.6 ± 6.5	24.7 ± 17.3
Sparidae					
Lagodon rhomboides	186.9 ± 42.9	100.6 ± 15.8	7.2 ± 2.5	2.5 ± 0.6	0
Gerreidae					
Eucinostomus spp.	0	20.6 ± 4.3	48.8 ± 13.4	34.5 ± 6.4	21.2 ± 17.0
Haemulidae					
Orthopristis chrysoptera	20.3 ± 17.2	0.9 ± 0.4	0	0	0
Sciaenidae					
Bairdiella chrysura	4.0 ± 2.9	9.5 ± 2.6	0.2 ± 0.2	0.3 ± 0.2	0
Syngnathidae					
Syngnathus scovelli	2.0 ± 1.1	2.0 ± 0.8	1.0 ± 0.4	0.4 ± 0.3	1.2 ± 0.7

Table 14. Taxonomic and common names of fishes collected in the 1989 fisheries surveys.

FAMILY	SCIENTIFIC NAME	COMMON NAME
Ariidae	Arius felis	sea catfish
Balistidae	Aleuterus heudeloti	dotterel filefish
	Monocanthus hispidus	planehead filefish
Batrachoididae	Opsanus beta	gulf toadfish
Belonidae	Strongylura notata	redfin needlefish
Blenniidae	Chasmodes saburrae	Florida blenny
Bothidae	Paralichthys lethostigma	Southern flounder
Carangidae	Oligoplites saurus	leatherjacket
	Chloroscrombrus chrysurus	Atlantic bumperfish
Centropomidae	Centropomus undecimalis	common snook
Clupeidae	Harengula pensacolae	scaled sardine
	Opisthonema oglinum	Atl. thread herring
Cynoglossidae	Symphurus plagiusa	black cheeked tongue
Cyprinodontidae	Lucania parva	rainwater killifish
Diodontidae	Chilomycterus schoepfi	striped burrfish
	Chilomycterus antillarum	web burrfish
Elopidae	Elops saurus	ladyfish
Engraulidae	Anchoa mitchilli	bay anchovy
	Anchoa hepsetus	striped anchovy
Ephippidae	Chaetodipterus faber	Atlantic spadefish
Exocoetidae	Hyporhamphus unifasciatus	halfbeak
Gerreidae	Eucinostomus argenteus	spotfin mojarra
	Eucinostomus gula	silver jenny
Gobiidae	Gobiosoma robustum	code goby
	Microgobius gulosus	clown goby
Haemulidae	Haemulon plumieri	white grunt
	Orthopristis chrysoptera	pigfish
Lutjanidae	Lutjanus griseus	gray snapper
	Lutjanus synagris	lane snapper
Rajidae	Raja eglanteria	clearnose skate
Scaridae	Nicholsina usta	emerald parrotfish
Sciaenidae	Cynoscion nebulosus	spotted seatrout
	Bairdiella chrysura	silver perch
	Leiostomus xanthurus	spot
Serranidae	Mycteroperca microlepis	gag
Soleidae	Achirus lineatus	lined sole
Sparidae	Archosargus probatocephalus	sheepshead
	Calamus arctifrons	grass porgy
	Lagodon rhomboides	pinfish
Syngnathidae	Syngnathus scovelli	gulf pipefish
	Hippocampus zosterae	Dwarf seahorse
Synodontidae	Synodus foetens	inshore lizardfish
Tetradontidae	Spoeroides nephelas	southern puffer