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# ENVIRONMENTAL RESPONSE OF WCA-2A TO REDUCTION IN REGULATION SCHEDULE AND MARSH DRAWDOWN

by

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# EXECUTIVE SUMMARY


Drawdown techniques have proven successful in stimulating desirable vegetation growth and enhancing wildlife use in lakes and wetlands. A similar management technique was used in WCA-2A to restore native plant communities drowned by prolonged flooding, to consolidate sediments and enhance other functional attributes of the marsh, such as wading bird use. Previous impoundment and effective water control significantly altered the hydroperiod of the marsh, resulting in a shift in vegetation to species favoring both longer hydroperiods and greater water depths. A multiyear reduction in the water regulation schedule was initiated in November 1980 that included annual drawdown to expose marsh soils. This study details results of changes in marsh plant communities (sloughs, tree islands, and sawgrass), water quality, soil fertility, and hydrology over a four year period (November 1980 - September 1984).

Initial drawdown of the marsh (November 1980 - May 1981) coincided with a large scale regional drought. Water levels in WCA-2A receded below ground around 11 April and remained below ground approximately 75 days before the marsh was reflooded by rainfall. Concern for regional water supplies prompted suspension of scheduled drawdown during the second year until late in the dry season. Partial dewatering of the marsh was accomplished but water levels remained at or near ground surface until the marsh reflooded. Unusually wet conditions prevailed during the dry seasons of the third and fourth years and prevented the marsh drying.

Because of inadequate drying, objectives of the drawdown were only partially successful. Changes in plant communities were highly dependent on extent and duration of soil drying, and vegetation type. In aquatic slough communities, biomass and dominance of water tolerant species (white water lily and bladderwort) was reduced while emergent species (spikerush) increased. However, at the conclusion of the fourth year, spatial and temporal comparisons indicated that community structure of sloughs located in the central marsh were least influenced by repetitive drawdown attempts. Lower water levels, did, however, create conditions conducive for expansion of spikerush in lower elevations of the marsh.

Tree island plant communities responded to drawdown with an influx of new species (primarily forbs and grasses) but dominant species were unchanged. Changes in species richness fluctuated inversely with flooding frequency. Although a majority of the newly established species were perennials, many were present for only a single year. Rapid turnover in these species suggest environmental conditions were not suitable to promote succession toward more mesic communities, particularly woody shrubs. Successful recruitment of wax myrtle and red bay seedlings occurred on islands above elevation 12.0 ft NGVD located near mature seed bearing individuals.

Sawgrass density increased following drawdown and burning, but declined again as the time lapse after burning increased. This pattern of increase and decline in density was consistent with general plant response to improved growing conditions followed by decline as growing conditions become less favorable. Significant site differences were observed in stand regrowth of density, biomass and culm size, but rates of regrowth (measured as percent increase or decrease in means between sampling periods) were similar. Water depth was somewhat negatively correlated with culm density and positively correlated with culm size. Size classification indicated that site differences in hydrology significantly influenced the development and number of larger culms produced at each site. These differences were attributed to adaptations in growth strategy in response to local hydrology.

Marked changes in water quality and soil fertility were associated with changes in marsh hydrology. Initial drawdown increased availability of some nutrients and other ions due to increased decomposition and leaching from exposed plant detritus and soils. During unsuccessful drawdown years, changes in water quality were strongly influenced by characteristics of the source water (rainfall and runoff). Despite the large export of water associated with each drawdown attempt, the marsh continued to assimilate nutrients, although less efficiently than in pre-drawdown years. Changes in uptake efficiency were attributed to fluctuations in inflow concentrations, residence time, and net losses associated with large outflow volumes. The flux of ions associated with the changes in hydrology caused the marsh to export these elements. Declines in soil stored potassium during periods of net export suggest soils may be a significant but temporary sink for this element.

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## ACKNOWLEDGEMENTS

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I wish to thank Professor Katherine Ewel, University of Florida, School of Forest Resources and Conservation, and Mr. Lance Gunderson, Everglades National Park, for their excellent reviews of this manuscript.


## ABSTRACT


A multi-year reduction in water regulation of an Everglades marsh (WCA-2A), initiated in November 1980, included an annual drawdown to restore native plant communities, consolidate sediments, and enhance other functional attributes of the marsh, such as wading bird use.

Gradient changes in plant communities (aquatic sloughs, tree islands and sawgrass) were attributed to annual and spatial differences in drawdown hydrology. Due to ponding effects, plant communities in the central marsh were least affected by the drawdown. Dominance and biomass of water tolerant species declined in aquatic sloughs while other wet prairie species increased. An influx of new species, mostly of grasses and forbs, was observed on tree islands. However, environmental conditions were unstable and a majority of these new arrivals drowned in succeeding years. Successful recruitment of woody seedlings was observed on islands above 12.0 ft NGVD, located near mature seed producing individuals. Culm densities in sawgrass communities also initially increased in response to drawdown and burning but later declined. Site differences in the rate of regrowth were weakly correlated with water depth. Stable flooding conditions (less extreme lows and highs) in the central marsh produced fewer and larger culms compared to other sites.

Temporal and spatial differences in marsh water quality and soils corresponded to changes in hydrology. Nutrient and ion concentrations increased with declining water levels. During flooding, water quality was frequently dominated by source water from the Everglades Agricultural Areas. Despite large changes in the net water balance, the marsh continued to assimilate nutrients but at a slightly less efficient rate compared to non-drawdown years.

# INTRODUCTION

Drawdowns have proven successful in stimulating desirable vegetation growth and enhancing wildlife use in lakes (Low and Bellrose, 1944; Uhler, 1944; McDonald, 1955; Dane, 1959; Kadlec, 1962; Holcomb and Wegener, 1971) and wetlands (Harris and Marshall, 1963; Dineen, 1974; Goodrick and Milleson, 1974). A similar management technique was used in an Everglades impoundment to restore functional attributes, such as wading bird use, and to reverse undesirable ecological changes resulting from prolonged flooding.

Water Conservation Area 2 (WCA-2) is one of three large impoundments managed by the South Florida Water Management District for water storage, flood control, and other purposes (Figure 1). These impoundments were created by a system of levees enclosing about one half the original Everglades. Impoundment of these marshes has significantly altered the timing of the hydroperiod and created greater water depths for longer periods. A shift in plant community composition has occurred to species favoring both longer hydroperiods and greater water depths, particularly in WCA-2A. Changes in hydrology have also been accompanied by an accumulation of flocculent plant detritus (gyttja), decline in wildlife use, creation of open water habitats, loss of unique vegetation communities, and creation of anaerobic soil conditions.

The purpose of this study was to stimulate regrowth of native plant communities by simulating natural drying through alteration of the regulation schedule in WCA-2A. A multiyear reduction in the water regulation schedule (from 13.0 - 14.5 NGVD to 9.5 - 12.5 NGVD) was initiated in November 1980. This report details results of plant community changes in response to annual drawdown over a four year period (1980-1984), together with analysis of the changes in water quality, soil fertility and hydrology.

# BACKGROUND

## Everglades Impoundment

Since formation of the Everglades Drainage District in 1907, natural hydrology of the Everglades has been altered to support a variety of uses including agriculture, urban development, water storage, flood control and wildlife preservation. An extensive system of levees and canals was later constructed in 1958 by the U.S. Army Corps of Engineers (USCOE, 1958) to regulate water levels, creating the Water Conservation Areas (Figure 1). As water demand from agriculture and urban development increased, the need to increase water storage in the Water Conservation Areas has grown. Regulation schedules were developed governing the timing and amount of water stored in the Water Conservation Areas. While these regulation schedules were developed with recognition of some environmental restrictions, the ability to accumulate and store water for prolonged periods has significantly altered the ecology of the area, particularly WCA-2A.

## Hydrology and Regulation Schedules

Hydrology of the Everglades included long periods of flooding with intermittant drying (Parker et al., 1955). Long term water records at the 2-17 gauge (ground elevation 11.1 NGVD) indicate the frequency of drying in WCA-2A (Figure 2) declined after completion of the L-35B levee in 1961 (Figure 4). Concurrently, a schedule was adopted with a maximum elevation varying seasonally between 12.0-14.5 NGVD. Under this schedule a majority of the land surface remained flooded throughout the year. In 1972, the minimum was increased from 12.0 to 13.0 NGVD to enhance fisheries potential (USCOE, 1972). With the exception of drought years (1962, 1971, and 1974) and an experimental drawdown (1973), the interior marsh has been flooded continuously since 1961 (Figure 2).

## Environmental Changes

Loveless (1959) described four basic plant communities in WCA-2; sloughs, wet prairies, tree islands and sawgrass marsh (Figure 3). Extensive wet prairies occurred throughout the east central portion of the marsh and were characterized by either maidencane (Panicum hemitomon), spikerush (Eleocharis cellulosa), or beakrush (Rhynchospora tracyi). Sloughs formed natural drainage channels that remained wet throughout the year. Water lily (Nymphaea odorata), floating heart (Nymphoides aquatica) and bladderwort (Utricularia spp.) were prevalent intermixed with wet prairie species. Tree islands, formed on peat mounds or rock outcrops, provided the only major topographic relief. These were dominated by dahoon holly (Ilex cassine), wax myrtle (Myrica cerifera) and red bay (Persea borbonia). Throughout the open marsh, sawgrass (Cladium jamaicense) was the dominant species occurring in pure stands or intermixed with other emergents such as flag (Sagittaria lancifolia), pickerelweed (Pontederia lanceolata), and arrow-arum (Peltandra virginica).

Increased frequency of flooding, greater water depths and high nutrient loading associated with agricultural runoff have significantly altered marsh ecology. Dineen (1972, 1974) observed changes that

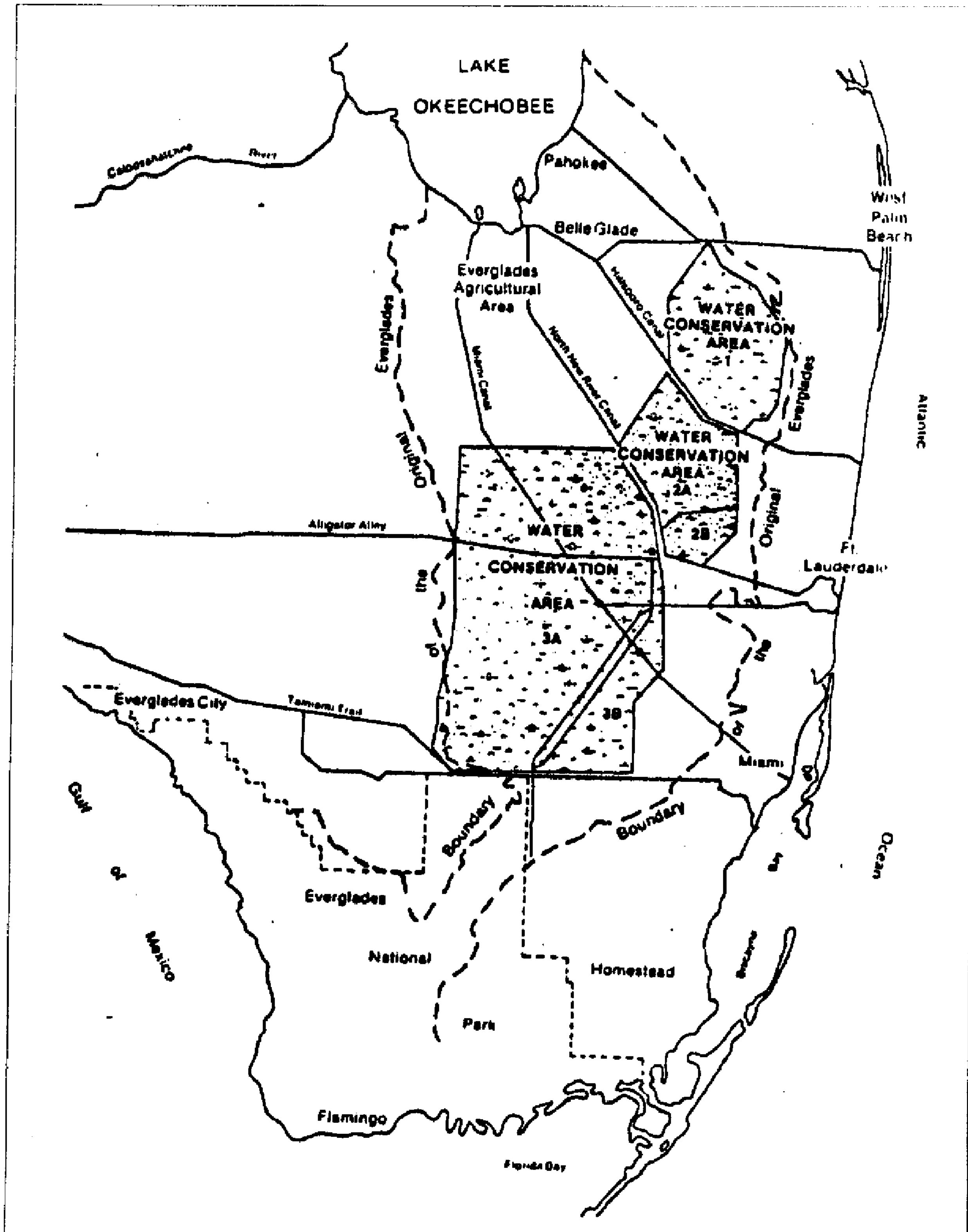
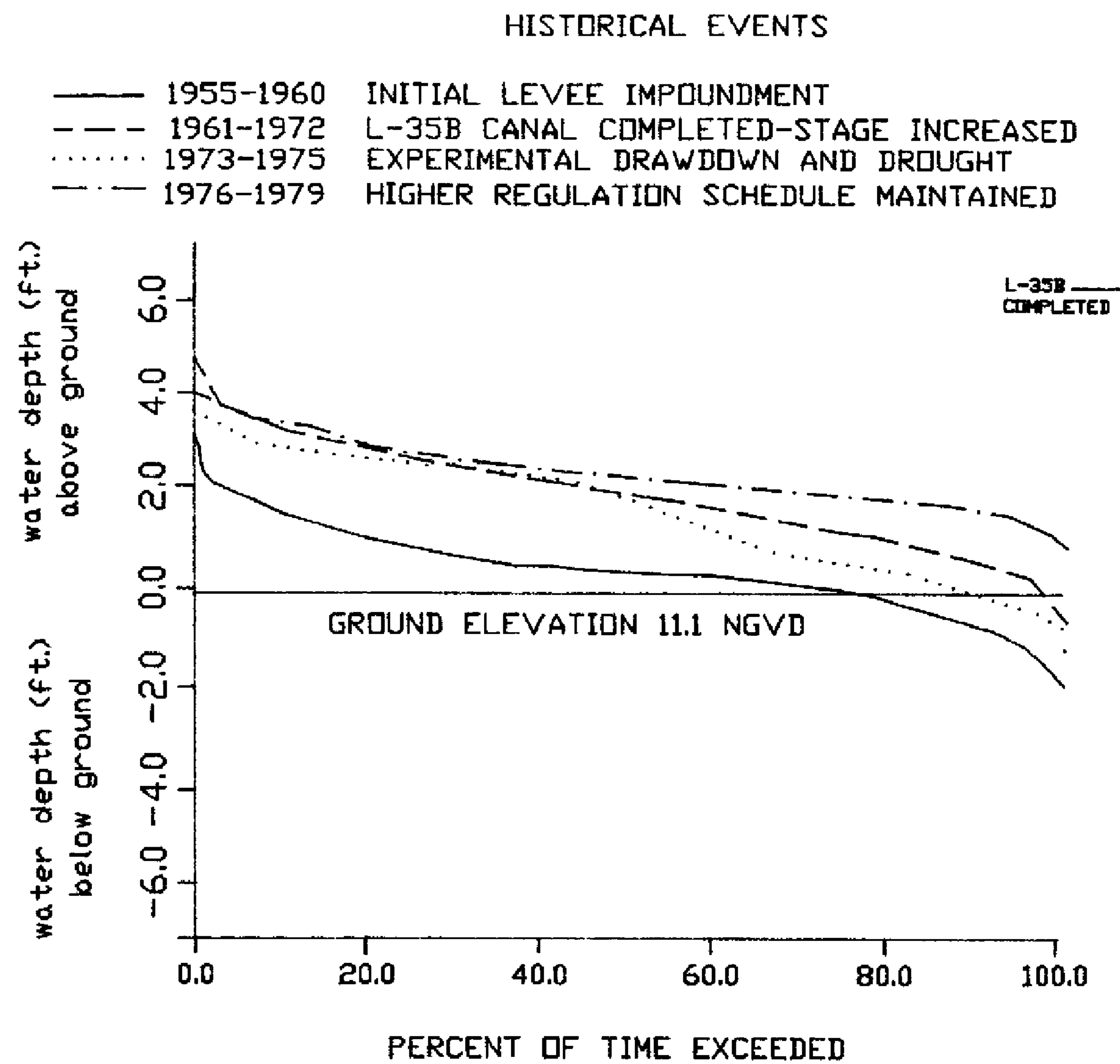



FIGURE 1. LOCATION OF EVERGLADES WATER CONSERVATION AREAS AND BOUNDARY OF ORIGINAL EVERGLADES IN SOUTH FLORIDA. (Adapted from Smith, 1968)




| YEAR | #DAYS DRY |
|---|---|
| 1955 | 110 |
| 1956 | 256 |
| 1957 | 108 |
| 1958 | 0 |
| 1959 | 0 |
| 1960 | 15 |
| 1961 | 0 |
| 1962 | 70 |
| 1963 | 0 |
| 1964 | 0 |
| 1965 | 0 |
| 1966 | 0 |
| 1967 | 0 |
| 1968 | 0 |
| 1969 | 0 |
| 1970 | 0 |
| 1971 | 47 |
| 1972 | 0 |
| 1973 | 71 |
| 1974 | 13 |
| 1975 | 12 |
| 1976 | 0 |
| 1977 | 0 |
| 1978 | 0 |
| 1979 | 0 |

FIGURE 2. HISTORIC STAGE LEVEL PERCENT EXCEEDENCE CURVES FOR WCA-2A; PERIOD OF RECORD 1955-1979. DATA FROM THE 2-17 GAUGE LOCATED IN THE INTERIOR MARSH

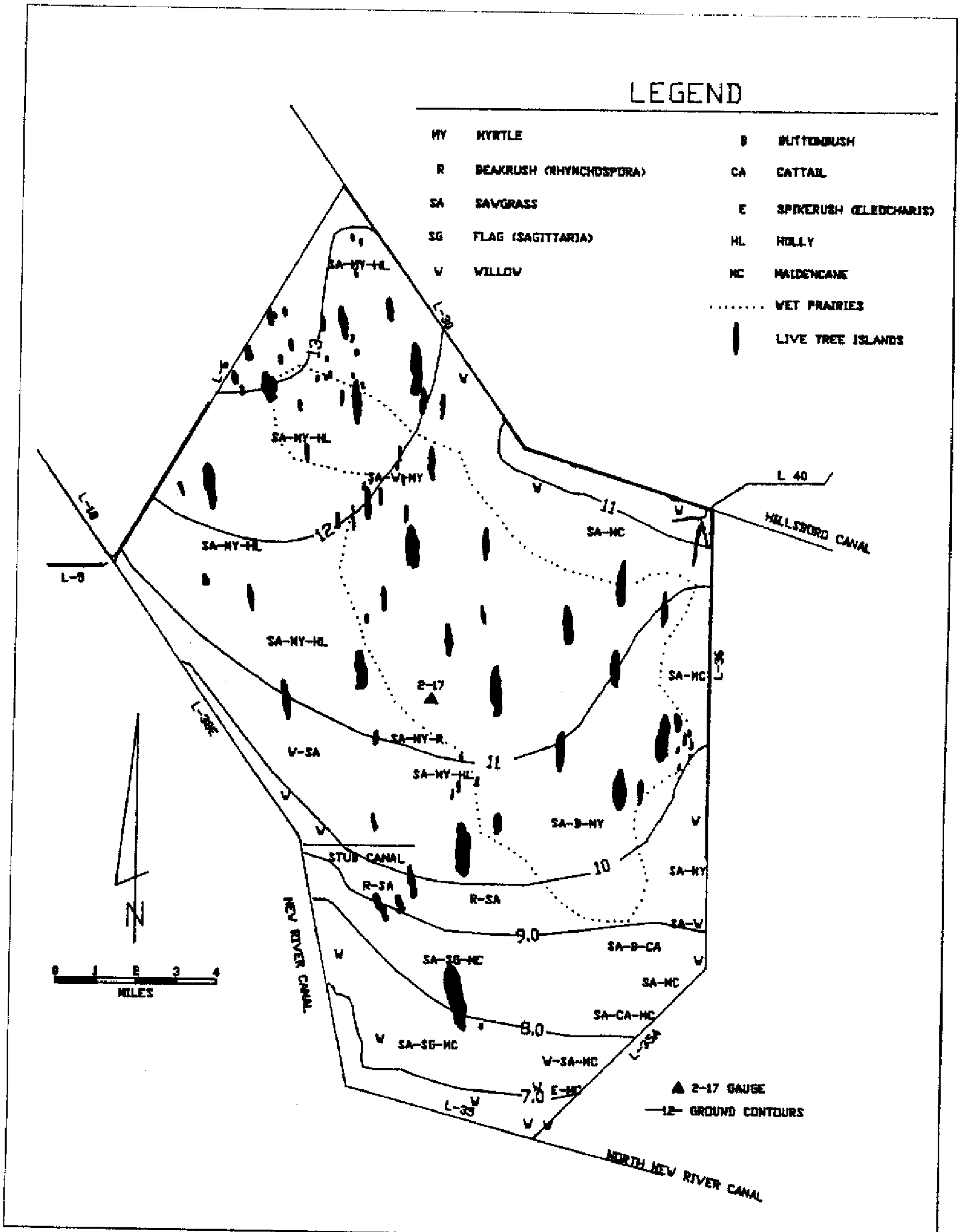



FIGURE 3. HISTORIC VEGETATION COMMUNITIES OF WCA-2 PRIOR TO CONSTRUCTION OF L-35B, AS REPORTED BY LOVELESS, 1959.

included elimination of wet prairie vegetation,drowning of tree islands, accumulation of a flocculent layer of plant detritus (gyttja) in sloughs, and loss of sawgrass along slough edges. Major plant communities in WCA-2A now consist of remnant drowned tree islands, open water sloughs, and large areas of sawgrass intermixed with dense cattail (primarily Typha domingensis, Figure 4).

Water quality of WCA-2A surface inflows is characterized by high concentrations of both nitrogen and phosphorus. Where inflows are forced over the marsh, nutrient concentrations are reduced within approximately 3.2 km (2 miles from entry (Gleason, 1974; Millar, 1981; Swift, 1981). Increased prevalence of cattail, water hyacinth (Eichhornia crassipes), water lettuce (Pistia stratiotes) and duckweed (Lemna spp.) is closely associated with the distribution of enriched inflows into the marsh (Figure 4). Interior marsh water quality is characterized as highly mineralized, alkaline, hard water (Swift, 1981) with low phosphorus (0.028 mg P/l) and moderate nitrogen (2.62 mg N/l as total N) concentrations (Millar, 1981).

### Previous Drawdown Efforts

An experimental drawdown was undertaken in February 1973 with the purpose of simulating natural drying conditions to promote regrowth of wet prairies and tree islands. This effort allowed the marsh to dry for approximately 71 days before it was reflooded by summer rains. Portions of the marsh failed to dry due to the late timing of the drawdown. However, efforts were partially successful in consolidating gyttja and in stimulating regrowth of some wet prairie species and woody shrubs on tree islands (Dineen, 1974). Other studies (Kushlan, 1974) indicated usage of the marsh by Everglades Kites and wading birds increased during falling water levels.

## STUDY COMPONENTS
### SECTION I - DRAWDOWN HYDROLOGY
### Methods and Analysis

Stage records and rainfall were obtained from South Florida Water Management District and U.S. Army Corps of Engineers gauging sites located throughout WCA-2A (Figure 4). Stage records at various gauges were referenced and corrected to the 2-17 gauge datum located in the interior marsh. Weighted rainfall amounts and discharge data were provided by the Corps.

Marsh drawdown was initiated in November 1980 with the goal of reducing water levels below ground in spring. The schedule was referenced to the 2-17 gauge with water levels fluctuating seasonally between 9.5-12.5 NGVD (Figure 5). Following the first year results, timing of the drawdown was modified (beginning in September) to extend the number of months the marsh remained dry. Discharges from WCA-2A were directed to WCA-3A through the S-11 structures located in the southwest corner, WCA-2B through the L-35B levee culverts (S-144, S-145, and 146) to the south and to the coast through the S-38 structure located at the southeast corner (Figure 4).

### Results

#### Discharge Routings

A majority of outflows (roughly 70%) and largest volume discharges were diverted to WCA-3A (Table 1). Smaller releases through the L-35B culverts and S-38 (C-14 canal) were later used to offset inflows and continue drawdown. Discharge to WCA-2B accounted for only 7-20% of the annual totals. Diverting water to WCA-2B was limited by the smaller storage area and design capacity of the smaller culverts (S-144, 145, 146). Discharge through these culverts was further constrained by dense vegetation near the outfall and ceased whenever upstream stage in the L-35B canal fell below 10.5 ft NGVD. Coastal discharge through the S-38 structure varied annually from 7-11% of the total depending on downstream canal capacity and coastal rainfall. S-38 releases accounted for 8.5% of annual totals during drought conditions coinciding with the first year drawdown.

#### Marsh Drawdown and Reflooding

Year 1: November 1980 - August 1981

Water levels in the lower marsh (L-35B canal) rapidly declined in response to large discharges in November and December. A gradient in water elevation (approximately 2 ft between the 2-17 gauge and L-35B canal) was created that allowed the interior marsh to drain until the 2-17 gauge reached 11.5 ft NGVD (Figure 6). At this stage, sawgrass ridges separating large slough systems were exposed, prohibiting overland flow, and ponding occurred throughout the central marsh. As discharges continued, the L-35B canal stage sharply declined.

Record drought conditions developed as the marsh contined to dry. Rainfall in WCA-2A totalled only 10.35 inches (66.5% of normal) during the seven month dry season between November 1980 - May 1981 (Lin, et. al., 1984). However, interior marsh water levels did not recede below ground until late in the dry season, around 11 April 1981. Soils were exposed only

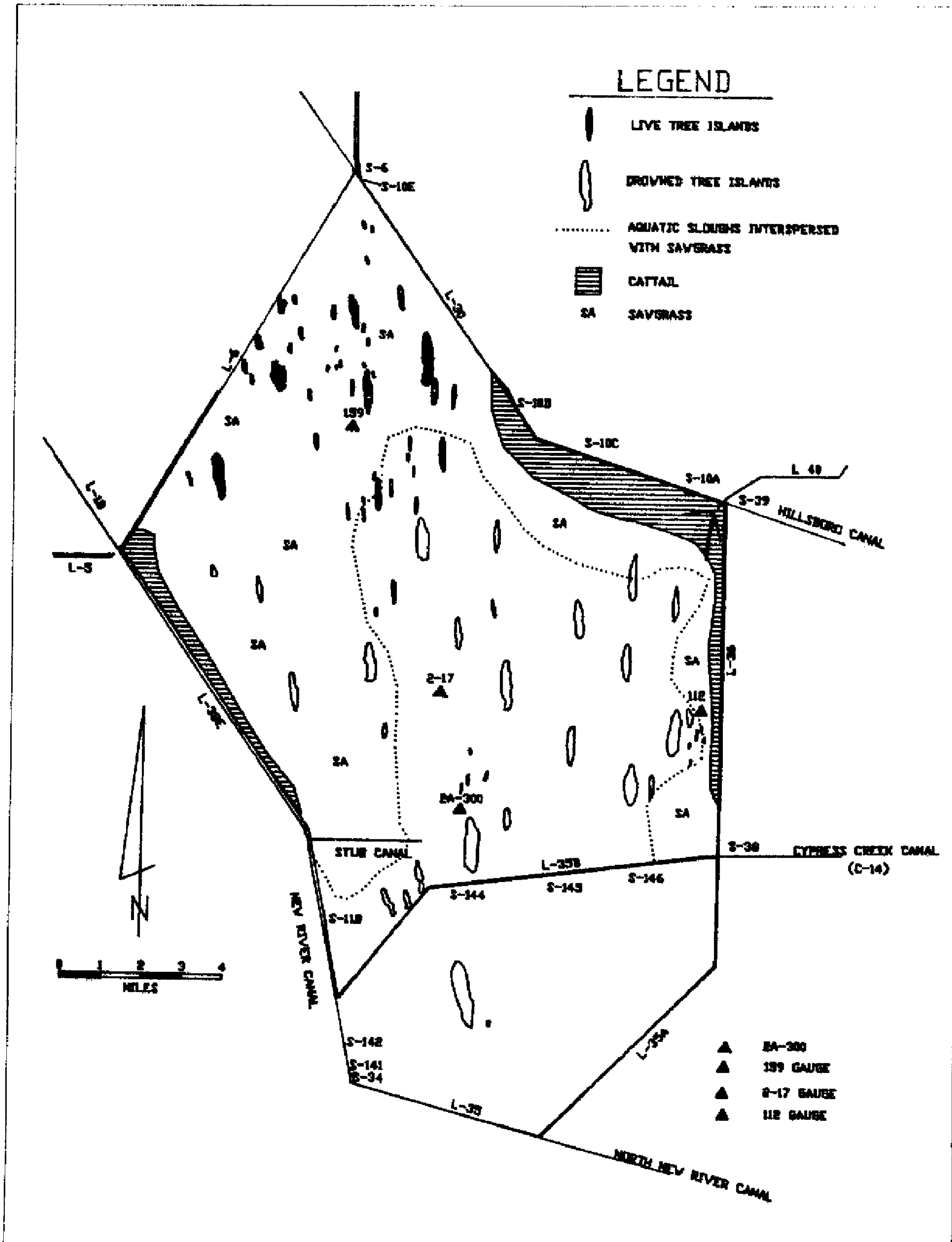



FIGURE 4. PRE-DRAWDOWN DOMINANT PLANT COMMUNITIES IN WCA-2A

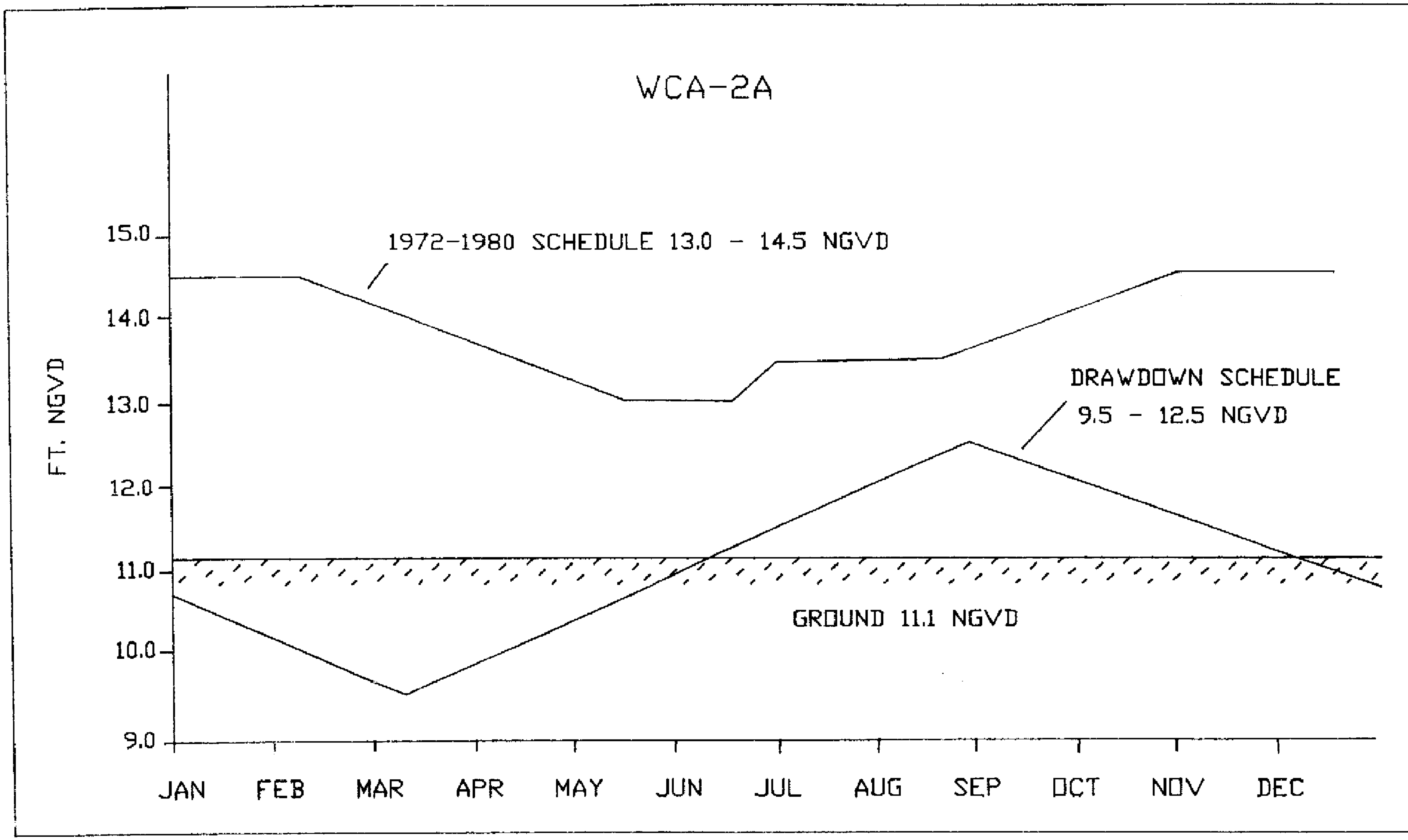



FIGURE 5. NORMAL OPERATION AND DRAWDOWN REGULATION SCHEDULES FOR WATER CONSERVATION AREA 2A

TABLE 1. TOTAL MONTHLY RAINFALL AND STRUCTURE INFLOW/OUTFLOW OF WCA-2A DURING THE DRAWDOWN PERIOD NOVEMBER 1980-SEPTEMBER 1984. RAINFALL UNITS ARE IN INCHES, INFLOW AND OUTFLOW ARE IN ACRE FEET.

| | | Inflow | | Outflow | | | | Inflow/ |
|---|---|---|---|---|---|---|---|---|
| Month | Rainfall | S-10's | S-7 | S-11's | S-38 | S-143 | S-144-46 | Outflow |
| **Year 1** | | | | | | | | |
| Nov. (Dr/dwn) | 2.17 | 0 | 3872 | 43127 | 771 | 1838 | 8251 | -50115 |
| Dec. | .40 | 0 | 1160 | 19676 | 1757 | 4292 | 783 | -25348 |
| Jan. 1981 | .54 | 0 | 0 | 0 | 1553 | 6644 | 0 | -8197 |
| Feb. | 1.71 | 0 | 3068 | 0 | 1053 | 2578 | 0 | -563 |
| Mar. | .63 | 0 | 809 | 0 | 2330 | 2036 | 0 | -3557 |
| Apr. | .24 | 60 | 9453 | 0 | 7067 | 7329 | 0 | -5003 |
| May | 4.66 | 355 | 6335 | 0 | 3697 | 3592 | 0 | -599 |
| Jun. | 1.26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jul. | 6.39 | 0 | 0 | 0 | 0 | 1321 | 5554 | -6875 |
| Aug. | 21.99 | 74310 | 47326 | 87465 | 0 | 0 | 0 | 34171 |
| **lst Year Totals*** | 39.99 | 74605 | 72023 | 150268 | 18228 | 29360 | 14588 | -66086 |
| **Year 2** | | | | | | | | |
| Sep. | 3.68 | 63536 | 2573 | 92939 | 0 | 0 | 28225 | -55055 |
| Oct. | 1.03 | 0 | 0 | 0 | 0 | 0 | 4106 | -4106 |
| Nov. | 4.05 | 0 | 8087 | 0 | 0 | 0 | 0 | 8087 |
| Dec. | .14 | 0 | 0 | 0 | 545 | 0 | 0 | -545 |
| Jan. 1982 | .24 | 0 | 0 | 0 | 2025 | 0 | 0 | -2025 |
| Feb. | 1.96 | 0 | 0 | 0 | 454 | 0 | 0 | -454 |
| Mar. | 4.20 | 10611 | 1092 | 2937 | 359 | 0 | 0 | 8407 |
| Apr. | 1.72 | 23645 | 351 | 9768 | 2046 | 987 | 0 | 11195 |
| May | 5.12 | 9153 | 24525 | 8345 | 0 | 0 | 0 | 25333 |
| Jun. | 12.69 | 240055 | 92393 | 84555 | 0 | 0 | 21934 | 225959 |
| Jul. | 3.86 | 62145 | 19404 | 194006 | 25535 | 20953 | 30379 | -189324 |
| Aug. | 3.79 | 17944 | 38146 | 0 | 8800 | 4478 | 19592 | 23220 |
| **2nd Year Totals** | 42.48 | 427089 | 186571 | 392550 | 39764 | 26418 | 104236 | 50692 |
| **Year 3** | | | | | | | | |
| Sep. 1982 | 5.09 | 6775 | 44672 | 23872 | 404 | 0 | 23597 | 3574 |
| Oct. | 3.33 | 99724 | 37997 | 170437 | 0 | 0 | 23225 | -55941 |
| Nov. | 2.29 | 0 | 476 | 72554 | 24 | 0 | 9361 | -81463 |
| Dec. | 1.20 | 0 | 0 | 60421 | 0 | 0 | 5573 | -65994 |
| Jan. 1983 | 4.70 | 36104 | 30004 | 65515 | 3917 | 0 | 7438 | -10762 |
| Feb. | 7.55 | 169641 | 61929 | 57658 | 19748 | 2408 | 18884 | 132872 |
| Mar. | 3.93 | 50758 | 31913 | 0 | 29957 | 10830 | 32450 | 9434 |
| Apr. | 2.66 | 2789 | 5175 | 6482 | 26747 | 17812 | 27729 | -70806 |
| May | 2.09 | 0 | 625 | 12954 | 3370 | 1472 | 5693 | -22864 |
| Jun. | 6.15 | 65684 | 24472 | 68298 | 0 | 0 | 10929 | 10929 |
| Jul. | 5.91 | 7224 | 6934 | 44474 | 571 | 0 | 13369 | -44240 |
| Aug. | 8.07 | 64486 | 48844 | 58620 | 0 | 0 | 14816 | 39894 |
| **3rd Year Totals** | 52.98 | 503185 | 293057 | 641285 | 84738 | 32522 | 193064 | -155367 |
| **Year 4** | | | | | | | | |
| Sep. | 4.68 | 36167 | 48467 | 131076 | 0 | 0 | 2936 | -49378 |
| Oct. | 4.60 | 87020 | 45713 | 80046 | 2208 | 0 | 4185 | 46235 |
| Nov. | 1.15 | 12998 | 7141 | 86673 | 24952 | 0 | 4840 | -96326 |
| Dec. | 5.47 | 0 | 25998 | 53073 | 8009 | 0 | 6268 | -41352 |
| Jan. 1984 | 0.44 | 29870 | 11540 | 26152 | 22745 | 7656 | 5653 | -20796 |
| Feb. | 1.37 | 3418 | 25163 | 28412 | 6903 | 1111 | 5375 | -13220 |
| Mar. | 4.62 | 31345 | 49242 | 39739 | 5647 | 0 | 5891 | 29310 |
| Apr. | 3.61 | 32869 | 41032 | 68298 | 20357 | 0 | 6070 | -20815 |
| May | 7.56 | 41060 | 21465 | 26757 | 8745 | 0 | 3312 | 23711 |
| Jun. | 5.78 | 63028 | 23917 | 79802 | 0 | 0 | 10413 | - 3270 |
| Jul. | 2.53 | 79606 | 42770 | 62258 | 0 | 0 | 11881 | 48237 |
| Aug. | 5.82 | 0 | 10638 | 57297 | 0 | 0 | 6328 | -52987 |
| **4th Year Totals** | 47.63 | 417322 | 353095 | 739583 | 99566 | 8767 | 73512 | -150651 |

*Totals for 10 month period only. All other totals represent 12 months.

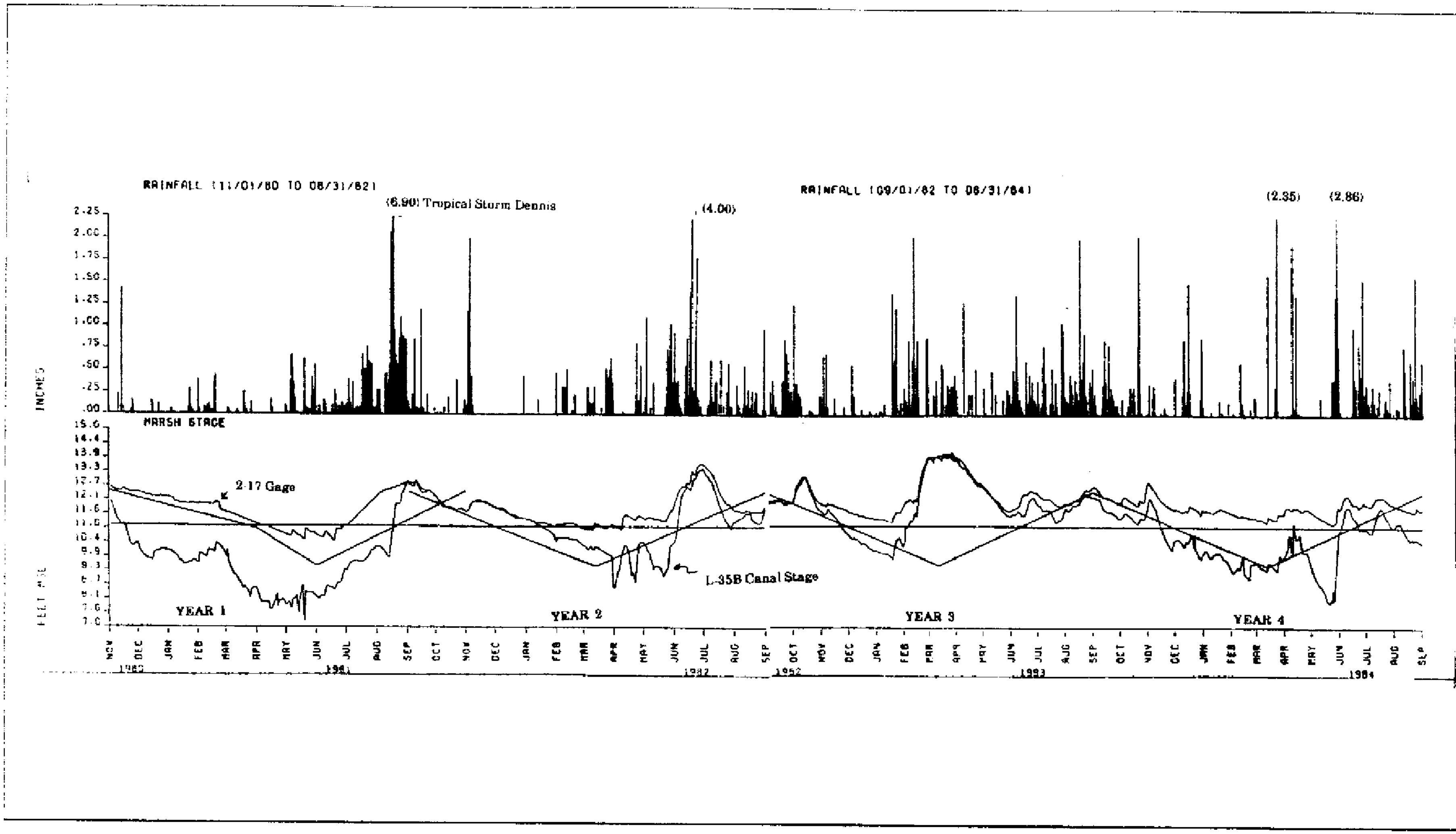



FIGURE 6. DAILY STAGE AND RAINFALL IN WCA-2A: NOVEMBER 1980 - AUGUST 1984. WATER LEVELS DEPICT INTERIOR MARSH CONDITIONS AS MEASURED AT THE 2-17 GAUGE. RAINFALL IS BASED ON A WEIGHTED AVERAGE OF RECORDING SITES BY ARMY CORPS OF ENGINEERS

a short time (approximately 75 days) before arrival of the rainy season. Lowest recorded stage level in the interior marsh was 10.50 NGVD on 19 June.

Reflooding occurred gradually until passage of Tropical Storm Dennis on 16 August (Figure 6). Heavy rainfall coupled with large S-10 releases from WCA-1 (Table 1) caused water levels to rapidly increase, reaching a peak stage of 12.65 NGVD on 10 September. Although the tropical storm relieved local drought conditions, Lake Okeechobee (primary water reservoir of south Florida) stage level remained far below its regulation schedule (10 September stage = 11.44 NGVD; normal regulation stage = 16.45 NGVD). All releases from WCA-2A, except those needed for water supply purposes, were suspended in late September as a precautionary measure to conserve water supplies, even though water levels in WCA-2A were far above the drawdown schedule.

Year 2: September 1981 - August 1982

Aided by drought weather conditions, the first year drawdown was marginally successful in attaining desired dry conditions in the interior marsh. To achieve more complete drying during the second year, timing of the drawdown schedule was advanced by two months, beginning in September 1981. However, because of continued low water levels in Lake Okeechobee, discharges from WCA-2A were restricted until March 1982 (Table 1). Partial dewatering of the marsh was accomplished through evapotranspiration but water levels remained above or near ground level throughout the 1981-82 winter months and prevented the interior marsh from drying (Figure 6).

Heavy rainfall and S-10 releases during summer 1982 (Table 1) again caused a rapid increase in water level similar to the pattern observed in fall 1981 (Figure 6). Flood stage reached 13.64 NGVD before it receeded and remained above schedule until late July.

Year 3: September 1982 - August 1983

Continued heavy rainfall throughout the 1982 fall and winter months caused water levels to remain above schedule during the third year drawdown (Figure 6). In late January, a stalled frontal system caused water levels throughout the Kissimmee Basin, Lake Okeechobee, and Water Conservation Areas to exceed flood control schedules, forcing control releases to be made. The WCA-2A drawdown schedule was again temporarily abandoned on 15 February and the prior regulation schedule of 13.0-14.5 NGVD adopted to utilize WCA-2A for additional flood storage. Agricultural runoff further contributed to large inflows through the S-10 structures in March (Table 1), causing the stage level to finally peak at 14.14 NGVD.

In response to high water levels during the previous winter months, the operating strategy was modified for the major outflow structures (S-11A, B, and C). Efforts were abandoned to regulate surface water levels by manipulating the S-11 structures. Instead, these structures were kept open so that inflows, either by direct rainfall or from agricultural runoff, (S-10 and S-7), were countered by immediate outflow through the S-11 structures. Stage levels in WCA-2A were allowed to fluctuate in response to conditions in WCA-3A. The net effect created sheet flow conditions across the marsh. High rainfall through the summer, however, kept the interior marsh stage well above the drawdown schedule.

Year 4: September 1983 - August 1984

Wet conditions persisted as the fourth year drawdown began. Large regulatory releases from WCA 1 in October, (Table 1) caused the interior marsh stage in WCA-2A to increase (Figure 6). Although the S-11 structures remained open, wet conditions throughout the lower Everglades prevented water levels in WCA-2A from receding in pace with the drawdown schedule. Low water stages again occurred late in the dry season, similar to the pattern observed during the second year drawdown attempt. Portions of the lower marsh dried (as reflected by the low stage in the L-35B canal) but the interior marsh remained flooded.

## SECTION II: VEGETATION STUDIES
### Methods and Materials

Initially, ten sites were selected in WCA2A to monitor plant community changes associated with marsh drawdown (Figure 7). Three sloughs, three tree islands, and four sawgrass study sites were selected along a north to south decreasing ground elevation gradient. Observations following the first and second year drawdowns indicated plant community response varied greatly even within small geographic areas. Consequently, ten additional tree island and six slough transects were added in 1983 to increase replication of the study results and provide a broader overview of marsh response to drawdown.

Sloughs

Sample collection and field documentation of slough transects was conducted prior to the drawdown (June-August 1980) and during the summer months of each drawdown year. A 183m transect was

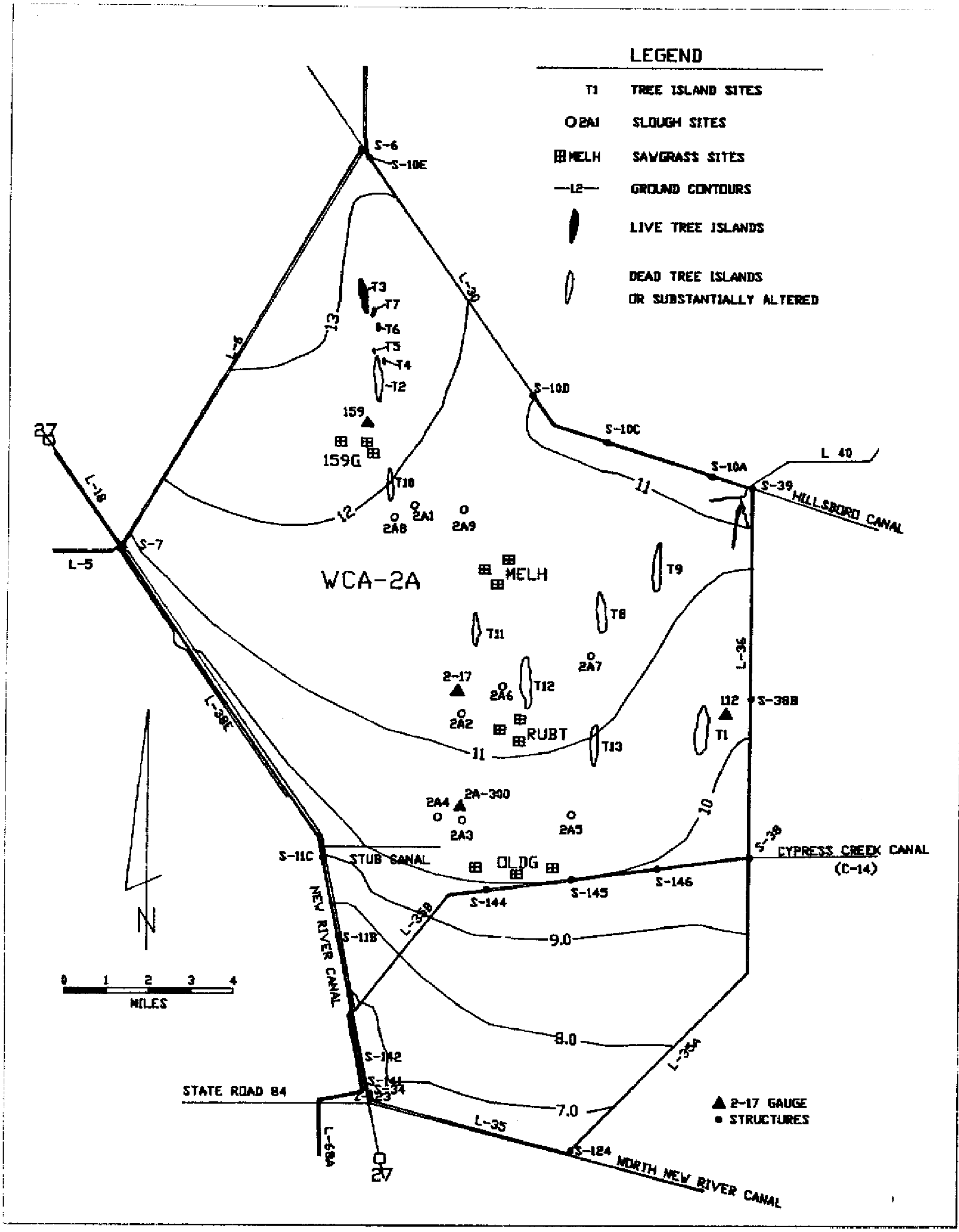



FIGURE 7. VEGETATION SAMPLE SITE LOCATIONS IN RELATION TO GENERALIZED SURFACE GROUND CONTOURS IN WCA-2A.

established along the longitudinal (north-south) axis of each slough. Species presence (frequency) was determined at all nine slough sites from 51 quadrats, 0.25m$^2$, examined at 3.7 m intervals, offset 3 m west of the transect line. Water depth and gyttja (unconsolidated sediment) were recorded within each quadrat. Soil elevation was then computed based on water surface elevation, corrected to the nearest surface water recording gauge (generally within 2.0 km). Measurements were further corrected by comparing water elevations among several reference gauges and computing differences in slope for each site. Biomass and density were estimated at slough sites 2A1, 2A2, and 2A3 from 10 0.25 m$^2$ quadrats randomly placed 3 m east of the transect line. All vegetation within these quadrats was clipped at soil surface and sorted by species. Stem density for each species was determined from the number of live shoots. Biomass was based on oven dry weight at 90°C for 48 hours. Other species not observed in the quadrats were also noted.

Estimates of species percent cover (Daubenmire, 1959) were added in 1983 and 1984 at all slough sites. Species cover was estimated in the same quadrats used for establishing species frequency. Seven classes were used to estimate species cover: (T) < 1%, (1) 1-5%, (2) 5-25%, (3) 25-50%, (4) 50-75%, (5) 75-95%, (6) 95-100%.

Tree Islands

Tree island study sites 1, 2, and 3 were selected representing the range of vegetation composition and community structure exhibited by living and drowned tree islands. Tree island 1 (Figure 7) is typical of the drowned tree islands found in the southern third of the Water Conservation Area. This island is devoid of trees except for a few live willows (Salix caroliniana) at the most northern apex of the island. The water tolerant shrub buttonbush (Cephalanthus occidentalis) is the most common woody species. Ground cover consists of a dense band of sawgrass along the island margin with cattail (Typha spp.) dominating the island interior. Tree island 2 is located in the north central apex of the area, with an average soil elevation about one foot higher than tree island 1. Although islands in this portion of the marsh are subjected to less frequent flooding, species composition has also been affected. Willow occupies the extreme north end of this island with woody shrubs like wax myrtle (Myrica cerifera) and buttonbush scattered throughout the island. Sawgrass (Cladium jamaicense) is the dominant ground cover. Tree island 3 is one of a few islands remaining with a well developed tree canopy. Dominant tree species is dahoon holly (Ilex cassine) with wax myrtle scattered throughout and forming a dense thicket at the island/sawgrass ecotone. Ferns are the dominant ground cover interspersed with various herbaceous, sedge and grass species.

Species composition and frequency was monitored at tree islands 1 and 2 in 51 1.0 m$^2$ quadrats offset 3 m north of permanently marked transect lines at 3.7 m intervals. The density of trees and understory vegetation at tree island 3 precluded using transects. Alternatively, five rectangular plots (9x3 m) were marked. Composition and frequency was determined by randomly nesting ten 1.0 m$^2$ quadrats in each plot (total = 50). All woody plants greater than 1 m in height within these plots were enumerated and stem diameter measured at breast height (2m). Herbaceous and woody cover estimates were added in 1983 and 1984. Herbaceous cover was estimated in the same quadrats used to obtain species frequency. Cover scales were identical to those used for slough vegetation. Woody cover was estimated at tree islands 1 and 2 and at ten additional sites (4-13) using the line intercept method (Mueller-Dombois and Ellenberg, 1974). All cover lines were equally spaced across the width of the islands and oriented parallel to the long axis. Species occurring within 3m of each line segment were noted. Several line cover segments were used to measure both woody cover and species richness depending on the size and variation in species composition. Water depth was measured in each quadrat and corresponding soil elevations computed using the same technique outlined for slough vegetation.

Sawgrass

Sawgrass communities were control burned in winter 1980-81 by the Florida Game and Freshwater Fish Commission to reduce chances of wildfires during dry conditions. Regrowth of burned sawgrass was monitored to determine what effects alternate drying and flooding would have on regrowth characteristics. Post burn samples were collected in April 1981 and repeated quarterly through May 1983. A final post burn sawgrass collection was made 12 months later in May 1984. Each sawgrass study site was comprised of three separate stands with similar ground elevations. Density and biomass were determined from five randomly placed 1.0 m$^2$ quadrats within each stand. Open or sparsely vegetated areas were intentionally avoided to reduce variability. Within each quadrat, all live vegetation was clipped at ground level and culms removed. Where tussock growth was prevalent, only culms were removed. Maximum length, total number of live leaves and basal diameter of each culm was measured after removal of attached dead material. Above ground biomass for each quadrat was weighed after oven drying for 72 hours at 90° C. Tissue-nutrient analyses were made from representative samples of collected live culms. Samples were oven dried at 90°C for 72 hours, ground in a Wiley mill and analyzed for nitrogen, phosphorus, potassium, calcium, and magnesium. Samples for tissue nutrient analyses were prepared following methods outlined by Jackson (1958) and measured using Technicon AutoAnalyzer II. Cations were analyzed following digestion using a lithium metaborate fusion method (Medlin et al., 1969) and measured by Atomic Absorption Spectrophotometry.

Data Analysis

Species frequency was calculated as the number of quadrats in which a species occurred divided by the total number quadrats examined. Species mean percent cover was computed by summing the midpoints of each estimated cover class (T=.5, 1=3.0, 2=15.0, 3=37.5, 4=62.5, 5=85.0, 6=97.5) and dividing by total number of quadrats examined. Patterns in slough species abundance and cover associated with elevation gradients were also analyzed by computing soil elevations for each quadrat and pooling observations into .03 m (0.1 ft) classes. Species relative frequency at a given elevation was computed by summing the observations of each species within a specified elevation class divided by total frequency of that elevation class. Species mean cover within each elevation class was computed in a similar manner. Year to year changes in species frequency and cover were compared using Wilcoxon Signed Ranks Test after percentages were arcsine transformed.

Changes in community structure resulting from marsh drawdown were analyzed by comparing similarity coefficients for species composition and frequency. Between-year and within-site comparisons were made to gauge the relative magnitude and rate of change in the plant community structure. Jaccard's coefficient was used for comparing floristic composition and Czekanowski coefficient for frequency (Mueller-Dombois and Ellenberg, 1974). Both similarity measures range from 0 indicating no similarity, to 1.0 when community structure is identical. Czekanowski coefficient was also used to compare changes in species percent cover, and each species relative contribution to community density and biomass at slough sites. All proportions were arcsine transformed prior to statistical test.

Site differences in regrowth of burned sawgrass were compared using one and two-way analysis of variance (ANOVA). Environmental parameters were correlated with biological data using multiple regression analysis (BMDP Statistical Software; Dixon and Brown, 1983) after appropriate transformations of all variates.

## Results

### a. Sloughs

Hydrology

Sites differed in length of time marsh soils were exposed (number of days dry) and water depth when reflooded (Table 2). Water tables fell below ground at all sites during the first year drawdown (1981).

TABLE 2 SUMMARY OF HYDROLOGIC CONDITIONS CORRESPONDING TO EACH DRAWDOWN WATER YEAR AT SLOUGH SITES 1-3 IN WCA-2A, 1980-1984

| SITES | DRAWDOWN YEAR | AVG WATER DEPTH CM WHEN REFLOODED | TOTAL DAYS DRY | NUMBER OF DAYS FLOODED | NUMBER OF DAYS DEPTH ≥0.3m | NUMBER OF DAYS DEPTHS ≥0.6m | WATER TABLE DEPTH BELOW GROUND |
|---|---|---|---|---|---|---|---|
| 2A1 | 1981 * | 17.9 | 56 | 248 | 14 | 0 | 12.2 |
| elevation | 1982 ** | 27.1 | 54 | 311 | 103 | 17 | 18.3 |
| 11.5 NGVD | 1983 + | 36.6 | 0 | 365 | 207 | 35 | - |
| | 1984 # | 31.0 | 0 | 365 | 206 | 0 | - |
| 2A2 | 1981 | 32.3 | 60 | 244 | 152 | 9 | 6.1 |
| elevation | 1982 | 33.7 | 0 | 365 | 128 | 50 | - |
| 10.7 NGVD | 1983 | 50.2 | 0 | 365 | 214 | 87 | - |
| | 1984 | 36.3 | 0 | 365 | 229 | 8 | - |
| 2A3 | 1981 | 16.0 | 69 | 235 | 8 | 6 | 19.1 |
| elevation | 1982 | 39.4 | 36 | 329 | 158 | 65 | 19.1 |
| 10.1 NGVD | 1983 | 56.9 | 0 | 365 | 109 | 183 | - |
| | 1984 | 27.8 | 0 | 365 | 124 | 9 | - |

* Water year Nov. 1, 1980 to Aug. 31, 1981
** Water year Sept. 1, 1981 to Aug. 31, 1982
\+ Water year Sept. 1, 1982 to Aug. 31, 1983
\# Water year Sept. 1. 1983 to Aug. 31, 1984

However, soils remained saturated near the surface in the central marsh (2A2) where depth to water table was only 6.1 cm below average ground. Drawdown of the marsh during the second year (1982) was less successful with only the northern slough sites (2A1) exposed to drying. All slough sites remained flooded during the third (1983) and fourth (1984) drawdown attempts.

Changes in Community Structure

With the exception of biomass, community composition and structure was similar among slough transects prior to the drawdown (Table 3). Floating and submerged plants such as white water lily (Nymphaea odorata) and bladderwort (Utricularia spp.) were the dominant species. Together, they comprised more than 50% of the community standing crop at each of the slough transects. In contrast, emergent plant density and biomass was sparse, consisting primarily of water tolerant species such as Eleocharis elongata and Paspalidium paludivagum.

Drawdown reduced stem density and biomass components of slough communities but had no significant influence on species richness (Table 3a-c). Comparisons of similarity in species frequency, density, biomass, and composition within each site further showed that overall community structure was virtually unchanged in the northern (site 2A1) and central marsh (site 2A2) (Table 4). White water lily and bladderwort continued to be the most prevalent species and account for most of the community biomass (Table 3A and 3b). As a result, similarity in species frequency, biomass, and composition remained relatively high (indexes exceeded 0.6 for between-year comparisons). Similarity in species density at site 2A1 was lower reflecting a decline of Eleocharis elongata as the numerically abundant species and an increase of spikerush (Eleocharis cellulosa (Table 3a).

Greater changes were observed in the southern portion of the marsh (site 2A3). Although composition of the community remained stable (similarity index >0.8), between-year similarity in frequency and biomass was low reflecting the shift from a predominantly submergent open-water community to one dominated by spikerush and other emergents (Table 3c). As a result of these changes, between-site compar-isons in species frequency, density, and biomass were lower at the conclusion of the drawdown study (Table 4).

Species Distribution and Elevation Gradients

Because elevation and hydrology are inter-related, it was assumed that repeated drawdown might result in changes in the distribution and relative frequency of species at different soil elevations. Water tolerant species such as bladderwort and Eleocharis elongata declined in frequency throughout a wide range of elevations following the first year drawdown (Figure 8). Incomplete drawdown and wet conditions during subsequent years permitted these species to reestablish throughout much of their predrawdown range. Data from other slough sites, however, suggest the elevation range of highest cover for Eleocharis elongata shifted to lower elevations in 1984, corresponding with a reduction in water depths, (Figure 9). In contrast, bladderwort attained higher relative frequency and cover in 1983 when water depths were greater (Figures 9 and 10).

Conversely, white water lily and spikerush increased in distribution and frequency after drawdown (Figure 8). Increases in white water lily were attributed to germination of seedlings during low water conditions. Under the predrawdown regulation schedule (13.0-14.5 ft NGVD), water depths at slough elevations below 10.2 NGVD exceeded 1.2 m, limiting growth and distribution of this species. Increases in spikerush were due primarily to vegetative expansion by established plants, suggesting growing conditions improved with lower water levels. Increased growth was particularly evident at elevations below 11.0 ft NGVD. In this region of the marsh, 40-60% of the annual hydroperiod included water depths ranging between 0.3-0.6 m (Table 2). Combined data from other slough sites suggested both species maintained higher frequencies with increased elevation (Fig. 9).

**b. Tree Islands**

Hydrology

Hydrologic conditions varied greatly among the tree island transects due primarily to site differences in elevation (Table 5). With the exception of the first year drawdown, tree island 1 remained flooded more than 8 months annually. Water depths over this island also varied over a wider range due to its direct downstream proximity to S-10A. During high regulatory releases from WCA-1, inflows through S-10A are directed south along the east perimeter next to the L-36 levee. As a result, water levels rise quickly over tree island 1 and exceeded 1.0 meters during high inflow periods in June-July 1982 (drawdown year 2) and February-March 1983 (drawdown year 3). In contrast, tree island 3 remained dry and was flooded only during extreme events.

Changes in Community Structure and Elevation/ Hydrology Gradients

TABLE 3 a. VEGETATION CHARACTERISTICS OBSERVED AT WCA SLOUGH SITE 2A1 (elevation 11.55 ft msl); 1980-1984.

| | Frequency (%)* | | | | | Density (stems/m2)** | | | | | Biomass (g/m2)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-drawdown | Drawdown | | | | | | | | | | | | | |
| Vegetation Composition | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| Floating | | | | | | | | | | | | | | | |
| Nymphaea odorata | 47.1 | 56.9 | 80.4 | 94.0 | 100.0 | 17.2 | 17.6 | 25.2 | NOT SAMPLED | 18.4 | 40.0 | 7.9 | 40.0 | NOT SAMPLED | 15.6 |
| Submergent | | | | | | | | | | | | | | | |
| Utricularia spp. | 92.0 | 3.9 | 9.8 | 96.0 | 100.0 | ND | ND | ND | | ND | 13.5 | .1 | 0.2 | | 3.3 |
| Chara spp. | -- | 35.3 | 5.9 | 6.0 | 3.9 | -- | ND | ND | | ND | -- | 10.0 | 2.1 | | 0.1 |
| Emergent | | | | | | | | | | | | | | | |
| Cladium jamaicensis | 2.0 | 9.8 | -- | 2.0 | 7.8 | NR | NR | -- | | | NR | NR | -- | | NR |
| Dichromena colorata | -- | -- | 2.0 | -- | -- | -- | -- | NR | | -- | -- | NR | | | |
| Eleocharis cellulosa | 23.5 | 19.6 | 39.2 | 48.0 | 47.1 | 12.0 | 2.0 | 20.0 | | 17.2 | 3.0 | 0.6 | 3.2 | | 3.6 |
| Eleocharis elongata | 33.3 | 15.7 | 17.6 | 14.0 | 17.6 | 225.0 | 3.2 | 21.2 | | NR | 7.8 | .1 | 0.7 | | NR |
| Panicum hemitomon | -- | 2.0 | 2.0 | 2.0 | -- | -- | 0.8 | NR | | -- | -- | 0.1 | NR | | -- |
| Paspalidium paludivagum | 2.0 | 5.9 | 3.9 | 8.0 | 7.8 | 2.5 | NR | NR | | NR | 3.3 | NR | NR | | NR |
| Peltandra virginica | -- | -- | 2.0 | -- | -- | -- | -- | NR | | -- | -- | -- | NR | | -- |
| Polygonum hydropiperoides | --- | 2.0 | 2.0 | 2.0 | -- | -- | NR | | | -- | NR | NR | | | NR |
| Pontederia lanceolata | 2.0 | 2.0 | 3.9 | -- | -- | NR | NR | NR | | -- | NR | NR | NR | | NR |
| Sagittaria lancifolia | 2.0 | 2.0 | 2.0 | 4.0 | 2.0 | 4.0 | NR | NR | | NR | 1.7 | NR | NR | | NR |
| Rhyncospora tracyi | | PR | -- | -- | -- | | NR | -- | | -- | | NR | -- | | -- |
| Total/m² All Species | | | | | | 261.2 | 23.6 | 66.4 | | 35.6 | 69.3 | 18.7 | 65.0 | | 22.6 |
| Total # Species | 8 | 11 | 12 | 10 | 8 | | | | | | | | | | |
| Mean # Species/0.25m² | 2.0(a) | 2.2(a) | 1.8(a) | 2.8(a) | 2.2(a) | | | | | | | | | | |

TABLE 3 b. VEGETATION CHARACTERISTICS OBSERVED AT WCA SLOUGH SITE 2A2 (elevation 10.71 ft msl); 1980-1984 (con't.)

| | Frequency (%)* | | | | | Density (stems/m2)** | | | | | Biomass (g/m2)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-drawdown | Drawdown | | | | | | | | | | | | | |
| Vegetation Composition | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| Floating | | | | | | | | | | | | | | | |
| Nymphaea odorata | 54.9 | 66.7 | 68.6 | 72.5 | 64.7 | 11.0 | 14.4 | 15.6 | NOT SAMPLED | 13.2 | 30.4 | 8.4 | 24.9 | NOT SAMPLED | 8.7 |
| Submergent | | | | | | | | | | | | | | | |
| Utricularia spp. | 92.2 | 3.9 | 2.0 | 94.1 | 82.4 | ND | ND | ND | | ND | 18.0 | NR | 0.1 | | 2.0 |
| Chara spp. | -- | 47.1 | 23.5 | 49.0 | 25.5 | ND | ND | ND | | ND | -- | 1.1 | 3.5 | | 1.0 |
| Emergent | | | | | | | | | | | | | | | |
| Cladium jamaicensis | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | NR | NR | 0.8 | | NR | NR | NR | 2.9 | | NR |
| Eleocharis celluslosa | 7.8 | 5.9 | 7.8 | 23.5 | 15.7 | 2.5 | 3.6 | 1.6 | | 6.4 | 1.4 | 0.9 | 0.5 | | 2.2 |
| Eleocharis elongata | 23.5 | 19.6 | 27.4 | 31.4 | 23.5 | 53.0 | 35.2 | 87.2 | | 43.6 | 1.1 | 0.3 | 1.4 | | 0.5 |
| Paspalidium paludivagum | 7.8 | 9.8 | 11.8 | 5.9 | 11.8 | 0.5 | 0.4 | NR | | NR | 0.1 | 0.1 | 1.3 | | NR |
| Sagittaria lancifolia | 5.9 | 5.9 | 2.0 | -- | 2.0 | 2.0 | 4.0 | NR | | 6.0 | 0.8 | 1.2 | NR | | 2.8 |
| Total/m2 All Species | | | | | | 69.0 | 57.6 | 106.8 | | 69.2 | 51.8 | 12.0 | 34.6 | | 17.2 |
| Total # Species | 7 | 8 | 8 | 7 | 8 | | | | | | | | | | |
| Mean # Species/0.25m² | 1.9(a) | 2.1(a) | 1.6(a) | 2.8(a) | 2.3(a) | | | | | | | | | | |

Table 3 c. VEGETATION CHARACTERISTICS OBSERVED AT WCA SLOUGH SITE 2A3 (elevation 9.86 ft msl); 1980-1984 (con't).

| | Frequency (%)* | | | | | Density (stems/m2)** | | | | | Biomass (g/m2)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-drawdown | Drawdown | | | | | | | | | | | | | |
| Vegetation Composition | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| Floating | | | | | | | | | | | | | | | |
| Nymphaea odorata | 3.9 | 3.9 | 9.8 | 7.8 | 7.8 | 2.4 | 8.0 | 4.8 | NOT SAMPLED | NR | 1.5 | 5.8 | 1.8 | NOT SAMPLED | NR |
| Submergent | | | | | | | | | | | | | | | |
| Utricularia spp. | 94.1 | 2.0 | 41.2 | 56.9 | 2.0 | ND | ND | ND | | ND | 16.8 | .1 | 1.[illegible] | | |
| Chara spp. | -- | 92.2 | 25.5 | 13.7 | 23.5 | -- | ND | ND | | ND | -- | 13.8 | 5.6 | | 0.2 |
| Emergent | | | | | | | | | | | | | | | |
| Eleocharis cellulosa | 7.8 | 15.7 | 23.5 | 31.4 | 54.9 | NR | 5.2 | 3.2 | | 75.2 | NR | 1.9 | 1.4 | | 15.6 |
| Eleocharis elongata | 54.9 | 19.6 | 41.2 | 25.5 | 41.2 | 252.4 | 216.8 | 136.0 | | 67.6 | 4.5 | 2.2 | 3.7 | | 1.1 |
| Paspalidium paludivagum | 23.5 | 39.2 | 19.6 | 45.1 | 29.4 | 8.8 | 20.8 | 8.8 | | 4.0 | 10.5 | 20.4 | 5.0 | | 3.0 |
| Crinum americanum | | | | | 2.0 | | | | | | | | | | |
| Typha sp. | | | | | 2.0 | | | | | | | | | | |
| Total/m2 All Species | | | | | | 263.6 | 250.8 | 152.8 | | 146.8 | 33.3 | 44.1 | 19.4 | | 19.9 |
| Total # Species | 5 | 6 | 6 | 6 | 8 | | | | | | | | | | |
| Mean # Species/0.25m2 | 1.9(a) | 1.7(a) | 1.6(a) | 1.3(a) | 1.6(a) | | | | | | | | | | |

*Frequency of occurrence in 51 quadrats 0.25m²
**Estimate from 10 quadrats 0.25m²

(a) Means with the same letter were compared and found not significantly different (P. > 05)

NR = Species not represented in sample
ND = No data obtained

PR = Present but rare

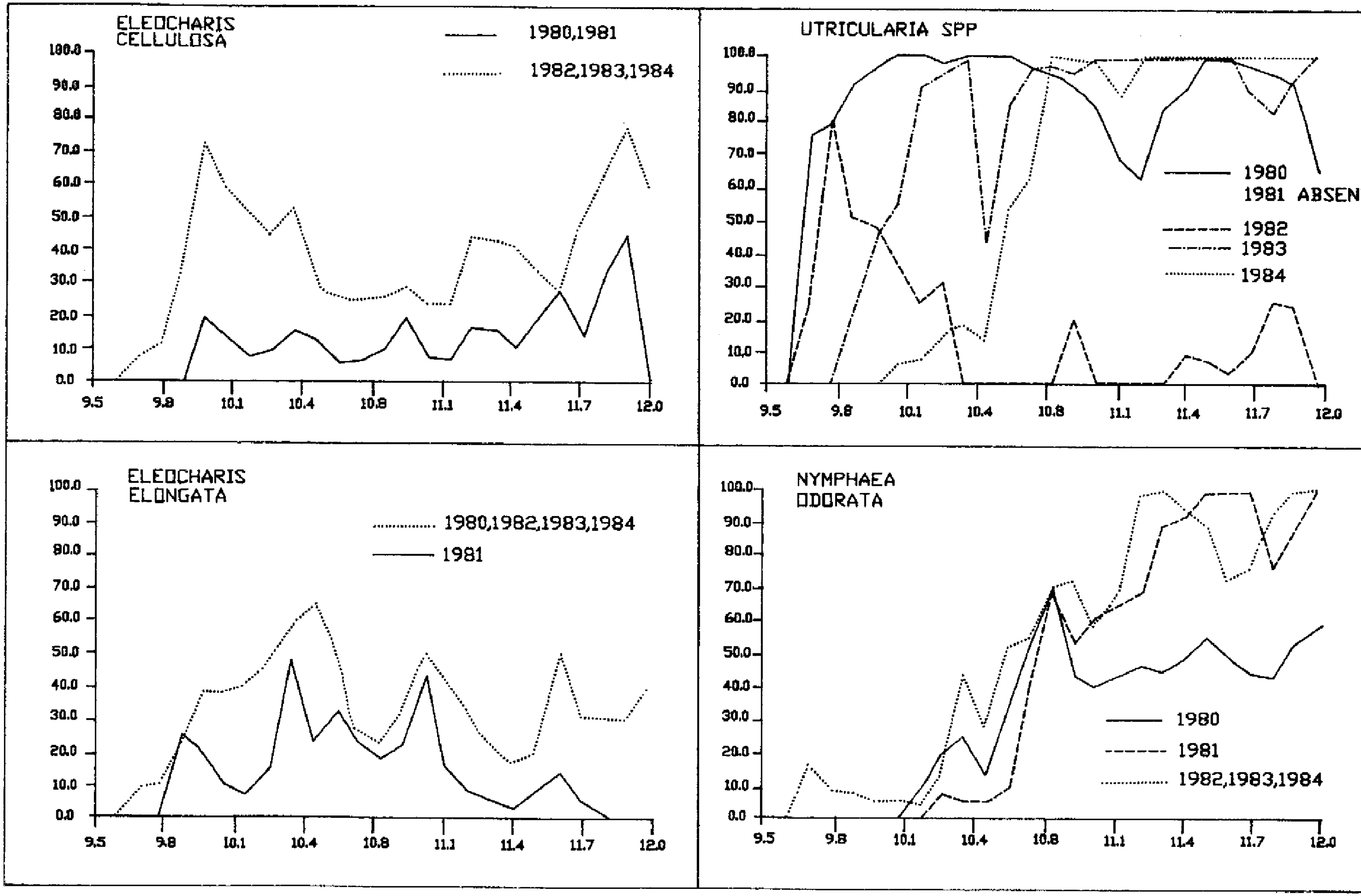



FIGURE 8. SPECIES RELATIVE FREQUENCY IN RELATION TO GROUND ELEVATION AT SLOUGH SITES 1-3 (POOLED). YEARS WITH SIMILAR TRENDS HAVE BEEN AVERAGED. TREND YEARS THAT WERE SIGNIFICANTLY DIFFERENT (BASED ON WILCOXON SIGNED RANKS TEST FOR PAIRED COMPARISONS) ARE GRAPHED SEPARATELY. (TRENDS FOR 1980 = PREDRAWDOWN, 1981 = DRAWDOWN YEAR 1, 1982 = DRAWDOWN YEAR 2, 1983 = DRAWDOWN YEAR 3, AND 1984 = DRAWDOWN YEAR 4).

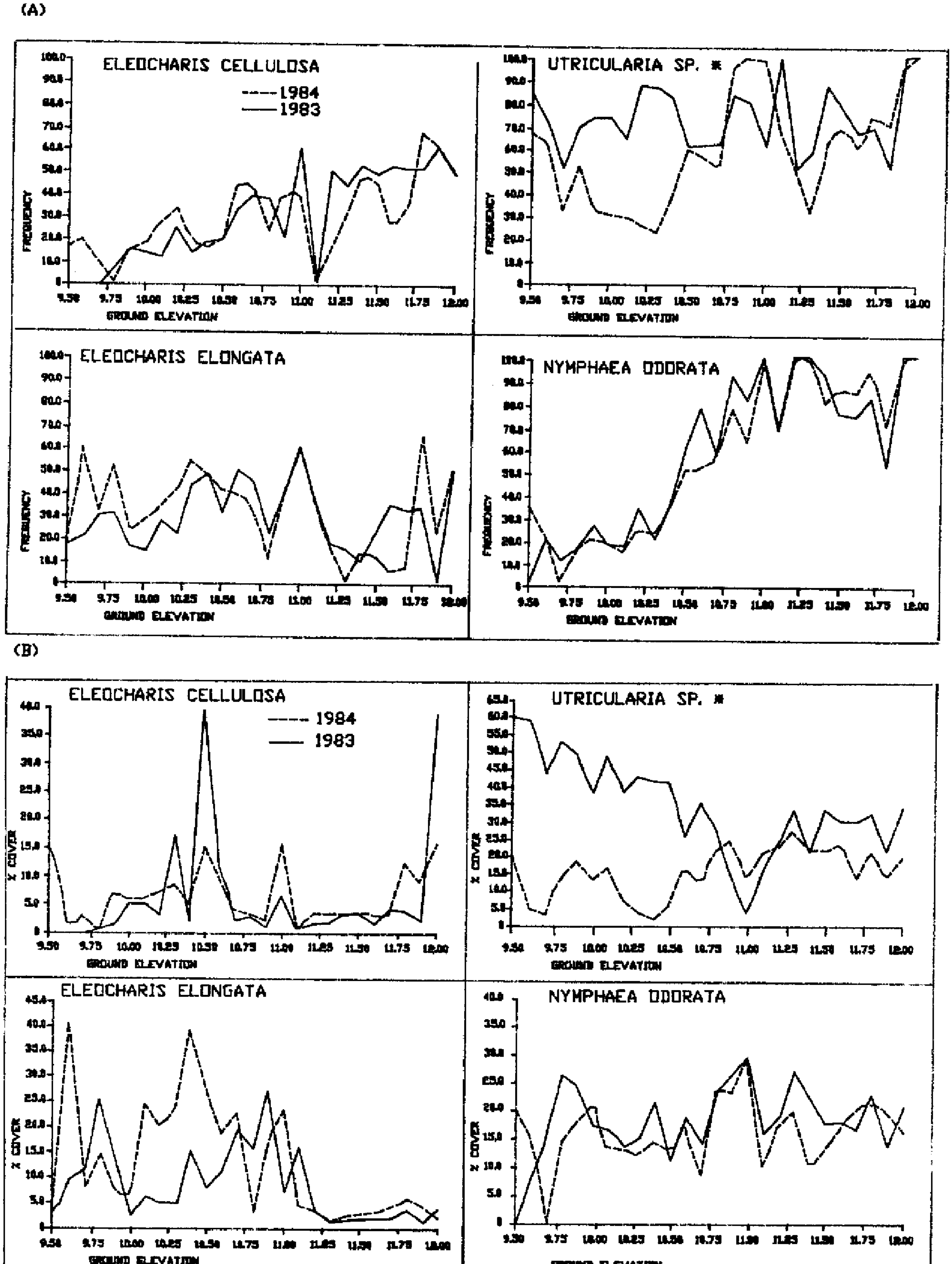



FIGURE 9. SPECIES RELATIVE FREQUENCY (A) AND MEAN COVER (B) IN RELATION TO GROUND ELEVATION, SLOUGH SITES 1-9, FOR 1983 AND 1984. TRENDS FOR 1983 = DRAWDOWN YEAR 3 AND 1984 = DRAWDOWN YEAR 4. * INDICATES TRENDS WERE SIGNIFICANTLY DIFFERENT (P>.05) BETWEEN YEARS (WILCOXON SIGNED RANKS TEST FOR PAIRED COMPARISONS).

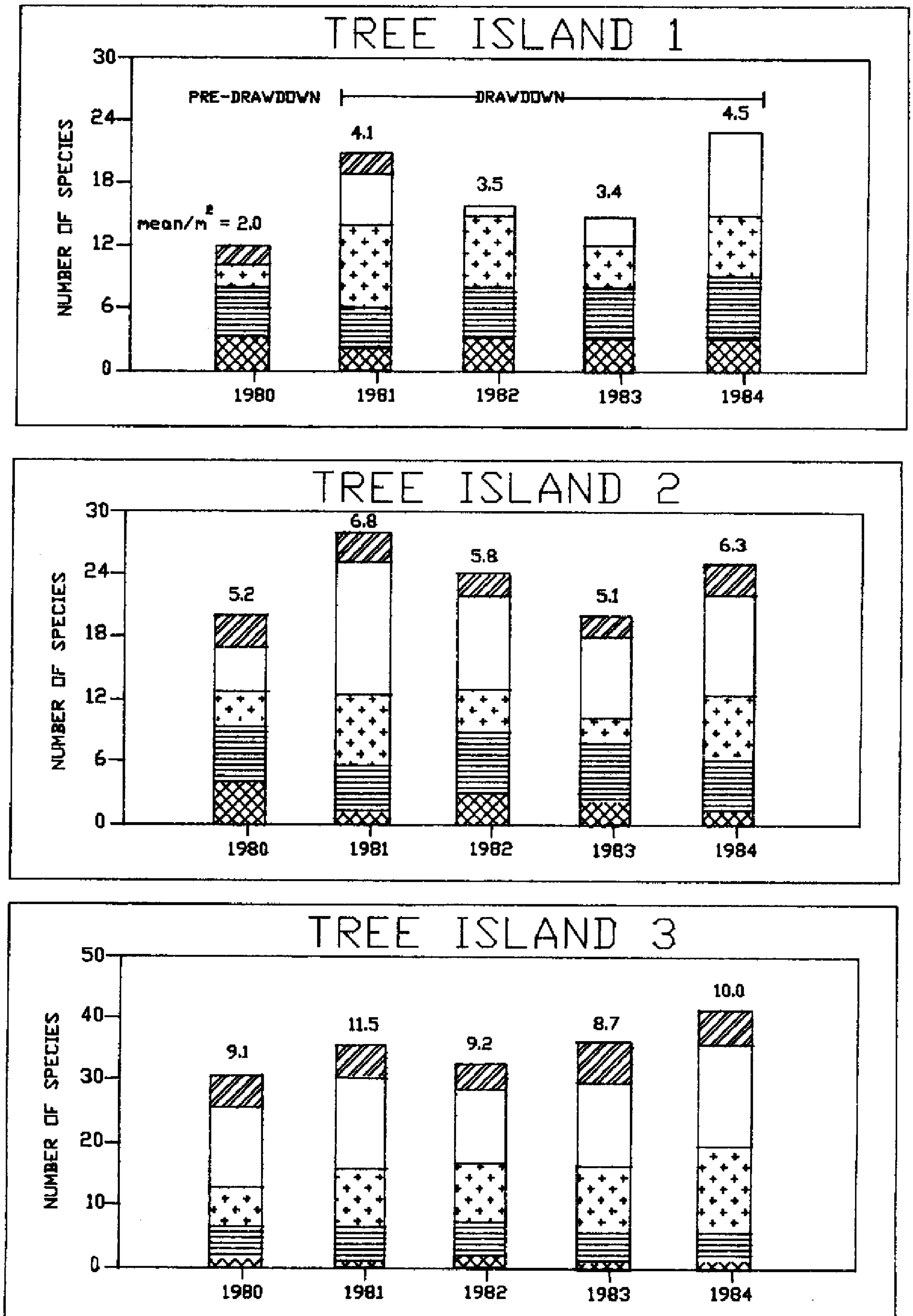



FIGURE 10. COMPARISON OF THE CHANGE IN SPECIES DIVERSITY OF PLANT GROUPS AT TREE ISLAND STUDY SITES 1-3 IN RESPONSE TO DRAWDOWN. 1980 = PRE-DRAWDOWN YEAR; 1981 = DRAWDOWN YEAR 1; 1982 = DRAWDOWN YEAR 2; 1983 = DRAWDOWN YEAR 3; 1984 = DRAWDOWN YEAR 4.

TABLE 4. COMPARISON OF SIMILARITY IN SPECIES FREQUENCY, DENSITY, AND BIOMASS AMONG AND WITHIN SLOUGH SITES 1-3, 1980-1984

| | | Between Sites (Within Years) | | | | |
|---|---|---|---|---|---|---|
| | | Pre-Drawdown | | Drawdown | | 1982 |
| Parameter | Year | 1980 | 1981 | 1982 | 1983 | 1984 |
| Frequency | | .772±.098 | .630±.219 | .549±.117 | .585±.199 | .529±.204 |
| Density* | | .852±.060 | .436±.241 | .576±.266 | | .286±.196 |
| Biomass* | | .551±.248 | .444±.129 | .433±.311 | | .361±.340 |
| Composition | | .738±.127 | .639±.127 | .583±.144 | .719±.130 | .756±.214 |

| | | Within Sites (Between Years:1980-1984) | | |
|---|---|---|---|---|
| Parameter | Sites: | 2A1 | 2A2 | 2A3 |
| Frequency | | .659±.152 | .729±.112 | .585±.135 |
| Density* | | .446±.226 | .845±.055 | .719±.240 |
| Biomass* | | .632±.151 | .696±.089 | .405±.201 |
| Composition | | .705±.117 | .900±.079 | .837±.128 |

*Comparisons were based on relative proportions (percent) of total community standing crop or density contributed by individual species.

TABLE 5. HYDROLOGIC CONDITIONS ASSOCIATED WITH TREE ISLAND SITES 1-3 IN WCA-2A, 1980-1984.

| SITE | DRAWDOWN YEAR | NUMBER DAYS FLOODED | AVG DEPTH CM WHEN FLOODED | NO DAYS DEPTHS 0.3 - 0.6 m | NO DAYS DEPTHS 0.6 - 0.9 m | NO DAYS DEPTHS >0.9m |
|---|---|---|---|---|---|---|
| 1 | 1981* | 65 | 10.7 | 0 | 0 | 0 |
| | 1982 ** | 217 | 24.7 | 77 | 8 | 1 |
| | 1983 + | 296 | 32.8 | 129 | 59 | 1 |
| | 1984 # | 236 | 21.5 | 59 | 0 | 0 |
| 2 | 1981 | 0 | 0.0 | 0 | 0 | 0 |
| | 1982 | 60 | 13.2 | 1 | 0 | 0 |
| | 1983 | 110 | 15.2 | 2 | 0 | 0 |
| | 1984 | 53 | 3.7 | 0 | 0 | 0 |
| 3 | 1981 | 0 | 0.0 | 0 | 0 | 0 |
| | 1982 | 8 | 7.0 | 0 | 0 | 0 |
| | 1983 | 36 | 5.6 | 0 | 0 | 0 |
| | 1984 | 0 | 0.0 | 0 | 0 | 0 |

* = Water year Nov 1, 1980 to Aug 31, 1981
** = Water year Sept 1, 1981 to Aug 31, 1982
+ = Water year Sept 1, 1982 to Aug 31, 1983
# = Water year Sept 1, 1983 to Aug 31, 1984

Appendix Table 2 lists the vegetation species composition, frequency and cover of tree island transects. Similarities in species frequency and composition among and within sites is summarized in Table 6. As expected, site similarity in species composition and frequency was low prior to the drawdown, reflecting large differences in the community structure between islands caused by prior flooding. Tree island 1 is dominated by cattail and had fewest number of species (14 compared with 22 at island 2 and 35 at island 3) and lowest species richness (average species/quadrat) compared with other tree island sites. Tree islands 2 and 3 had a greater number of species in common but each had distinctly different dominant ground cover, predominantly sawgrass at site 2 and ferns at site 3. Woody species composition also differed. Shrubs (Myrica cerifera and Cephalanthus occidentalis) account for a majority of the woody cover on tree island 2 while hardwood tree species (Ilex cassine) dominate the island interior at tree island 3.

Despite differences in elevation, tree islands responded similarly to changes in hydrology. Following the first year drawdown, a large number of new species were found at all sites (Appendix Table 2), causing average species richness to increase from 2.0 to 4.1/$m^2$, 5.2 to 6.8/$m^2$, and 9.1 to 11.5 $m^2$ at sites 1, 2, and 3, respectively. A majority of the new species were colonizing forbs and perennials consisting of sedges and grasses (Figure 10). Similarity between sites increased slightly with the influx of these species and the decline in frequency of aquatic species. Reflooding tree islands, particularly at sites 1 and 2, caused average and total species richness to decline. Reduced frequency of flooding in 1984 again produced an increase in species richness of grasses and forbs at these and other islands. This pattern of increase and decline in diversity of grasses and forbs was consistent, even among tree islands with widely different annual frequencies of flooding (Table 7).

Most permanent species (those present at the initial drawdown and retained after repeated drawdown and reflooding) showed no significant variation in annual frequency in response to changes in hydrology (Table 8). Of those species that varied significantly in frequency, most increased or decreased for a single year. This relative stability in annual species composition and frequency was reflected in high values of similarity (>.75) at tree islands 2 and 3. In contrast, within-site similarity at tree island 1 was lower due to high annual turnover in herbaceous species (Figure 11).

Annual variations in shrub frequency were not significant at any of the tree island sites monitored (G-Test, $P > .05$). A slight increase in buttonbush (Cephanathus occidentalis) was noted at tree island 1 together with an increase in canopy cover of willow (Salix caroliniana) following burning. Drier conditions at tree island 2 produced opposite effects causing a slight decline in buttonbush which increased again when moderate flooding resumed. Wax myrtle seedlings (Myrica cerifera) were found emerging at all sites during the first drawdown but were rare at tree island 1 and absent from this site during succeeding drawdown attempts. Seedling frequency of this species also declined when islands reflooded. Average change in woody cover was highest among predominately dry sites, suggesting growing conditions improved for islands above elevation 12.0 NGVD (Table 7).

TABLE 6. COMPARISON OF SIMILARITY IN SPECIES FREQUENCY, DENSITY, AND COMPOSITION AMONG AND WITHIN TREE ISLAND SITES, 1980-1984

| | | Between Sites (Within Years) | | | | |
|---|---|---|---|---|---|---|
| | | Pre-Drawdown | Drawdown | | | |
| Parameter | Year | 1980 | 1981 | 1982 | 1983 | 1984 |
| Frequency | | ..235±.141 | .240±.211 | .199±.194 | .270±.103 | .315±.167 |
| Floristic Composition | | .334±.143 | .360±.191 | .335±.188 | .323±.147 | .321±.156 |

| | | Within Sites (Between Years:1980-1984) | | |
|---|---|---|---|---|
| Parameter | Sites: | Tree-1 | Tree-2 | Tree-3 |
| Frequency | | .592±.075 | .787±.069 | .785±.059 |
| Floristic Composition | | .440±.094 | .637±.066 | .755±.057 |

TABLE 7 COMPARISON OF THE AVERAGE CHANGE IN WOODY SPECIES COVER AND SPECIES RICHNESS AMONG TREE ISLAND SITES SURVEYED IN 1983 and 1984.

| | Predominately Flooded Sites *(N=3) | | | Intermittently Dry (N=4) | | | Predominately Dry (N=5) | | |
|---|---|---|---|---|---|---|---|---|---|
| Woody Cover (Mean %) | 1983 | 1984 | Avg. Change | 1983 | 1984 | Avg. Change | 1983 | 1984 | Avg. Change |
| Ilex Cassine | | | | | | | + | + | |
| Myrica Cerifera | | | | 2.3 | 2.2 | .1 | 27.6 | 35.2 | 7.6 |
| Salix Caroliniana | 13.0 | 16.8 | 3.8 | 16.0 | 18.2 | 2.1 | + | 1.3 | 1.3 |
| Persea Borbonia | | | | | + | | 1.2 | 4.1 | 2.9 |
| Ceptalanthus Occidentalis | 30.1 | 31.5 | 1.4 | 21.2 | 22.9 | 1.7 | 1.4 | 3.8 | 2.4 |
| Baccharis spp. | | + | | | | | + | + | |
| Anona Glabia | | | | + | + | | | | |
| Total Shrub Cover | 43.1 | 48.3 | 5.2 | 39.5 | 43.3 | 3.9 | 30.2 | 44.4 | 14.2 |
| Ground Cover Species | | | | | | | | | |
| Mean Number Aquatic Species | 2.0 | 2.3 | 0.3 | 2.0 | 2.3 | 0.3 | 1.0 | 0.8 | 0.2 |
| Mean Number Paludol Herbs and Vines | 4.0 | 5.7 | 1.7 | 4.5 | 5.0 | 0.5 | 5.6 | 6.2 | 0.6 |
| Mean Number Sedges and Grasses | 2.7 | 3.0 | 0.3 | 1.0 | 2.0 | 1.0 | 2.2 | 4.6 | 2.4 |
| Mean Number Mesophytic Forbs | 2.7 | 5.0 | 2.3 | 2.5 | 5.5 | 3.0 | 7.4 | 9.2 | 1.8 |
| Mean Number Ferns | 0.7 | 0.7 | 0.0 | 1.0 | 1.5 | 0.5 | 2.8 | 2.6 | 0.2 |
| Mean Number Species | 12.1 | 16.7 | 4.6 | 11.0 | 16.3 | 5.3 | 19.0 | 23.4 | 5.2 |

*Relative frequency of flooding was inferred based on island location in relation to topographic slope of the marsh.
+Mean <.1%

TABLE 8. BETWEEN YEAR FREQUENCY COMPARISONS (G-Test) FOR PERMANENT SPECIES (see text) FOUND ALONG TREE ISLAND TRANSECTS 1-3. Note: Frequencies Followed by Same Letter were not Significantly Different (P=.05).

| | Tree Island 1 | | | | | Tree Island 2 | | | | | Tree Island 3 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 | 1980 | 1981 | 1982 | 1983 | 1984 |
| **Species** | | | | | | | | | | | | | | | |
| **Aquatics** | | | | | | | | | | | | | | | |
| Utricularia spp. | 13.7a | 0b | 3.9a | 3.9a | 9.8a | 32.7b | 0b | 3.8b | 2.0b | 0b | | | | | |
| **Herbs and Vines** | | | | | | | | | | | | | | | |
| Ipomoea sagittata | 2.0a | 2.0a | 0b | 3.9a | 5.9a | | | | | | | | | | |
| Mikania scandens | | | | | | 15.4a | 28.9a | 32.7a | 30.8a | 57.7b | | | | | |
| Peltandra virginica | | | | | | 59.6a | 21.2b | 61.5a | 42.3a | 48.1a | 56.0a | 82.0b | 100.0b | 90 | 92.0b |
| Sarcostemma clausa | 25.5a | 0b | 3.9b | 33.3a | 23.5a | 9.6a | 19.2a | 2.0b | 13.5a | 17.3a | 54.0a | 68.0a | 46.0a | 31.4b | 36.0b |
| **Sedges and Grasses** | | | | | | | | | | | | | | | |
| Dichromena colorata | | | | | | 2.0a | 23.1b | 1.0a | 2.0a | 7.7a | 24.0a | 24.0a | 4.0b | 22.0a | 28.0a |
| **Mesophytic Forbs** | | | | | | | | | | | | | | | |
| Boehmeria cylindrica | | | | | | 7.7a | 25.0b | 30.8b | 15.4a | 36.5b | 42.0a | 76.0b | 68.0b | 54.0b | 74.0b |
| Centella asiatica | | | | | | | 3.9a | 44.2b | 15.4a | 11.6a | 13.5a | | | | |
| Eupatorium capillifolium | | | | | | | | | | 10.0a | 40.0b | 10.0a | 1.0a | 4.0a | |
| Eupatorium colestinium | | | | | | | | | 10.0a | 24.0a | 14.0a | 4.0b | 10.0a | | |
| Vicia acutifolia | | | | | | | | | | | 18.0a | 18.0a | 0b | 8.0a | 8.0a |
| **Ferns** | | | | | | | | | | | | | | | |
| Blechnum serrulatum | | | | | | | | | | | 80.0a | 86.0a | 84.0a | 68.0b | 64.0b |
| **Shrubs and Trees** | | | | | | | | | | | | | | | |
| Myrica cerifera seedlings | | | | | | | | | | 28.0a | 60.0b | 10.0a | 6.0a | 20.0a | |
| Number Permanent Species Unchanged | | | 7 | | | | | 10 | | | | | 20 | | |
| Total Number Species Found Annually | 13 | 25 | 17 | 18 | 27 | 22 | 30 | 27 | 23 | 28 | 35 | 33 | 33 | 37 | 46 |

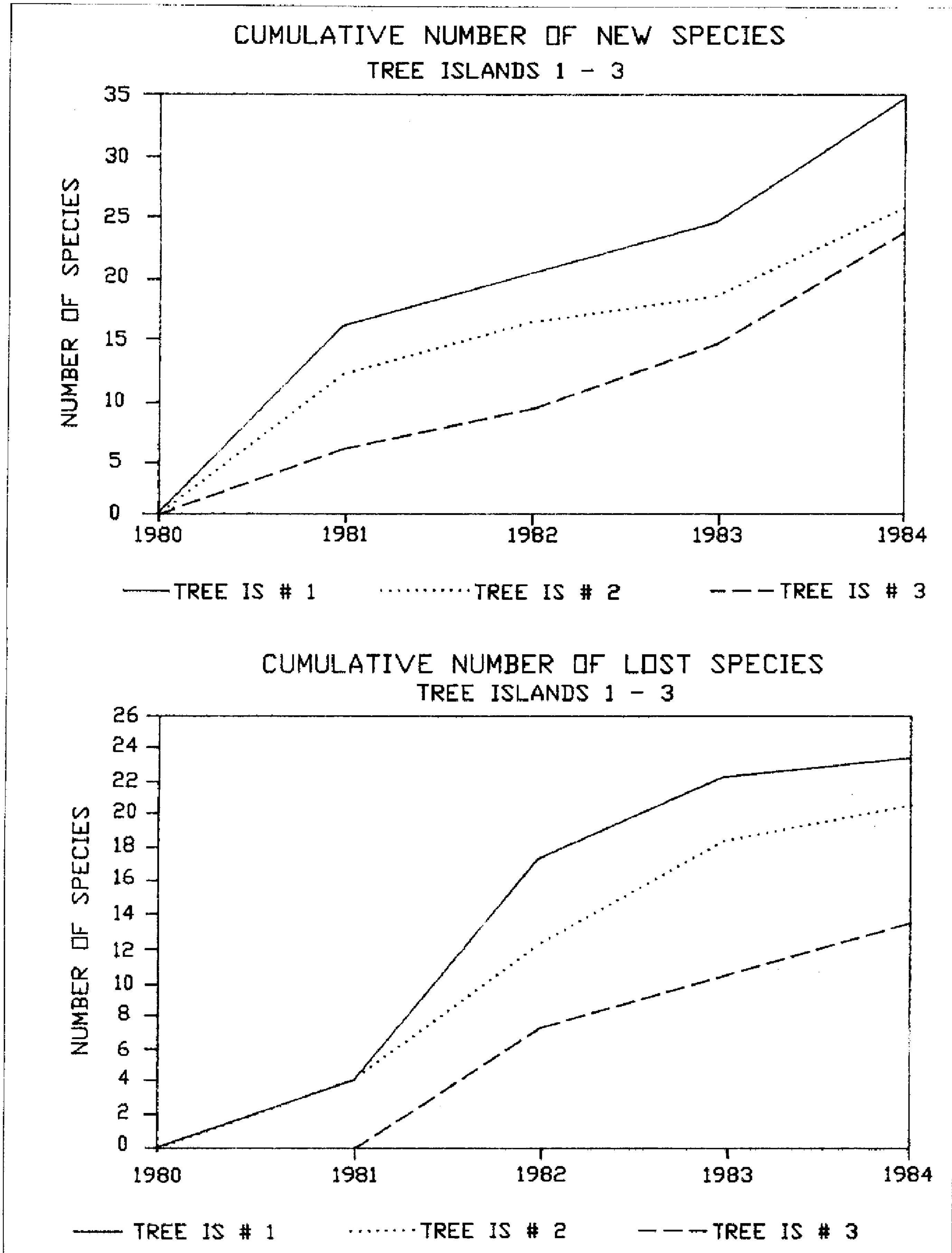



FIGURE 11. COMPARISON OF THE RATE OF SPECIES TURNOVER AMONG TREE ISLAND SITES 1-3 IN RESPONSE TO DRAWDOWN

## c. Sawgrass

### Site Hydrology

Water depth and duration of flood exposure varied between collection periods and among sites (Table 9). In general, water depth and duration of flooding increased with decreasing site elevation, however, some anomalies were apparent resulting from spatial differences in drainage and water surface slope. Large discharges during the initial drawdown (January-May 1981) rapidly removed water from the marsh surrounding the OLDG site resulting in slightly lower water depths and duration of flooding compared to stands with higher elevation at site RUBT. In contrast, the relative isolation from natural drainage flow ways (sloughs) and dense growth of sawgrass at the 159 G site occasionally resulted in

TABLE 9. HYDROLOGIC CONDITIONS ASSOCIATED WITH SAWGRASS SITES PRIOR TO SAMPLE COLLECTION.

| TIME PERIOD | SITE | AVG WATER DEPTH CM ABOVE GND | NO DAYS FLOODED | NO DAYS DEPTH > 0.3 M | NO DAYS DEPTH > 0.6 M | NO DAYS DEPTH > 0.9 M |
|---|---|---|---|---|---|---|
| 1-01-81 | 159G | 4.7 | 35 | 0 | 0 | 0 |
| TO | MELH | 10.9 | 62 | 0 | 0 | 0 |
| 4-30-81 | RUBT | 21.1 | 107 | 27 | 0 | 0 |
| | OLDG | 8.1 | 103 | 27 | 7 | 0 |
| 5-01-81 | 159G | 15.1 | 39 | 9 | 0 | 0 |
| TO | MELH | 22.9 | 47 | 15 | 0 | 0 |
| 8-31-81 | RUBT | 31.6 | 68 | 38 | 0 | 0 |
| | OLDG | 24.2 | 72 | 14 | 6 | 0 |
| 9-01-81 | 159G | 13.7 | 88 | 14 | 0 | 0 |
| TO | MELH | 15.3 | 105 | 15 | 0 | 0 |
| 12-31-81 | RUBT | 12.9 | 122 | 55 | 0 | 0 |
| | OLDG | 52.0 | 122 | 122 | 33 | 0 |
| 1-01-82 | 159G | 8.5 | 3 | 0 | 0 | 0 |
| TO | MELH | 0.0 | 0 | 0 | 0 | 0 |
| 4-31-82 | RUBT | 7.3 | 118 | 0 | 0 | 0 |
| | OLDG | 17.3 | 89 | 14 | 0 | 0 |
| 5-01-82 | 159G | 23.6 | 123 | 39 | 0 | 0 |
| TO | MELH | 24.0 | 97 | 39 | 4 | 0 |
| 8-31-82 | RUBT | 31.6 | 68 | 38 | 0 | 0 |
| | OLDG | 43.2 | 118 | 87 | 32 | 0 |
| 9-01-82 | 159G | 16.0 | 115 | 9 | 0 | 0 |
| TO | MELH | 17.3 | 97 | 17 | 0 | 0 |
| 12-31-82 | RUBT | 31.9 | 122 | 63 | 7 | 0 |
| | OLDG | 52.0 | 122 | 122 | 33 | 0 |
| 1-01-83 | 159G | 29.6 | 120 | 60 | 0 | 0 |
| TO | MELH | 48.4 | 97 | 71 | 45 | 0 |
| 4-30-83 | RUBT | 56.8 | 120 | 88 | 63 | 10 |
| | OLDG | 71.8 | 120 | 84 | 72 | 59 |
| 5-01-83 | 159G | 14.6 | 365 | 6 | 0 | 0 |
| TO | MELH | 14.1 | 316 | 20 | 0 | 0 |
| 4-30-84 | RUBT | 30.7 | 365 | 172 | 0 | 0 |
| | OLDG | 37.8 | 365 | 212 | 44 | 0 |

slightly longer durations of flooding than stands near MELH with lower soil elevations.

## Culm Regrowth

Culm density and biomass increased steadily during the late spring and summer following burning and then declined, reaching stable levels approximately 28 months after the initial burn (Figure 12). Density comparisons between sites were significantly different (ANOVA; $P>.05$) when first examined after the initial burn (May 1981) and remained different throughout the subsequent collections. Seedling emergence accounted for a large percentage of total density at sites MELH (mean = 7%) and OLDG (mean = 27%) following the first drawdown (Worth, 1983). Seedlings were later drowned when the marsh reflooded causing densities to decline slightly and were not observed during subsequent drawdown attempts due to inadequate drying. Culm density was greatest at the 159G site and remained high, compared to other sites, throughout the four draw-down years. This site was generally subject to less frequent flooding and lower water depths prior to the initial drawdown as well as during the drawdown years.

Standing crop biomass was also significantly different (ANOVA: $P>.05$) among sites following burning. Differences were attributed to site variations in density and size (length and diameter) of culms, which persisted throughout the first year of regrowth. Biomass differences among sites were not significant in December 1981 or May 1982 due to extreme variability in the quantity of biomass measured among replicate stands. Later, in May 1984, site differences were again significant.

In contrast, changes in tissue nutrient concentrations during culm regrowth were similar among sites and over time (2 way ANOVA, $P>.05$; Table 10). Tissue N and P was highest shortly after burning (May, 1981), but declined as stands matured, similar to results described by Steward and Ornes (1975). Cations K, Mg, and Ca were also initially found in high concentration, declined quickly then remained relatively stable throughout the remaining collection periods. While mean cation concentrations at each site were not significantly different, site differences in mean K concentrations appeared to increase in August 1982 and persist throughout the remainder of the study.

TABLE 10. TISSUE NUTRIENT AND CATION CONCENTRATIONS (% WEIGHT) MEASURED IN SAWGRASS CULMS

| SITES | | MAY 81 | AUG 81 | DEC 81 | MAY 82 | AUG 82 | DEC 82 | MAY 83 | MAY 84 |
|---|---|---|---|---|---|---|---|---|---|
| 159G | N | 1.00 | 0.93 | 0.68 | 0.97 | 0.69 | 0.64 | 0.77 | .65 |
| | P | .035 | .022 | .019 | .024 | .024 | .021 | .021 | .018 |
| | K | .99 | .68 | .51 | .45 | .60 | .62 | .56 | .64 |
| | Ca | .24 | .26 | .10 | .17 | .20 | .14 | .11 | .18 |
| | Mg | .06 | .08 | .05 | .05 | .06 | .06 | .06 | .06 |
| MELH | N | 1.22 | - | 0.87 | 0.81 | 0.85 | 0.62 | 0.71 | .68 |
| | P | 0.43 | - | .023 | .025 | .033 | .025 | .029 | .029 |
| | K | 1.20 | - | .57 | .45 | .74 | .63 | .73 | .66 |
| | CA | .27 | - | .12 | .09 | .18 | .14 | .15 | .17 |
| | Mg | .09 | - | .05 | .03 | .08 | .06 | .08 | .07 |
| RUBT | N | 1.25 | .80 | .82 | .78 | .79 | .66 | .67 | .58 |
| | P | .040 | .021 | .021 | .020 | .028 | .023 | .022 | .022 |
| | K | 1.04 | .54 | .50 | .41 | .47 | .53 | .63 | [illegible] |
| | Ca | .25 | .20 | .09 | .07 | .18 | .11 | .20 | .12 |
| | Mg | .08 | .07 | .04 | .02 | .08 | .06 | .08 | .06 |
| OLDG | N | 1.09 | - | .52 | .73 | .66 | .71 | .73 | .63 |
| | P | .037 | - | .021 | .020 | .027 | .022 | .024 | .025 |
| | K | .99 | - | .51 | .40 | .47 | .55 | .71 | .49 |
| | Ca | .27 | - | .09 | .11 | .16 | .13 | .15 | .22 |
| | Mg | .10 | - | .04 | .04 | .06 | .06 | .08 | .08 |

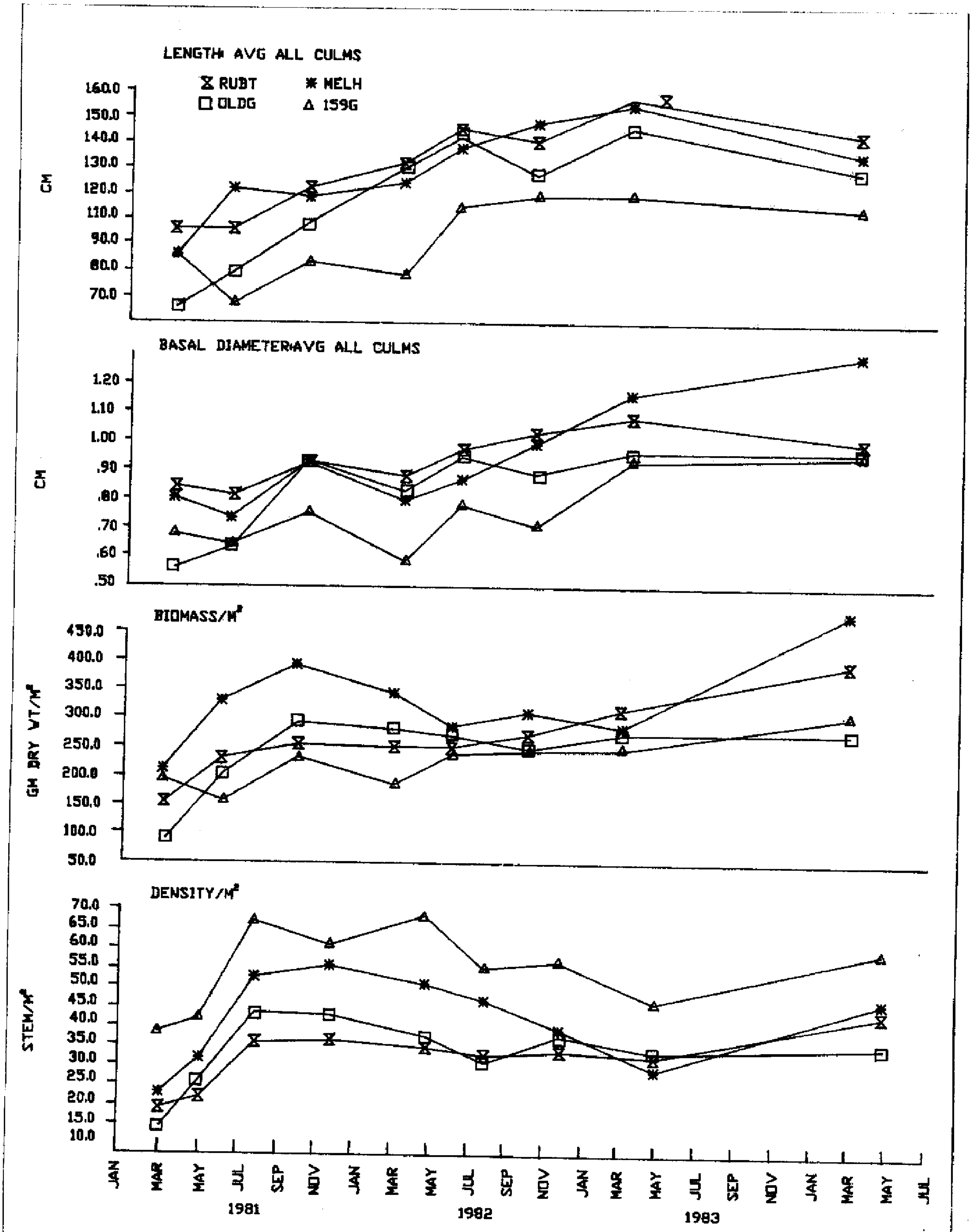



FIGURE 12. REGROWTH CHARACTERISTICS OF BURNED SAWGRASS IN WCA-2A: MARCH 1981 - MAY 1984. ALL SITES INITIALLY BURNED IN WINTER 1980.

Growth Characteristics and Elevation/Hydrology Gradients

Despite apparent site differences in culm growth, site hydrology was not as significant an influence on rates of regrowth as expected. Percentage increase or decrease in density, biomass, culm height and basal width was not significantly different among sites, but the rate of change varied significantly with time (2-way ANOVA, $P > .05$). Multiple regression analysis relating hydrologic characteristics over time with biological data (sites pooled) showed changes in the rate of stand regrowth were only weakly correlated with local hydrologic conditions. Of the hydrologic variables considered, a slight negative correlation was found between percent change in culm density and maximum water depth while a slight positive correlation was found between percent increase in culm width and both minimum and maximum water depth (Table 11).

Comparing size distributions of culms indicate local hydrology may exert a stronger influence on culm regrowth than the above correlations suggest. Histograms of culm height and width show significant size differences quickly develop as culms mature (Figure 13). The proportion of young culms (height <60 cm and basal width <40 cm) present in populations at each site was similar (ANOVA, $P > .05$), although the proportion declined over time (Table 12). In contrast, the proportion of culms reaching larger size classes (Table 13) varied significantly among sites ($P > .05$). Pairwise comparisons showed sites MELH, RUBT, and OLDG contained significantly greater ($P > .05$) numbers of larger culms and generally experienced longer periods of flooding compared to site 159G. Results indicate that while site differences in water depth and hydroperiod had little influence on rates of new culm production, local hydrology appeared to significantly influence the number of culms maturing to larger size classes. Thus, increasing water depths and longer hydroperiods reduce culm survival and at the same time stimulate more robust culm development.

## SECTION III: WATER QUALITY AND SOILS

### Methods and Materials

Surface water samples were collected at approximately six week intervals from February 1980 to February 1984 at 21 interior marsh stations Collection techniques and analytical methods are outlined by Millar (1981). Parameters monitored included the following:

| Nutrients | Ions | Other Quality Measures |
|---|---|---|
| Total Nitrogen | K | Alkalinity |
| Total Kjeldahl Nitrogen | Ca | Hardness |
| NH4 | Mg | Conductivity |
| NO3 | Cl | Color |
| o-PO4 | $SO_4$ | $T\text{-}PO_4$ |

Nutrient budgets were calculated for each drawdown year (September to August) based on procedure also outlined in Millar (1981). Budgets are based on water samples collected upstream from inflow (S-10A, 10C, 10D, and S-7) and outflow (S-11A, 11B, 11C, S-38) structures at two week intervals during periods of operation. Rainfall nutrient (nitrogen and phosphorus) and chloride contributions were based on total weighted rainfall amounts recorded in WCA-2A.

TABLE 11. REGRESSION OF THE PERCENT CHANGE IN SAWGRASS GROWTH PARAMETERS WITH HYDROLOGIC ENVIRONMENTAL VARIABLES. ALL DATA TRANSFORMED PRIOR TO ANALYSIS.

| | | SIMPLE CORRELATION COEFFICIENT | | | | | | |
|---|---|---|---|---|---|---|---|---|
| PARAMETER | MULTIPLE $r^2$ | Avg. Water Depth | Max. WATER Depth | Min, Water Depth | Total Days Flooded | No. Days Depth >0.3 FT | No. Days Depth >0.6 FT | No. Days Depth >0.9 FT |
| Density | .303 | -.329 | -.391* | -.251 | .117 | -.226 | -.274 | -.251 |
| Biomass | .189 | -.029 | -.018 | .067 | .267 | -.014 | -.136 | -.085 |
| Culm Height | .264 | .190 | .197 | .210 | -.243 | -.044 | -.011 | .129 |
| Culm Basal Width | .250 | .375 | .402* | .466* | .179 | .288 | .225 | .119 |

*Regression is significant at $P > .05$.

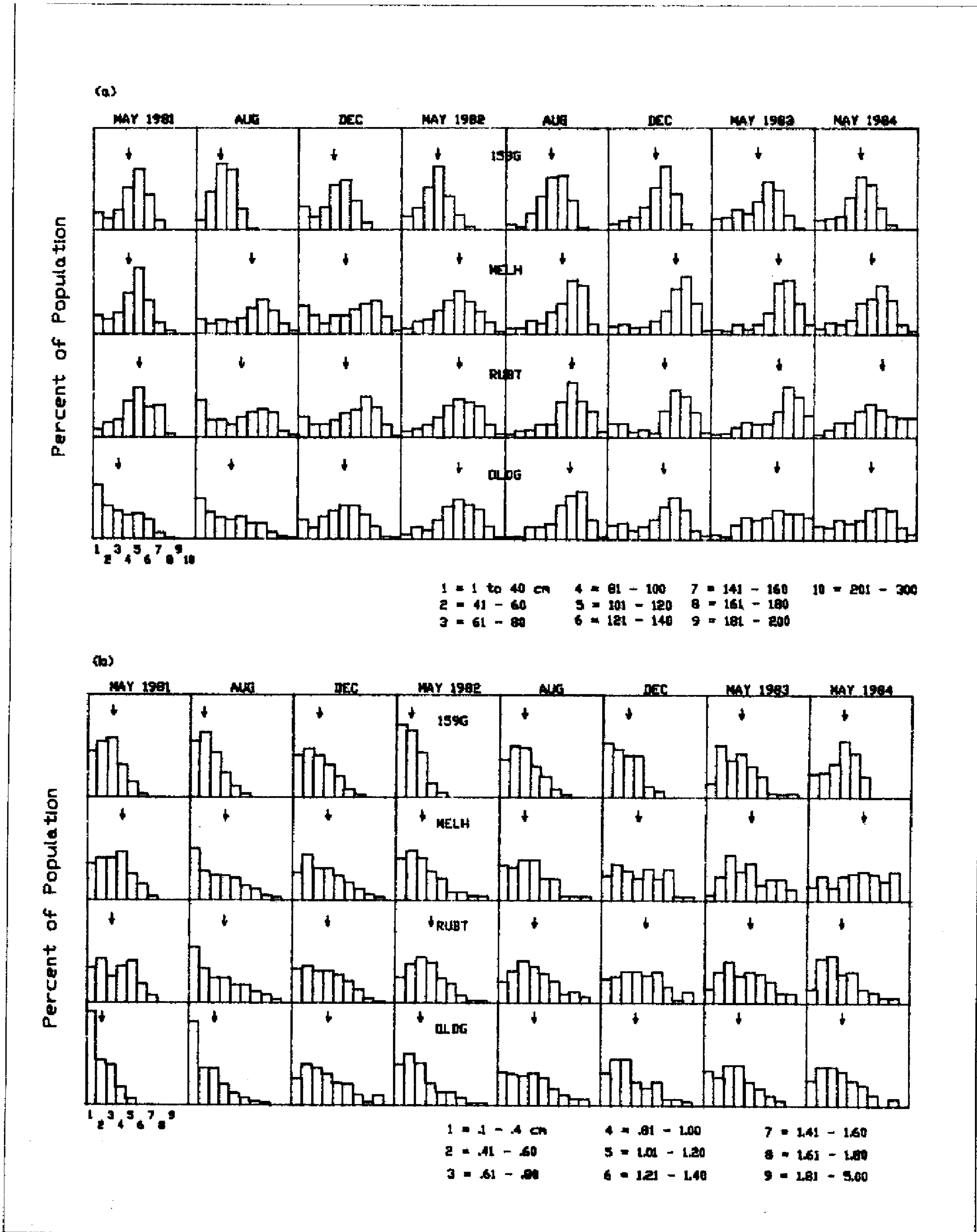



FIGURE 13. FREQUENCY DISTRIBUTION OF CULM HEIGHT (a) AND BASAL DIAMETERS (b) OBSERVED AT BURNED SAWGRASS SITES DURING REGROWTH. ALL SITES INITIALLY BURNED LATE 1980. ARROW INDICATES MEAN CLASS.

TABLE 12. COMPARISON OF THE PERCENTAGE OF YOUNG AND LARGER SIZE CULMS FOUND AT EACH SITE BASED ON HISTOGRAM DISTRIBUTIONS OF CULM BASAL WIDTH AND HEIGHT.

**CULM BASAL WIDTH**

| | 159G | | MELH | | RUBT | | OLDG | |
|---|---|---|---|---|---|---|---|---|
| | New Culms* | Mature Culms** | New Culms | Mature Culms | New Culms | Mature Culms | New Culms | Mature Culms |
| May 81 | 22.4 | 0 | 17.5 | 2.3 | 16.2 | 3.9 | 44.8 | 0 |
| Aug | 27.2 | .3 | 34.9 | 8.6 | 28.7 | 10.8 | 40.8 | 3.5 |
| Dec | 22.0 | 2.5 | 14.1 | 12.3 | 16.7 | 11.5 | 13.9 | 12.6 |
| May 82 | 36.0 | .1 | 20.8 | 5.5 | 12.3 | 5.2 | 20.1 | 7.3 |
| Aug | 18.8 | 2.1 | 18.7 | 4.6 | 10.0 | 10.3 | 17.6 | 12.1 |
| Dec | 28.0 | 0 | 12.0 | 17.0 | 12.0 | 14.0 | 16.0 | 8.0 |
| May 83 | 7.0 | 5.0 | 3.0 | 24.0 | 7.0 | 17.0 | 17.0 | 11.0 |
| May 84 | 11.0 | 0 | 7.1 | 36.0 | 8.0 | 12.0 | 13.0 | 9.0 |

**CULM LENGTH**

| | 159G | | MELH | | RUBT | | OLDG | |
|---|---|---|---|---|---|---|---|---|
| | New Culms+ | Mature Culms++ | New Culms | Mature Culms | New Culms | Mature Culms | New Culms | Mature Culms |
| May 81 | 16.2 | .5 | 16.5 | 1.0 | 12.9 | 2.9 | 44.0 | 1.3 |
| Aug | 24.1 | 0 | 12.3 | 19.0 | 27.3 | 19.4 | 32.6 | 8.3 |
| Dec | 18.8 | .5 | 22.8 | 26.0 | 16.3 | 22.3 | 16.6 | 11.6 |
| May 82 | 18.8 | .2 | 8.8 | 17.6 | 6.8 | 24.7 | 8.4 | 22.5 |
| Aug | 6.7 | 2.0 | 6.2 | 30.1 | 5.2 | 33.6 | 4.6 | 36.4 |
| Dec | 8.8 | 3.5 | 8.6 | 44.2 | 13.8 | 36.8 | 16.2 | 23.2 |
| May 83 | 12.2 | 8.5 | 3.9 | 47.5 | 3.2 | 55.8 | 5.2 | 39.9 |
| May 84 | 11.4 | 3.0 | 8.5 | 22.7 | 5.8 | 33.0 | 14.2 | 25.8 |

*Percent population with a culm basal width $\leq$.40 cm diameter.
**Percent population with a culm basal width $\geq$1.4 cm diameter.
+Percent population with culm height $\leq$60 cm.
++Percent population with culm height $\geq$161 cm.

Rainfall water quality was obtained from a collection station located at District headquarters in West Palm Beach, Florida.

Replicate (2-6) soil cores were collected from each vegetation study site following each marsh drawdown and reflooding. Cores were collected to a depth of 20 cm with an aluminum cylindrical tube 7.5 cm in diameter. Following colletion, all samples were immediately iced in the field and frozen until analyzed. Samples were oven dried and ground in a Wiley Mill until the entire sample passed through a #10 mesh sieve (U.S. Standard Sieve Series). Aliquot subsamples were further ground until 5 gm were obtained after passing through a #35 mesh sieve. Nutrients (N and P) and cations (K, Ca, and Mg) were measured according to procedures outlined for sawgrass tissue analysis.

Multivariate statistical treatments (Discriminant analysis) were used to analyze soil and water chemistry results (BMDP Statistical Software; Dixon and Brown, 1983). All data were transformed prior to analysis.

## Results

### a. Water Quality - Spatial and Temporal Patterns

With the exception of sites located in close proximity to major structure inflows (S-10A, B, C and S-7), areal trends in marsh water quality remained consistent throughout the repeated drawdown. Discriminant function analysis identified five water quality variables (Mg, Total N, Total P, $NO_3$ and $PO_4$) that were important in separating impacted from interior and peripheral marsh sites (Figure 15).

TABLE 13. AVERAGE SOIL CHEMISTRY OF TREE ISLAND, SAWGRASS, AND SLOUGH SITES PRIOR TO THE DRAWDOWN AND FOLLOWING EACH MARSH DRAWDOWN AND REFLOODING EVENT. CONCENTRATIONS BASED ON PERCENTAGE WEIGHT OF SAMPLES. ANOVA (F VALUES) TEST IS FOR SIGNIFICANT DIFFERENCES IN SOIL CHEMISTRY AMONG EVENTS.

| | | Pre-Drawdown *(Fall 1980)* | Draw-down 1 *(Summer 1981)* | Reflood-1 *(Fall 1981)* | Draw-down 2 *(Spring 1982)* | Reflood-2 *(Fall 1982)* | Draw-down 3 *(Winter 1982)* | Reflood-3 *(Summer 1983)* | Draw-down 4 *(Summer 1984)* | ANOVA* Among Events |
|---|---|---|---|---|---|---|---|---|---|---|
| **Tree Island** | | | | | | | | | | |
| | N | 2.654 | 2.700 | 3.083 | 2.704 | | 2.886 | 3.078 | 2.946 | 5.680*** |
| | P | .036 | .057 | .060 | .045 | | .040 | .047 | .049 | 5.088 *** |
| | Mg | .361 | .392 | .368 | .365 | | .362 | .391 | .409 | .858 NS |
| | Ca | 3.420 | 2.881 | 3.512 | 3.570 | | 3.642 | 3.629 | 3.804 | 2.554 NS |
| | K | .051 | .036 | .074 | .068 | | .014 | .025 | .021 | 129.944 *** |
| **Sawgrass** | | | | | | | | | | |
| | N | 2.796 | 2.604 | 2.963 | 2.676 | 2.592 | 2.965 | 3.322 | 2.873 | 10.859 *** |
| | P | .033 | .029 | .027 | .033 | .031 | .029 | .032 | .036 | 3.567** |
| | Mg | .334 | .286 | .349 | .379 | .277 | .359 | .368 | .534 | 13.494 *** |
| | Ca | 2.051 | 1.689 | 1.868 | 2.658 | 2.430 | 2.743 | 3.138 | 3.139 | 43.585** |
| | K | .075 | .046 | .084 | .089 | .063 | .020 | .044 | .033 | 112.936 *** |
| **Slough** | | | | | | | | | | |
| | N | 2.991 | 3.381 | 3.613 | 2.868 | 3.784 | 3.469 | 3.417 | 3.151 | 6.167*** |
| | P | .020 | .025 | .027 | .033 | .029 | .023 | .022 | .024 | 5.974 *** |
| | Mg | .222 | .246 | .271 | .235 | .259 | .241 | .266 | .267 | 2.448 NS |
| | Ca | 1.816 | 3.211 | 2.443 | 3.751 | 2.617 | 2.105 | 2.953 | 3.008 | 3.899 *** |
| | K | .075 | .050 | .091 | .078 | .089 | .021 | .053 | .048 | 65.879 *** |

*All parameters transformed prior to analysis; * Significant at P= >.05, **Significant at P= >.01, ***Significant at P= >.001

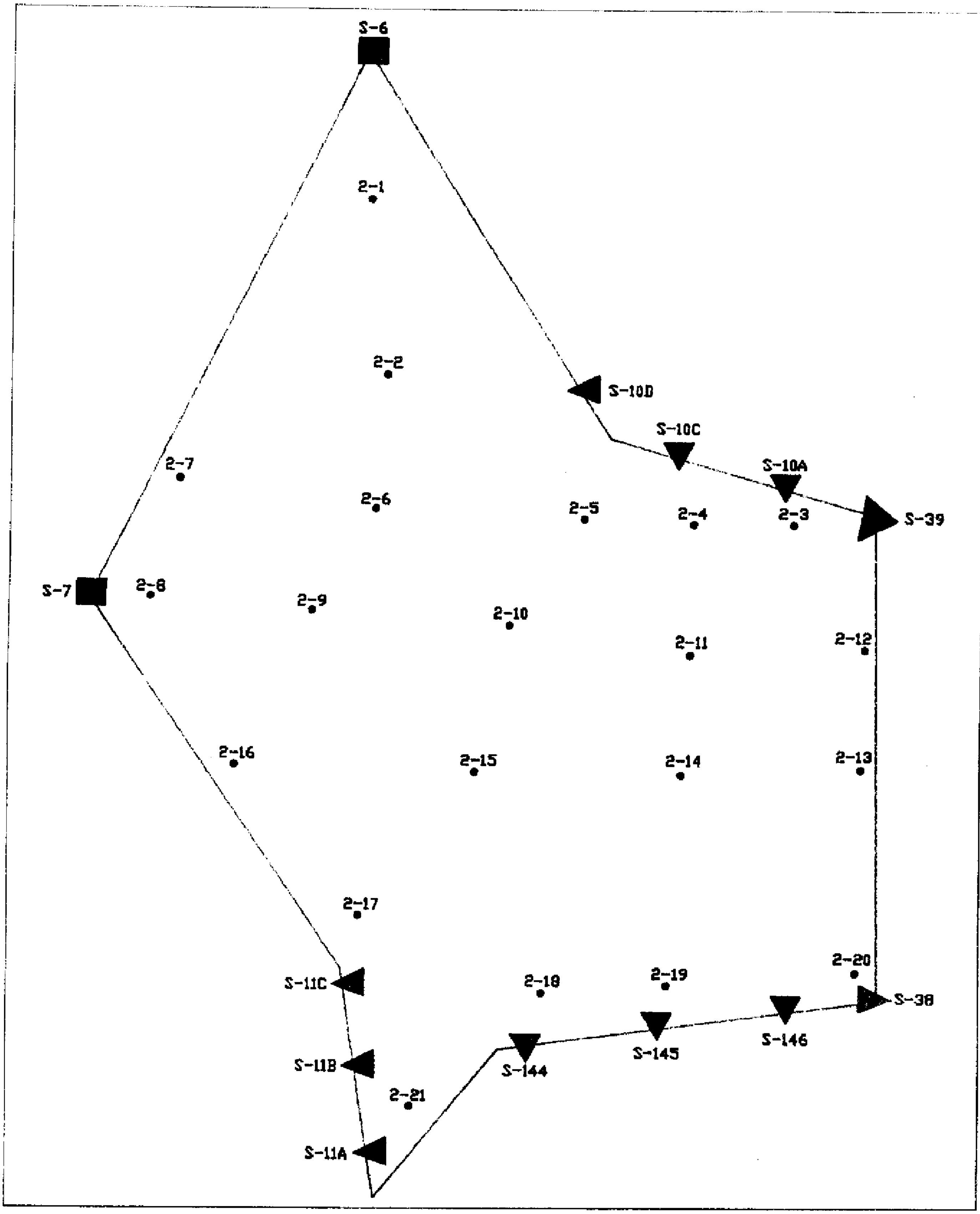



FIGURE 14. MAJOR INFLOW AND OUTFLOW STRUCTURES OF WCA-2A AND INTERIOR WATER QUALITY SAMPLING SITES

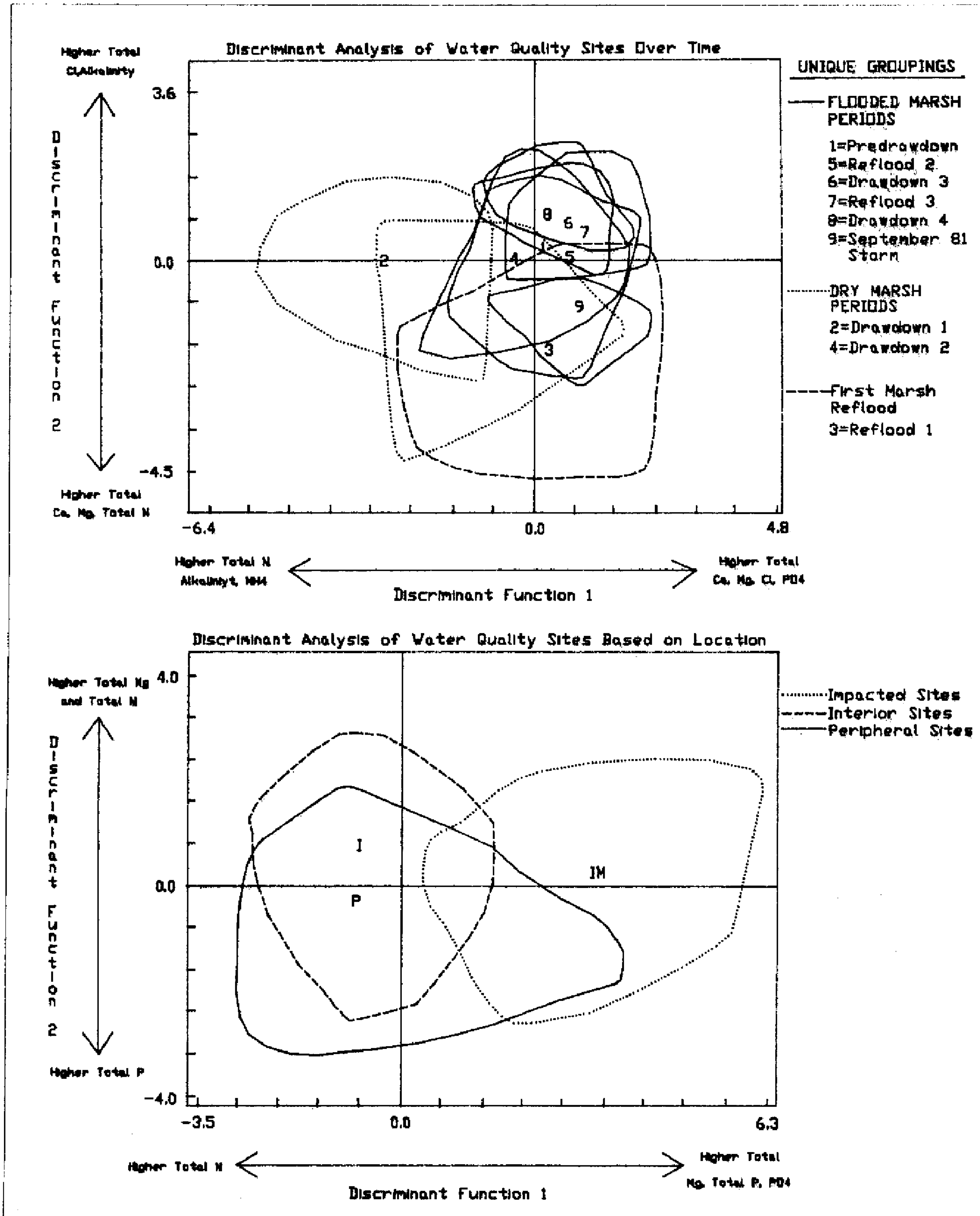



FIGURE 15. RESULTS OF DISCRIMINATE ANALYSIS COMPARING WATER QUALITY AMONG SITES AND DRAWDOWN-REFLOODING EVENTS.
(NOTE: Lines enclosing the scatter of samples correspond to each designated group identified in the legend. Position of numbers and letters identify the centroid of the sample scatter).

Impacted sites (those adjacent to structure inflows; sites 3-5 and 8) generally had highest concentrations of nitrogen (total N and nitrate) and phosphorus (total P and ortho-P). Interior sites (those located in the marsh interior that drain slowly and remained wet; sites 6, 9-11, 14 and 15) and peripheral sites (located along the peripheral marsh that drain quickly and may dry; sites 1, 2, 7, 12-13, 16-21) were frequently similar in water quality (Appendix Figures 1-3). Sites 11, 12, and 16 were identified as transitional sites that resembled impacted sites during periods of high S-10 and S-7 inflows.

Temporal differences in marsh water quality were associated with extreme low water conditions, particularly the first year of marsh dewatering and reflooding, and large volume inflows . Discriminant analysis, comparing nine separate collection periods corresponding to annual drawdown and reflooding events (Figure 15), showed that 7 of the original 16 water quality variables were important in identifying significant differences over time (Appendix Table 6 ). Two periods were unique in water quality compared to other collections. The first consist of samples collected during the first year drawdown (December 1980 through 21 May 1981; Figure 15). Nitrogen concentrations (total N, dissolved N, and ammonia), particulate phosphorus and ions ($Ca^{++}$, $Mg^{++}$, and $CL^{-}$), together with alkalinity and hardness were higher at a majority of sampling sites after drawdown. Similar changes in water quality were observed during the second year marsh dewatering (Centroid 4, Figure 15). These samples were collected coinciding with low water levels in late February 1982 when interior marsh sites contained slightly higher nutrients (nitrogen and phosphorus) and ion concentrations.

A second change in water quality resulted from marsh reflooding by rainfall in May 1981, following an extended dry period (Centroid 3, Figure 15). These samples were lower in chlorides and alkalinity and contained moderately high concentrations of total N, calcium, and magnesium. Ion concentrations and dissolved organic nitrogen at interior and peripheral marsh sites increased sharply from mineralization and re-dissolving organic matter. Large increases in phosphorus (dissolved organic, particulate, and inorganic) also occurred in July 1981 at the impacted sites as the marsh continued to reflood from rainfall (no S-10 inflows occurred during this month).

The remaining collection dates (pre-drawdown, tropical storm Dennis and the third and fourth year drawdown-reflood events) were all influenced by large inflows from the EAA with water quality characterized by high concentrations of ions (Cl, Ca, and Mg) and ortho-phosphorus (Figure 15). Passage of the tropical storm in late August 1981 contributed large rainfall amounts, causing temporary reductions of nutrients and ions at interior and peripheral marsh sites. Sites impacted by S-10 and S-7 inflows, however, contained high phosphorus and nitrate nitrogen concentrations reflecting water quality of pumped inflows (Appendix Figures 1-3). "Sheet flow" across the marsh was maintained throughout the third and fourth drawdown years as a result of constant inflow and discharge through the S-10 and S-11 structures, respectively (Table 1). Compared to previous years, nearly three times the volume of water passed through WCA-2A (Table 1). Consequently, impacted sites were generally higher in nutrients, particularly phosphorus, than interior or peripheral sites.

**b. Soils**

Significant changes in soil fertility were evident among drawdown and reflooding events (Table 13). Using discriminant functions (Appendix Table 7), three separate phases in soil fertility were distinguished among collection periods (Figure 16). These temporal differences were largely the result of changes in potassium, calcium, and nitrogen content of soils in response to marsh drying and periods of high inflows and outflows, similar to patterns expressed in water quality.

Samples obtained before drawdown, after reflooding (reflood 1), and after the second year drawdown (drawdown 2) and reflooding (reflood 2), were each higher in potassium and moderately higher in calcium compared with other collections. Although these samples were collected during different seasons, they reflect soil conditions after the marsh was flooded for several months. Concentrations of nutrients and ions were quite similar among respective sawgrass and slough samples, as evidenced by the large areas of overlap in soil fertility (Figure 16).

Drying marsh soils, as in the first year (drawdown 1), lowered the nitrogen, postassium, and calcium content of tree island and sawgrass soils while increasing concentrations in sloughs. Mineral and nutrient declines at tree island and sawgrass sites coincided with a surge in new plant growth, occurring shortly after soils were exposed. As the marsh continued to drain, some of these elements may have been carried to the lower lying sloughs, contributing to the influx of minerals and nitrogen in slough soils. A greater potential source of increase was the consolidation of flocculent plant detritus (gyttja), accumulated after long periods of flooding. This material remained suspended above the substrate

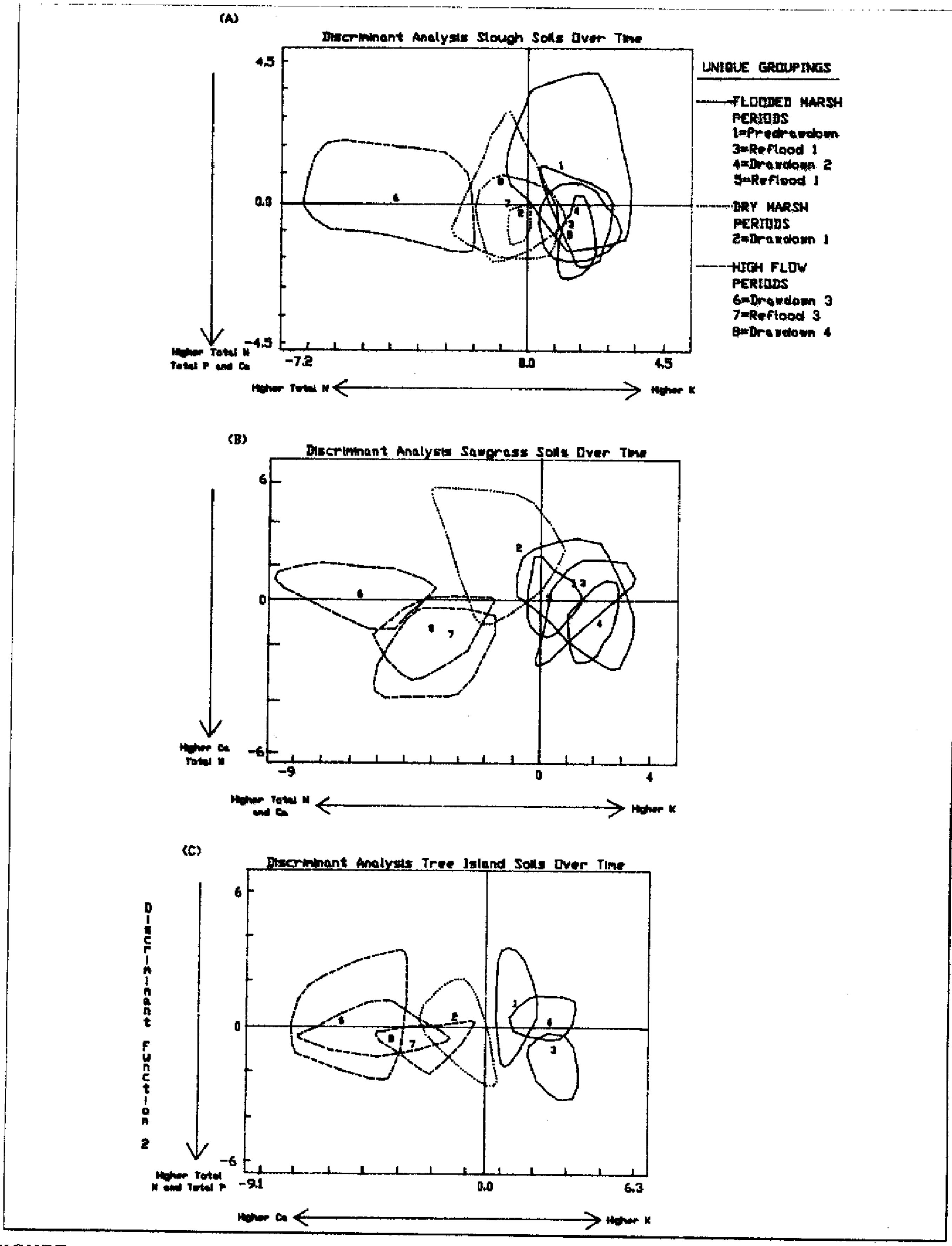



FIGURE 16. RESULTS OF DISCRIMINATE ANALYSIS COMPARING CHANGES IN SOIL FERTILITY AMONG DRAWDOWN - REFLOODING EVENTS FOR SLOUGHS (A), SAWGRASS (B), TREE ISLANDS (C).

forming mats 21 cm in thickness in portions of the marsh prior to the drawdown (Table 14). After drawdown, dried deposits, more than 5 cm in thickness in some localities, contained high concentrations of phosphorus, calcium, and magnesium (Worth, 1980). Subsequent drawdown attempts failed to sufficiently dry surface soils, leading to new accumulations of gyttja (Table 14).

TABLE 14. AVERAGE THICKNESS OF GYTTJA SUSPENSIONS MEASURED AT SLOUGH SITES DURING FLOODED MARSH CONDITIONS; 1980-1984 (UNITS IN CM)

| | YEARS | | | | |
|---|---|---|---|---|---|
| Sites | 1980 | 1981 | 1982 | 1983 | 1984 |
| 2A1 | 14.5 | 0 | 6.4 | 6.7 | 8.6 |
| 2A2 | 17.1 | 0 | 9.4 | 7.6 | 8.4 |
| 2A3 | 21.0 | 0 | 8.5 | 5.0 | 10.3 |
| 2A4 | | | | 6.1 | 9.4 |
| 2A5 | | | | 7.9 | 11.8 |
| 2A6 | | | | 7.9 | 6.7 |
| 2A7 | | | | 13.4 | |
| 2A8 | | | | 6.0 | 9.2 |
| 2A9 | | | | 7.9 | 6.5 |

A third and final transition in soil fertility occurred under high rates of inflow and outflow during the third and fourth year drawdowns (Drawdown 3, Reflood 3, and Drawdown 4). As stated earlier, the rapid rate of water exchange created "sheet flow" conditions within the marsh. Soils collected under these conditions were generally lowest in potassium, higher in calcium, and somewhat higher in nitrogen content compared to other periods.

In summary, increase and decrease in certain soil nutrients and ions appeared to correlate with changes in marsh hydrology. Drawdown when coupled with adequate drying of soils reduced concentrations of potassium and calcium in tree islands and sawgrass sites while increasing these elements in sloughs. Conversely, flooding soils and moderate levels of inflow and outflow allowed these elements to accumulate. High rates of inflow and discharge, altered equilibria causing soils to again lose potassium while accumulating calcium. Nitrogen and phosphorus did not appear to be as closely correlated with changes in hydrology resulting from marsh drawdown and reflooding.

#### c. Nutrient Retention and Export

Mass budgets, including annual weighted rainfall, were calculated for major nutrients and ions (Table 15). Results showed the marsh was an effective sink for phosphorus throughout all four drawdowns, retaining 54 - 87% of loadings. Efficiency of P removal was proportional to the magnitude of loadings and inflow concentrations. Mean outflow concentrations ranged from 57 - 93% lower than inflows (Table 16). Highest outflow concentrations were measured with passage of the tropical storm (Figure 17).

Nitrogen retention ranged from 25 - 50% annually, but unlike phosphorus, uptake efficiency was less consistent and varied with inflow concentration and changes in marsh hydrology (Table 16). Outflow concentrations increased with declining water level during active drawdown months causing the marsh to export nitrogen, particularly in the fourth drawdown year when outflow concentrations frequently exceeded inflows (Figure 17). The amount of nitrogen retained during the second and third drawdown years closely followed the net water balance, suggesting the marsh was a passive sink, since the amount of nitrogen retained was proportional to the quantity of water held in storage. In contrast, a higher proportion of nitrogen was retained by the marsh in the fourth year even though the amount of water in storage was similar to the previous year and outflow concentrations frequently exceeded inflows.

Ion mass balance indicates the marsh lost chloride ions in every year except the second drawdown. Losses were attributed to increased mineralization of materials bound with organics, together with rainfall dilution and subsequent export in outflows. Net retention of chloride in the second drawdown year was enhanced by an increase in volume storage compared to other years. Although cations were not measured frequently enough to reliably compare annual trends, significant correlations between chloride and other ion (Mg, K, and Ca) inflows and outflows (inflow $r2 > .9$, outflow $r2 > .6$; $P > .05$) suggest retention of these ions was similar to that of chloride.

## DISCUSSION

### Marsh Drawdown Limitations

The use of radical drawdown in an Everglades environment has many practical limitations as a method to enhance or stimulate new species growth. Control of water is crucial, both in ability to remove excesses to facilitate drying of soils and to control water depth after reflooding when newly emerging plant growth is most vulnerable to drowning. The ability to move water rapidly into WCA-2A by gravity inflow and pumping currently surpasses the capacity to remove or control the internal distribution of water.

TABLE 15. ANNUAL WATER, NUTRIENT, AND ION BUDGETS ASSOCIATED WITH DRAWDOWN OF WCA-2A. NUTRIENT AND ION UNITS REPORTED IN METRIC TONS (tonnes).

| | Drawdown Year 1* | | | | % |
|---|---|---|---|---|---|
| | Inflow | | Outflow | Net Gain or Loss | Retention |
| | Rainfall | Structures | | | |
| Acre ft. | | | | | |
| Water | 369007.7 | 146628.0 | 212715.2 | 302920.5 | 58.7 |
| Total N | 327.7 | 978.4 | 859.9 | 446.2 | 34.2 |
| Total P | .3 | 35.5 | 16.2 | 19.6 | 54.7 |
| Total Mg | | 4698.2 | 5786.4 | -1088.2 | -23.2 |
| Total Cl | 5188.6 | 23355.8 | 29886.0 | -1341.6 | -4.7 |
| Total K | | 1316.7 | 2693.0 | -1376.3 | -104.5 |
| Total Ca | | 13773.4 | 16449.3 | -2675.9 | -19.4 |

| | Drawdown Year 2** | | | | % |
|---|---|---|---|---|---|
| | Inflow | | Outflow | Net Gain or Loss | Retention |
| | Rainfall | Structures | | | |
| Acre ft. | | | | | |
| Water | 389492.8 | 613661.8 | 563013.8 | 440140.8 | 43.9 |
| Total N | 283.4 | 3170.0 | 1706.5 | 1746.9 | 50.6 |
| Total P | 14.9 | 124.3 | 17.6 | 121.6 | 87.4 |
| Total Mg | | 22245.1 | 14481.4 | 7763.7 | 34.9 |
| Total Cl | 1489.3 | 99054.4 | 73506.5 | 27037.2 | 26.9 |
| Total K | | 5487.0 | 4906.5 | 580.5 | 10.6 |
| Total Ca | | 68903.2 | 43518.8 | 25384.4 | 36.8 |

| | Drawdown Year 3+ | | | | % |
|---|---|---|---|---|---|
| | Inflow | | Outflow | Net Gain or Loss | Retention |
| | Rainfall | Structures | | | |
| Acre ft. | | | | | |
| Water | 488780.7 | 796210.5 | 951603.4 | 333387.8 | 25.9 |
| Total N | 283.3 | 3368.7 | 2712.2 | 939.8 | 25.7 |
| Total P | 10.2 | 108.5 | 26.8 | 91.9 | 77.4 |
| Total Mg | | 26820.3 | 30276.8 | -3456.5 | -12.9 |
| Total Cl | 1688.0 | 150611.7 | 154819.0 | -2519.3 | -1.7 |
| Total K | | 5911.2 | 7735.3 | -1824.1 | -30.9 |
| Total Ca | | 78327.2 | 78444.4 | -117.2 | -0.1 |

| | Drawdown Year 4## | | | | % |
|---|---|---|---|---|---|
| | Inflow | | Outflow | Net Gain or Loss | Retention |
| | Rainfall | Structures | | | |
| Acre ft. | | | | | |
| Water | 477154.0 | 770449.2 | 921081.5 | 326521.7 | 26.2 |
| Total N | 506.1 | 3902.8 | 2703.8 | 1705.1 | 38.7 |
| Total P | 32.4 | 108.2 | 43.2 | 97.4 | 69.3 |
| Total Mg | | 26097.5 | 32673.2 | -6575.7 | -25.2 |
| Total Cl | 3354.6 | 123491.4 | 141529.8 | -14683.8 | -11.6 |
| Total K | | 5050.6 | 6392.9 | -1342.3 | -26.6 |
| Total Ca | | 69220.6 | 77801.4 | -8580.8 | -12.4 |

* = Water Year Nov. 1, 1980 to Aug. 31, 1981
** = Water Year Sept. 1, 1981 to Aug. 31, 1982
+ = Water Year Sept. 1, 1982 to Aug. 31, 1983
## = Water Year Sept. 1, 1983 to Aug. 31, 1984

TABLE 16. AVERAGE NUTRIENT AND ION CONCENTRATIONS (mg/l) IN SURFACE WATER INFLOWS AND OUTFLOWS OF WCA-2A; NOVEMBER 1980 - AUGUST 1984.

| Parameter | | Drawdown Year 1 (Nov. 1980-Aug. 1981) | Drawdown Year 2 (Sept. 1981-Aug. 1982) | Drawdown Year 3 (Sept. 1982-Aug. 1984) | Drawdown Year 4 (Sept. 1983-Aug. 1984) | Average (4 Years) |
|---|---|---|---|---|---|---|
| N | Inflow | 4.74 | 5.07 | 3.35 | 2.88 | 3.74 |
| | Outflow | 2.63 | 2.33 | 2.09 | 2.63 | 2.39 |
| | % Reduced | 44.5 | 54.0 | 37.6 | 8.7 | 36.1 |
| P | Inflow | .091 | .275 | .137 | .127 | .165 |
| | Outflow | .039 | .019 | .018 | .043 | .031 |
| | % Reduced | 57.1 | 93.1 | 86.9 | 66.1 | 81.2 |
| Cl | Inflow | 158.2 | 155.3 | 157.3 | 110.8 | 141.25 |
| | Outflow | 93.8 | 116.2 | 119.8 | 125.7 | 118.79 |
| | % Reduced | 40.7 | 25.2 | 23.9 | -13.4 | 15.9 |
| K | Inflow | | 7.45 | 6.24 | 4.58 | 6.09 |
| | Outflow | | 6.45 | 5.32 | 5.48 | 5.75 |
| | % Reduced | | * | * | * | 5.6 |
| Ca | Inflow | 76.52 | 86.21 | 66.21 | 47.27 | 71.84 |
| | Outflow | 65.80 | 64.77 | 67.76 | 62.90 | 60.05 |
| | % Reduced | * | * | * | * | 16.4 |
| Mg | Inflow | 26.51 | 26.51 | 21.67 | 17.55 | 23.76 |
| | Outflow | 23.68 | 22.01 | 24.02 | 25.69 | 21.64 |
| | % Reduced | * | * | * | * | 8.9 |

*Percent reduction was not calculated due to small sample size

Timing of drawdown is then crucial, as is the volume of surface storage that must be removed. Although adjustments in timing of the drawdown were made to enhance potential drying, unseasonably high rainfall amounts during "normal" dry season periods prolonged flooding conditions. Successful drawdown was accomplished only during drought conditions coinciding with the first year (1980-81) when dry season rainfall amounts were 66% of normal (Lin et al., 1984).

An additional limitation is the physical movement of water through a densely vegetated marsh of low topographic relief. Natural flow ways, such as sloughs, greatly enhanced water removal, particularly in the southern portion of the marsh where several large sloughs are interconnected and extend to the L-35B canal. Sloughs more centrally located and separated by dense stands of sawgrass drained slowly, even under drought conditions. As a result, water tends to pond in the central portion of the marsh (2-17 gauge) as stage levels approach 11.5 ft msl.

Downstream water conditions in WCA-3A and WCA-2B further limit the ability to remove water from WCA-2A. Downstream constraints are twofold, dealing with the physical export of water and consequences of impacting downstream ecology. Rising water levels in WCA-3A and WCA-2B created high tailwater stages at the outflow structures (S-11's and S-144, 145, 146) in WCA-2A and reduced outflow capacities. This was particularly evident during the wetter third and fourth drawdown years when outfall structures frequently remained fully opened, yet daily discharge volumes were quite low. Balancing biological impacts of drawdown or transfer of water to downstream bodies involves more problematic issues. Consideration of downstream biologial impacts, such as concern for deer habitat, prompted suspension of drawdown efforts during the second year.

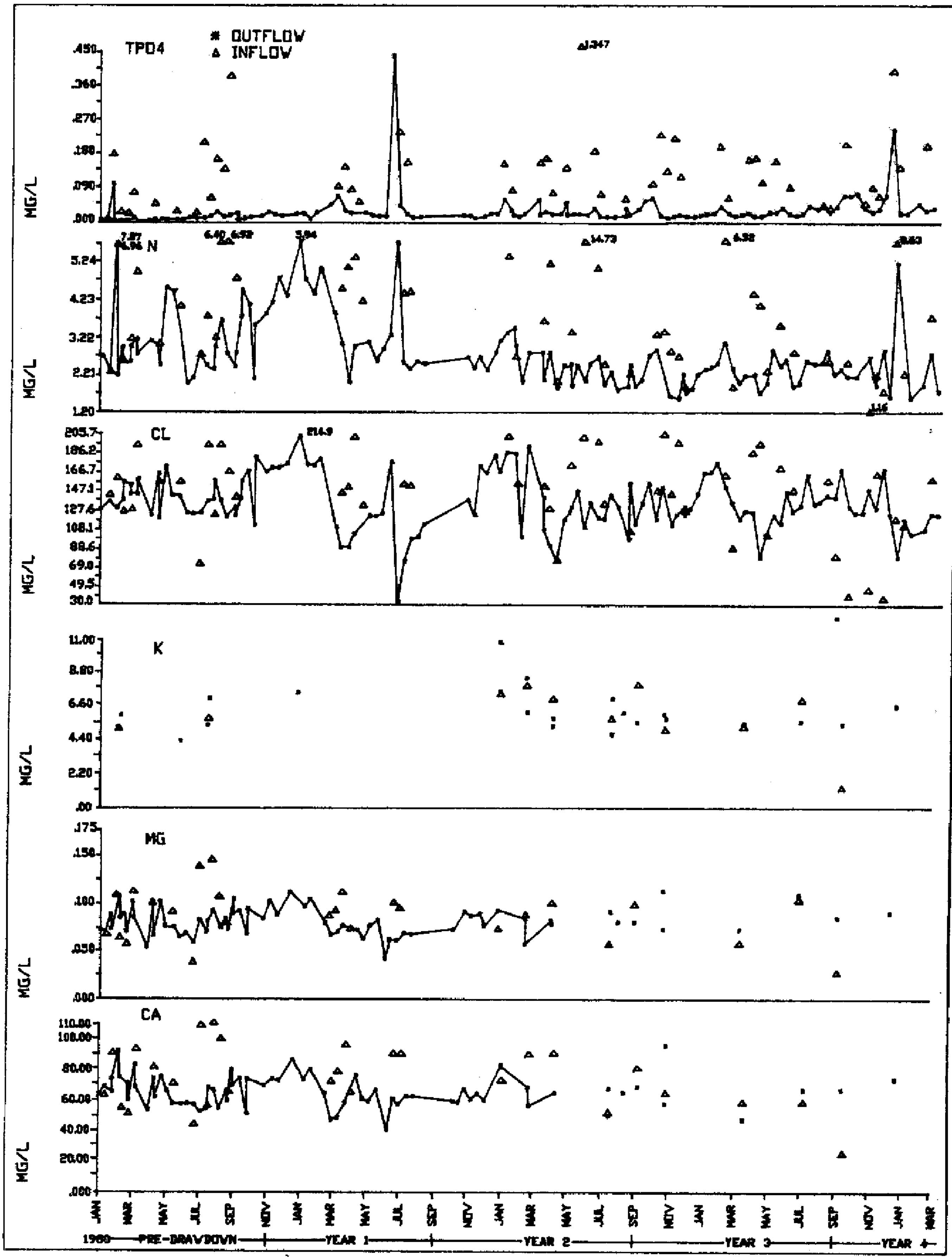



FIGURE 17. WATER QUALITY CHARACTERISTICS OF WCA-2A INFLOWS AND OUTFLOWS

## Plant Community Responses

Preliminary results from the first year drawdown (Worth, 1983) indicated that factors such as extent of soil drying, duration, and vegetation type play an important role in the introduction and reestablishment of marsh plant species. Although repeated attempts to duplicate adequate drawdown conditions failed, repetitive reductions in water levels to near ground surface did successfully stimulate regrowth of some species. At the same time, species normally more accustomed to hydroperiods of longer duration and deeper water conditions were reduced but generally not eliminated.

Changes in aquatic slough communities were more readily apparent. Initial drawdown of water levels helped to eliminate or reduce dominant aquatic species (i.e. bladderwort and white water lily), but exploitation of resources, either created by reduction in local species dominance or by increased availability of habitat, occurred slowly and was limited to a small region of the marsh. Suitability of growth sites particularly during post drawdown periods when the marsh was reflooded, may have restricted more rapid growth or expansion of some species. While competition may influence species distribution, relative frequency - elevation relationships for slough species appeared more to reflect individual species response to changing drawdown hydrology than competition for resources. Species preferring wetter conditions declined along elevations where water depths decreased most rapidly. Conversely, species better adapted to shallow water depths increased in these areas.

Repeated drawdown attempts were conducive to some wet prairie species development and expansion, particularly in the southern third of the marsh. Spikerush became the most prevalent species, first appearing in portions of the marsh adjacent the L-35B canal and gradually expanding northward into the marsh interior. Field observations indicate this expansion resulted from vegetative growth (rhizomes) rather than seedling establishment. Expansion of existing spikerush communities by vegetative means rather than seed germination, is consistent with the observed gradual increase in species distribution.

Many factors such as soil moisture content, aeration of seeds, temperature and light exposure affect seed germination of wetland plants (Kadlec and Wentz, 1974; Van der Valk and Davis, 1978). Accumulation of organic detritus (gyttja) may further inhibit potential seed germination as this material settles on deposited seeds during drawdown (Harris and Marshall, 1963; Sykora, 1979). Under extreme drying conditions, such as first year drawdown, settling and compaction of gyttja may have reduced potential germination (Worth, 1983).

Tree island plant communities were equally slow in responding to changes in drawdown hydrology. Dominant species were generally unchanged. However, species richness appeared to fluctuate inversely with flooding duration, with higher species richness occurring in years with fewer days of flooding. Perennials comprised over 70% of transient species at all sites, but rapid turnover in these species indicate environmental conditions were too unstable to facilitate continued succession toward more mesic tree island conditions. Tree islands located below the generalized 12 ft NGVD contour are particularly vulnerable to extremes in both flooding depth and duration. While drawdown might provide favorable conditions for establishment of more mesic species at these sites, subsequent flooding greatly reduces their likelihood of survival to the next dry period.

Factors affecting seedling distribution and emergence of pioneer terrestrial species are similar to those influencing aquatic slough species. Although recent studies suggest seeds of wetland species (floating and emergent) may survive for long periods (Van der Valk, 1981), terrestrial perennials may not be as long-lived (Werner, 1979). Prolonged flooding of tree island sites may have eliminated seed banks for some of the more mesic species. Woody seedlings. (wax myrtle and red bay) were primarily observed on islands lying above the 12 ft NGVD contour and in close proximity to mature seed bearing populations. Dispersal of seeds from surrounding live islands may be an important mechanism in the revegetation of drowned islands. Successful recruitment would then be dependent upon the successional status of the island community and related competition from existing species. Other studies indicate ground litter and cover can markedly influence seedling establishment of woody species (Hosner and Minckler, 1960).

Drawdown influence was more ephemeral on sawgrass communities examined in this study. Although combining reduced water levels and burning initially helped to increase sawgrass density, fewer number of culms appeared to survive as the time lapse after burning increased. Moreover, sites appeared to uniformly decline in density, despite obvious differences in site hydrology. This pattern of increase and decline follows a trend consistent with general plant response to improved growing conditions followed by readjustment as environmental limiting conditions reassert controls on population levels.

Although direct hydrologic influences on sawgrass regrowth were weakly correlated, site position along the general elevation gradient and corresponding hydrology appeared to indirectly affect culm regrowth by influencing size distribution of individuals in the population. More robust culm development in the central (sites MELH and RUBT) portions of the marsh lead to higher accumulation in standing crop biomass and greater culm length than sites in the north (159G). Site differences are attributed to the larger percentage of individuals reaching larger size classes at these sites. Comparisons in hydrology indicate sites located in the central marsh experienced more stable water conditions (remained flooded longer with less extreme lows and highs) during the repeated drawdown attempts. More stable flooding conditions (less extreme highs and lows) appear to favor survival of fewer and larger culms which in turn are able to cope with greater water depths.

Thus, site differences in sawgrass size, density, and standing crop appear to result from differing adaptations in growth strategy in response to local flooding conditions. As an example, all culms at OLDG sites were perched above the soil substrate on tussocks prior to the drawdown, a growth strategy typical of areas subjected to high water levels and long periods of flooding. Repeated drawdown attempts significantly reduced water depths in this area of the marsh. In response to this change a large proportion of young culms were found emerging from the soil substrate where environmental conditions were more stable. Histograms of the basal diameter classes in this population were skewed to smaller individuals reflecting a higher proportion of young culms entering the population.

In conclusion, drawdown produced some measurable changes in individual species within each plant community, but overall community structure changed very little. Year to year differences in species richness were not significant, nor were fluctuations in annual frequencies of most species. Observed changes in community structure were minor and resulted largely from adjustments by existing species to newly established resource conditions. Consequently, composition and, in many cases, the relative importance of species contribution to community structure remained stable. Brief reductions in water levels were not sufficient to produce lasting changes in community structure. More permanent changes in community structure might be accomplished by altering the current regulation schedule so that water depths remain low (<0.5 m) over a longer period and span a portion of active growing season (May - August).

## Drawdown and Marsh Fertility

Initial drawdown produced marked changes in water quality as a result of increased leaching of nutrients from plant detritus, increased mineralization, and concentration of nutrients by evaporation (Worth, 1983). Partial or incomplete drying during succeeding drawdown attempts produced only minor increases in nutrient availability compared to the first year drawdown results. Increased nutrient availability following radical marsh drainage has been observed in several marsh systems (Kadlec, 1962; Klopatek, 1978). Drainage of submerged soils results in complex changes of soil-water nutrient equilibria (Patrick and Mikkelson, 1971; Ponnamperuma, 1972; Kadlec, 1976; Reddy and Patrick, 1976 and Reddy, 1982). In WCA-2A, reductions in water levels with continued flooding had little impact on increasing availability of nutrients already bound to soils.

Marsh drainage can result in a significant loss of nutrients and ions from the ecosystem (Kadlec, 1978). For WCA-2A, the rate of efflux of nutrients was only slightly higher than non-drawdown years. Millar (1982) reported average P and N retention rates of 85.2 and 65.3, respectively, for a two year period (1978-79). Compared with results obtained during this study, uptake efficiencies for P ranged from 2% higher to 35% lower, while uptake of N was 22-47% lower. Declines in nutrient uptake efficiency can be directly related to fluctuations in inflow concentrations and the result of losses associated with large discharges. Plant uptake and related seasonal variation in growth may have further contributed to the annual variations in nutrient retention.

Marsh drawdown had a more significant effect on the flux of chloride and ions. Although estimates of the actual quantity of ions entering or leaving the marsh may be underestimated, patterns of ion influx and efflux were similar to chloride. Those results showed net losses of chloride were measured in each year that surface water outflows exceeded inflows. Again, under non-drawdown conditions, WCA-2A normally functions as a chloride sink, retaining 12-31% (Millar, 1982), and presumably retains ions as well. Despite net losses of these elements during three of four drawdown years, no corresponding pattern of reduction, with the exception of K, was detected in soil storages of these elements. Declines in soil stored K corresponded to periods of net export of this element from the marsh, suggesting soils may be a significant but temporary mode of removal.

# RECOMMENDATIONS

1. Modify the present drawdown schedule to fluctuate seasonally between 11.0-13.0 NGVD as depicted in Figure 18. One of the original objectives in implementing the drawdown schedule was to dry the marsh soils in hopes that seed banks, particularly those of wet prairie communities, would germinate and enhance habitat diversity. Results indicated long periods of flooding may have eliminated seed banks or that environmental conditions were not conducive for seed germination. Alternatively, reduced water depths appeared to stimulate expansion of some wet prairie species through vegetative propagation. Management of water levels to sustain this mode of reproduction could, in time, promote further expansion of the wet prairie communities, without the necessity to dry the marsh on an annual basis. The proposed modification will meet this objective by sustaining low water depths over a large portion of the marsh. Tree islands, as well, will benefit from increasing the duration of low water stages by further reducing the duration of flooding. In addition, modifications in the schedule timing will better coincide with the normal rainy season.

Undesirable impacts of the current schedule will be minimized with the proposed revision. Attempts to dry the marsh requires extreme low stages (<9.0 ft NGVD) be maintained in the L-35B canal. However, canal stages below 10.5 ft NGVD overdrain the lower marsh without appreciably reducing the ponding in the central marsh (2-17 gauge). Overdrainage is also less desirable since this reduces the fisheries habitat to the confines of the canal, where juvenile fish are subject to more intense predation.

2. The District and Game and Freshwater Fish Commission should continue close coordination and develop a fire management plan for WCA-2A. Fire is an integral component in the Everglades ecology. Because of past regulation schedules, which maintained high water levels, the frequency of fire in WCA-2A has mostly coincided with drought. A planned program of periodic burning would promote increased sawgrass densities and reduce risk of destructive burns during drought or low water conditions. Management practices, such as controlled burning, that sustain health of existing sawgrass communities may in turn enable sawgrass to better compete with invasive species such as cattail.

**Recommended Operation of Structures**

The revised schedule will vary seasonally from 11.0-13.0 ft NGVD. Peak stage level will coincide with the end of the normal rainy season (October 1), then decline to 11.0 ft NGVD by February 1, remain at 11.0 ft through June 30, and begin increasing on July 1. The intent of the revised schedule is to prevent overdrainage of the lower marsh and maintain lower water depths during early spring when plant growth begins to accelerate. The proposed stage levels and the timing of the drawdown, however, are intended to result in the marsh continuing to dry during drought years.

Regulation of water levels and operation of outfall structures will be keyed to both the interior marsh stage levels (2-17 gauge) and water levels in the lower marsh as approximated by S-11B headwater. Discharges will be coordinated between the S-11 structures and the L-35B canal culverts (S-144, 145, and 146). Opening of the S-11 structures will be made on an "as needed" basis to prevent stage levels from increasing more than 0.5 ft above the target schedule. Once this threshold has been reached, S-11 structures should be opened, and remain open, until stage levels again coincide with the scheduled drawdown. To prevent overdrainage in the lower pool, gate openings on structures will be adjusted so that the S-11B headwater stage does not fall below 10.5 ft NGVD.

Drawdown will begin on October 1 and continue through January 31 using the 2-17 (C.O.E. 111) gauge as reference. As stage levels at the 2-17 gauge reach 11.5 ft NGVD, stage regulation will be keyed to S-11B headwater. Regulation using S-11B headwater will continue until July 1, then revert back to the 2-17 gauge.

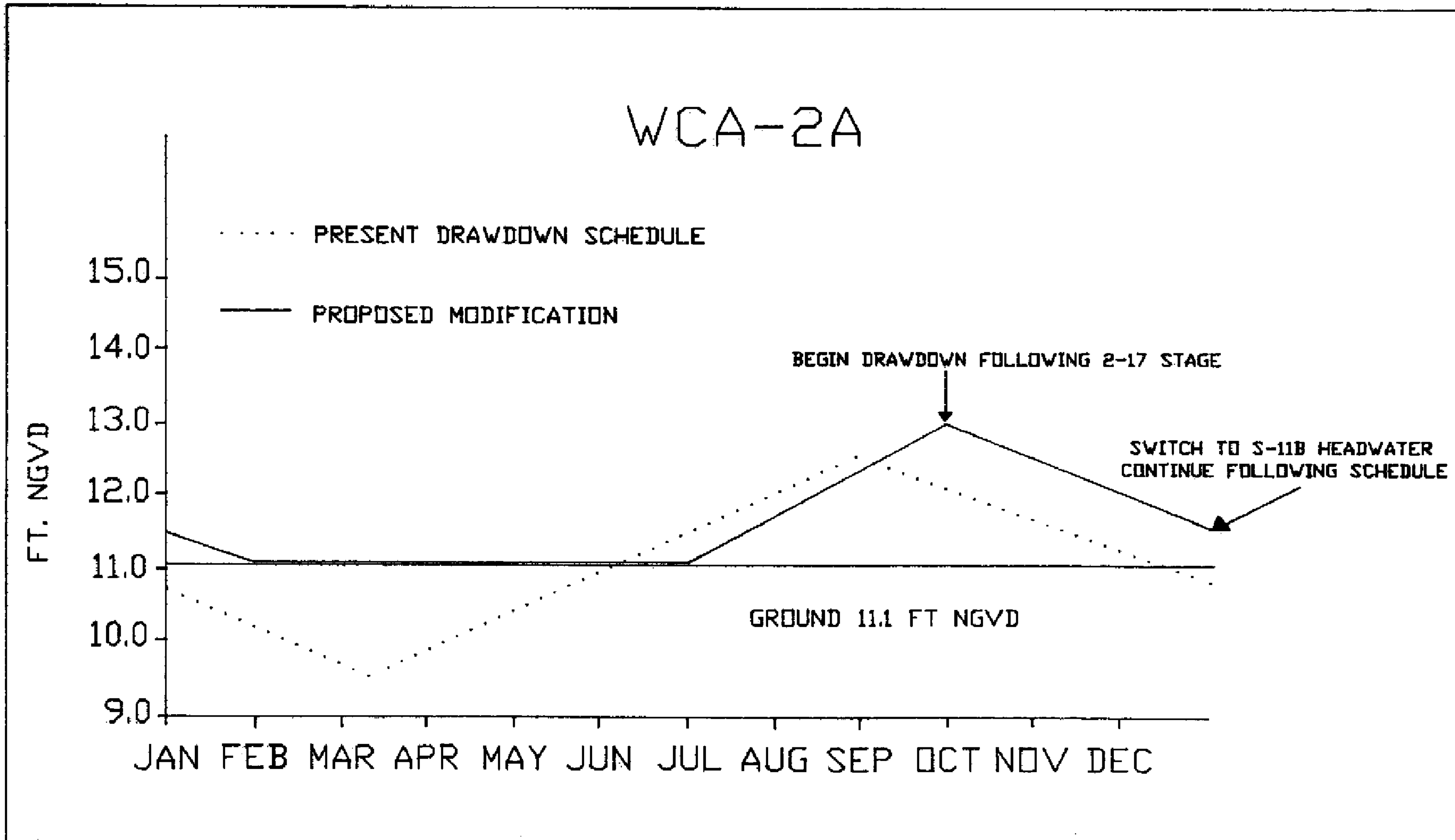



FIGURE 18. CURRENT AND PROPOSED DRAWDOWN SCHEDULE FOR WCA-2A, STAGE SCHEDULE BASED ON 2-17 GAUGE LOCATED IN MARSH INTERIOR

# SUMMARY

1. Implementation of the drawdown schedule (9.5-12.5 ft msl) was only partially successful in meeting desired program objectives. Drawdown of the marsh was dependent on coincident drought conditions (1981) to achieve maximum drying effect on soils, both in aerial extent and duration. Water depth and duration of flooding during subsequent marsh reflooding, in turn, strongly influenced plant species establishment and survival potential.

2. Slough species exhibited a trend of increasing relative frequency with increasing elevation, similar to predrawdown patterns. However, as a result of repeated drawdown attempts, moderate changes occurred in slough community composition and structure. Wet prairie species such as spikerush increased in relative abundance and distribution, particularly in the southern third of the marsh. Predominantly aquatic species (white water lily and bladderwort) initially declined in response to drawdown but later reestablished community dominance as wetter conditions prevailed during succeeding drawdown attempts.

3. Drawdown resulted in a large influx of new herbaceous species on tree islands but dominant species remained largely unchanged. Many of the new species were short lived even though a majority of these were perennials. Annual reflooding appeared to hinder permanent recruitment of new species There was also little evidence of woody species colonizing drowned tree islands below a general marsh elevation of 12.0 ft NGVD. Proximity of seed sources and unfavorable hydrologic conditions may have influenced the recolonization of these sites by hardwoods. In contrast, continued recruitment of woody species such as wax myrtle and red bay was observed on islands in the north central portion of the marsh where flooding was less severe.

4. Drawdown and burning of sawgrass initially stimulated increases in stand density, then declined at all sites and finally stabilized approximately two years after initial burning. Culm regrowth differed significantly among sites in absolute density, biomass, culm height, and basal diameter but not in rates of increase or decrease over the study period. Sites were also not significantly different in the accumulation of tissue nutrients. Weak correlations were found between culm density and maximum water depth (negatively correlated) and between culm basal diameter and maximum and minimum water depth (positively correlated). Sawgrass sites located in the central portion of the marsh had significantly greater number of individuals reaching larger size classes than other sites. This difference was attributed to more stable flooding (less severe lows and highs) occurring in the central marsh throughout the repeated drawdown attempts.

5. Major changes in marsh water quality resulted from initial drawdown (November 1980 - May 1981) during the first year. Large increases in nitrogen, particulate phosphorus, and ions were observed as water levels declined. Increases were attributed to more complete decomposition and mineralization of exposed litter and soils, as well as to concentration by evapotranspiration. Similar increases in nutrients and ions were observed during the second drawdown but not observed in the third and fourth years, perhaps because of insufficient exposure of litter and soils. Water quality during reflooding was frequently dominated by structure inflows (S-10 and S-7 inflows) and resembled ambient conditions of non-drawdown years.

6. Changes in certain soil nutrients and ions also appeared to correlate with changes in marsh hydrology. Drying the marsh increased concentrations of nutrient ions in slough soils, while at the same time reduced concentrations in tree island and sawgrass soils. Flooded soils, under moderate inflow and outflow regimes, appeared to accumulate ions. Increased rates of flow-through caused soils to lose ions. Changes in soil nutrients, nitrogen and phosphorus, were not as closely correlated with changes in hydrology.

7. Comparison of the flux of nutrients and ions entering and leaving the marsh showed nutrients (N and P) were retained during all four drawdown water years but at a somewhat less efficient rate compared to non-drawdown years. Declines in uptake efficiency were attributed to large net export of these elements during periods when structure outflows exceeded inflows. Uptake of phosphorus increased proportionately with loading and inflow concentration. However, uptake of nitrogen varied with inflow concentration and changes in marsh hydrology. Since inflows are the major source of mineral supply to the marsh, more frequent discharge resulted in a net loss of minerals during three of the four drawdown years.

## LITERATURE CITED


Dane, C.W. 1959. Succession of aquatic plants in small artificial marshes in New York state. New York Fish and Game J. (6):57-76.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. Vol. 33(1):43-64.

Dineen, J.W. 1972. Life in the Tenacious Everglades. C.& S. F.F.C.D. In Depth Report Vol. 1(5):12 pp.

Dineen, J.W. 1974. Examination of water management alternatives in Conservation Area 2A.. C.& S.F. F.C.D. In Depth Report Vol. 2(3):11 pp.

Dixon, W.J., and Brown, M.B., editors. 1983. BMDP-83. Biomedical Computer Programs, P. Series. University of California Press, Berkeley, Cal. U.S.A.

Forthman, C.A. 1973. Effects of prescribed burning on sawgrass. M.S. Thesis, University of Miami, Coral Gables, FL.

Gleason, P.J. 1974. Chemical quality of water in Conservation Area 2A and associated canals. C.& S. F. F.C.D. Tech. Pub. 74-1:72 pp.

Goodrick, R.L. and Milleson, J.F. 1974. Studies of floodplain vegetation and water level fluctuations in the Kissimmee River Valley. Central and Southern Florida. F.C.D.Tech. Pub. 74-2:60 pp.

Harris, S.W. and Marshall, W.H. 1963. Ecology of water level manipulations on the northern marsh. Ecology:44(2):331-342.

Holcomb, D. and Wegener, W. 1971. Hydrophytic changes related to lake fluctuations as measured by point transects. Proc. 25th Ann. Conf. S.E. Assoc. G. & F. Comm.

Hosner, J.F. and Minekler, C.S. 1960. Hardwood reproduction in the river bottom of southern Illinois. For. Sci. 6:67-77.

Jackson, M.L. 1958. Soil chemical analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J. 498 pp.

James, S.W. 1985. An unexpected effect of autumn burning on tallgrass prairie. Am. Midland Nat., 114(2):400-403.

Kadlec, J.A. 1962. The effects of a drawdown on a waterfowl impoundment. Ecology 43:267-281.

Kadlec, J.A. 1976. Dissolved nutrients in a peatland near Houghton Lake, Michigan. In: Freshwater wetlands and sewage effluent disposal, D.L. Tilton, R.H. Kadlec, and C.J. Richardson, eds. Proc. of National Symp., May 10-11, pp. 25-50.

Kadlec, J.A. and Wentz, W.A. 1974. State-of-the-art survey and evaluation of marsh plant establishment techniques: induced and natural. Vol. 1. Report on research. U.S. Army Coastal Eng. and Res. Center, Fort Belvoir, VA.

Klopatek, J.M. 1978. Nutrient dynamics of freshwater riverine marshes and the role of emergent macrophytes. In:Freshwater wetlands ecological processes and management potential (R.E. Good, D.F. Wigham and R.L. Simpson, eds.). Academic Press, pp. 195-216.

Kushlan, J.A. 1974. The ecology of the white ibis in southern Florida, a regional study. Ph.D. Thesis, Univ. of Miami, Coral Gables, FL.

Lin, S., Love., J., and Marban, J. 1984. Meteorological and hydrological analysis of the 1980-1982 drought. Tech. Pub. 84-7, June 1984, So. Fl. Water Management District, West Palm Beach, FL.

Loveless, C.M. 1959. A study of vegetation of the Florida Everglades. Ecology 40(1):1-9.

Low, J.B. and Bellrose, F.C. Jr. 1944. The seed and vegetation yield of waterfowl food plants in the Ilinois River Valley. J. Wild. Mang. 8(1):7-22.

McDonald, M.E. 1955. Cause and effects of a die-off of emergent vegetation. J. Wild. Mang. 19:24-35.

Millar, P.S. 1981. Water quality analysis in the Water Conservation Areas 1978 and 1979. South Florida Water Management District. Tech. Memo. Interim Progress Report:63 pp.

Mueller-Dombois, D. and Ellenberg, H. 1974. Aims and methods of vegetation ecology. J. Wiley and Sons. N.Y. N.Y. USA.

Old, S.M. 1969. Microclimates, fire, and plant production in an Illinois prairie. Ecol. Monogr:,39:355-384.

Parker, G.G., Ferguson, G.E. and Love. S.K. 1955. Water resources of southeastern Florida. U.S.G.S. Water Supply Paper 1255:965pp.

Patrick, W.H. and Khalid, R.A. 1974. Phosphate release and sorption by soils and sediments: effect of aerobic and anaerobic conditions. Science, Vol. 186:53-55.

Ponnamperoma, F.N. 1972. The chemistry of submerged soils. Advan. Agron. 22:29-96.

Reddy, K.R. and Patrick, W.H. Jr. 1976. Effect of frequent changes in aerobic and anaerobic conditions in redox potential and nitrogen loss in a flooded soil. Soil Biol. and Biochem. 8:491-495.

Reddy, K.R. 1982. Phosphorus transformation in f looded organic soils and sediments. In: Progress in wetlands utilization and management. ed. by P.M. McCaffrey, et al. Coordinating Council on the Restoration of the Kissimmee.

Richardson, C.J., Tilton, D.L. Kadlec, J.A., Chamie, J.P.M. and Wentz, W.A. 1978. Nutrient dynamics of northern wetland ecosystems. In:Freshwater wetlands: ecological processes and management potential (R.E. Good, D.F. Whigham, and R.L. Simpson, eds). Academic Press, pp. 217-241.

Steward, K.K. and Ornes, W.H. 1975. The autecology of sawgrass in the Florida Everglades. Ecology 56:162-171.

Swift, D. 1981. Preliminary investigations of periphyton and water quality relationships in the Everglades Water Conservation Areas. Tech. Pub. 81-5, Dec. 1981, South FloridaWater Management District, West Palm Beach, FL.

Sykora, K.V. 1979. The effects of the severe drought of 1976 on the vegetation of some moorland pools in the Netherlands. Biol. Conservation, 16:145-162.

Tiltman, J.T. Habitat utilization by round-tailed muskrats (Neofiber alleni) in Everglades National Park. M.S. Thesis. Humboldt St. Univ., Arcota, Calif.

Uhler, F.M. 1944. Control of undesirable plants in waterfowl habitats. Trans. N. Amer. Wild. Conf. 9:295-303.

U.S. Army Corps of Engineers. 1968. General Design Memorandum. Conservation Area 2. Supp. #27.

U.S. Army Corps of Engineers. 1972. General Design Memorandum. Conservation Area 2. Supp. #49.

Van der Valk, A.G. 1981. Succession in wetlands: A Gleasonian approach. Ecology 62(3):688-696.

Van der Valk, A.G. and Davis, C.B. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. Ecology, 59:(2):322-335.

Worth, D.F. 1983. Preliminary environmental response to marsh dewatering and reduction in water regulation schedule in Water Conservation Area 2A. Tech. Pub. 83-6, September 1983, South Florida Water Management Distric t, West Palm Beach, Fl.

Werner, P.A. 1979. Competition and coexistence of similar species. Pages 287-310 in D.T. Solbrig, S. Jain, G.B. Johnson, and P.H. Raven, ed. Topics in plant population biology. Columbia University Press, New York, New York, U.S.A.

# APPENDIX

ENVIRONMENTAL RESPONSE OF WCA-2A TO REDUCTION IN REGULATION SCHEDULE AND MARSH DRAWDOWN

## APPENDIX TABLE 1.
### Frequency and Cover of Vegetation Species Observed at Slough Sites During 1983 and 1984.

| Site | 2A1 | | | | 2A8 | | | | 2A9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation (ft NGVD) | 11.55 | | | | 11.57 | | | | 11.78 | | | |
| Year | 1983 | | 1984 | | 1983 | | 1984 | | 1983 | | 1984 | |
| Vegetation Composition | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % |
| Floating | | | | | | | | | | | | |
| Nymphaea odorata | 18.2 | 94.0 | 8.5 | 100.0 | 10.1 | 68.9 | 14.4 | 78.3 | 16.9 | 74.4 | 16.4 | 77.8 |
| Submergent | | | | | | | | | | | | |
| Chara spp. | * | 6.0 | * | 3.9 | 6.8 | 75.6 | .8 | 50.0 | .2 | 23.3 | .4 | 4.4 |
| Utricularia spp. | 26.2 | 96.0 | 21.9 | 100.0 | 30.5 | 93.3 | 13.8 | 84.8 | 4.0 | 30.2 | * | 4.4 |
| Emergent | | | | | | | | | | | | |
| Cladium jamaicensis | .1 | 2.0 | .3 | 7.8 | .3 | 2.2 | .1 | 4.3 | .1 | 4.7 | | |
| Eleocharis cellulosa | 2.2 | 48.0 | 1.6 | 47.1 | 1.1 | 28.9 | .9 | 39.1 | .8 | 74.4 | 2.0 | 31.1 |
| Eleocharis elongata | .3 | 14.0 | .6 | 17.6 | .4 | 15.6 | .6 | 19.6 | .2 | 37.2 | * | 2.2 |
| Panicum hemitomon | .1 | 2.0 | - | - | - | - | - | - | - | - | - | - |
| Paspalidium paludivagum | .1 | 8.0 | .4 | 7.8 | * | 2.2 | - | - | - | - | - | - |
| Polygonum hydropiperoides | * | 2.0 | - | - | - | - | | - | - | - | - | - |
| Sagittaria lancifolia | .3 | 4.0 | .3 | 2.0 | - | - | * | 2.2 | * | 2.3 | - | - |
| Typha sp. | - | - | - | - | - | - | .1 | 2.2 | - | - | - | - |
| Mean # Species/0.25m² | 2.8 | | 2.2 | | 2.9 | | 2.8 | | 2.5 | | 1.2 | |
| Total # Species | 10 | | 8 | | 7 | | 8 | | 7 | | 6 | |
| Total Plant Cover | 47.5 | | 33.6 | | 49.2 | | 30.7 | | 22.2 | | 18.5 | |

| Site | 2A2 | | | | 2A6 | | | | 2A7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation (ft NGVD) | 10.71 | | | | 10.70 | | | | 10.25 | | | |
| Year | 1983 | | 1984 | | 1983 | | 1984 | | 1983 | | 1984 | |
| Vegetation Composition | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % |
| Floating | | | | | | | | | | | | |
| Nymphaea odorata | 18.1 | 72.5 | 13.2 | 64.7 | 9.5 | 68.6 | 8.7 | 52.9 | 4.4 | 31.4 | 3.7 | 35.3 |
| Submergent | | | | | | | | | | | | |
| Chara spp. | 5.2 | 49.0 | 1.0 | 25.5 | 9.6 | 88.2 | 1.5 | 41.2 | * | 2.0 | * | 2.0 |
| Utricularia spp. | 27.1 | 94.1 | 18.1 | 82.4 | 5.4 | 43.1 | 5.3 | 43.1 | 41.2 | 76.5 | 3.1 | 47.1 |
| Emergent | | | | | | | | | | | | |
| Cladium jamaicensis | .1 | 2.0 | .1 | 2.0 | - | - | | | - | - | | |
| Crinum americanum | - | - | - | - | .1 | 7.8 | .2 | 5.9 | - | - | - | - |
| Eleocharis cellulosa | .5 | 23.5 | .6 | 15.7 | 3.5 | 41.2 | 3.0 | 49.0 | .3 | 2.0 | * | 2.0 |
| Eleocharis elongata | 3.1 | 31.4 | 2.8 | 23.5 | 6.1 | 49.0 | 7.1 | 41.2 | .1 | 7.8 | 1.1 | 13.7 |
| Paspalidium paludivagum | * | 5.9 | .3 | 11.8 | - | - | * | 2.0 | - | - | - | - |
| Sagittaria lancifolia | - | - | * | 2.0 | - | - | .1 | 2.0 | - | - | - | - |
| Typha sp. | - | - | - | - | - | - | .1 | 2.0 | - | - | - | - |
| Mean # Species/0.25m2 | 2.8 | | 2.3 | | 3.1 | | 2.4 | | 1.2 | | 1.0 | |
| Total # Species | 7 | | 8 | | 7 | | 9 | | 5 | | 5 | |
| Total Plant Cover | 54.1 | | 36.1 | | 34.5 | | 26.0 | | 46.0 | | 7.9 | |

| Site | 2A3 | | | | 2A4 | | | | 2A5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevation (ft NGVD) | 9.86 | | | | 9.95 | | | | 9.70 | | | |
| Year | 1983 | | 1984 | | 1983 | | 1984 | | 1983 | | 1984 | |
| Vegetation Composition | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % | Cover % | Freq. % |
| Floating | | | | | | | | | | | | |
| Nymphaea odorata | 1.4 | 7.8 | .9 | 7.8 | - | - | - | - | 7.9 | 34.7 | 6.0 | 29.4 |
| Submergent | | | | | | | | | | | | |
| Chara spp. | .1 | 13.7 | 2.1 | 23.5 | * | 5.9 | 1.2 | 25.5 | * | 8.2 | 1.3 | 31.4 |
| Utricularia spp. | 17.1 | 56.9 | .1 | 2.0 | 42.1 | 84.3 | .1 | 2.0 | 44.8 | 87.8 | 11.5 | 78.4 |
| Emergent | | | | | | | | | | | | |
| Crinum americanum | - | - | .1 | 2.0 | - | - | - | - | - | - | - | - |
| Eleocharis cellulosa | 2.2 | 31.4 | 4.0 | 54.9 | .1 | 3.9 | .7 | 5.9 | .4 | 10.2 | .4 | 9.8 |
| Eleocharis elongata | 1.5 | 25.5 | 3.8 | 41.2 | 6.0 | 52.9 | 26.2 | 60.8 | 3.0 | 22.4 | 8.9 | 45.1 |
| Paspalidium paludivagum | .5 | 45.1 | .6 | 29.4 | .6 | 54.9 | 3.1 | 49.0 | - | - | - | - |
| Typha sp. | - | - | .1 | 2.0 | - | - | - | - | - | - | .13 | .9 |
| Mean # Species/0.25m2 | 1.3 | | 1.6 | | 2.0 | | 1.4 | | 1.7 | | 2.0 | |
| Total # Species | 6 | | 8 | | 5 | | 5 | | 6 | | 6 | |
| Total Plant Cover | 22.8 | | 11.7 | | 48.8 | | 31.3 | | 56.2 | | 28.2 | |

**APPENDIX TABLE 2.**
**Frequency and Cover of Vegetation Species on Tree Islands in WCA-2A, 1980-1984.**

**Site: Tree Island #1**
Vegetation Composition

| Species | Pre-Drawdown 1980 | Pre-Drawdown 1981 | Drawdown Years FREQUENCY (%) 1982 | Drawdown Years FREQUENCY (%) 1983 | Drawdown Years FREQUENCY (%) 1984 | MEAN COVER (%)* 1983 | MEAN COVER (%)* 1984 |
|---|---|---|---|---|---|---|---|
| Aquatics | | | | | | | |
| Nymphaea odorata | 11.8 | 3.9 | 11.8 | 11.8 | 17.6 | 2.3 | 2.8 |
| Typha spp. | 88.2 | 78.4 | 64.7 | 74.5 | 82.4 | 5.4 | 8.7 |
| Utricularia spp. | 13.7 | | 3.9 | 3.9 | 9.8 | .8 | .1 |
| Paludal Herbs and Vines | | | | | | | |
| Crinum americanum | | 2.0 | | | 2.0 | | .1 |
| Hymenocallis sp. | | 2.0 | 3.9 | | | | |
| Ipomoea sagittata | 2.0 | 2.0 | | 3.9 | 5.9 | .1 | .1 |
| Mikania scandens | | | 11.8 | 11.8 | 37.3 | .2 | .3 |
| Peltandra virginica | 3.9 | | 2.0 | | | | |
| Pontederia lanceolata | 2.0 | | | 35.3 | 23.5 | .6 | .7 |
| Sagittaria lancifolia | 11.8 | 11.8 | 15.7 | 13.7 | 19.6 | .4 | .8 |
| Sarcostemma clausa | 25.5 | | 3.9 | 33.3 | 23.5 | .5 | 1.1 |
| Sedges and Grasses | | | | | | | |
| Cladium jamaicensis | 25.5 | 27.5 | 29.4 | 29.5 | 33.3 | 6.5 | 7.7 |
| Cyperus odoratus | | 9.8 | | | 2.0 | | .1 |
| Echinochloa spp. | | 25.5 | | | | | |
| Echinochloa walteri | | 15.7 | 9.8 | | 2.0 | | .1 |
| Eleocharis vivipara | | 2.0 | | | | | |
| Eleocharis elongata | 5.9 | 5.9 | 7.8 | 7.8 | 9.8 | 1.8 | .8 |
| Leersia hexandra | | | | 3.9 | | .1 | |
| Paspalidium paludivagum | | 2.0 | 2.0 | | | | |
| Seteria geniculata | | | | | 5.9 | | .1 |
| Seteria magna | | 3.9 | 13.7 | | | | |
| Sacciolepis striata | | 23.5 | 49.0 | 33.3 | 41.4 | .5 | .7 |
| Mesophytic Forbs | | | | | | | |
| Diodia virginiana | | 2.0 | | 9.8 | 25.5 | .4 | 1.5 |
| Eupatorium capillifolium | | 2.0 | | | 7.8 | | .2 |
| Eupatorium colestinium | | 2.0 | | | | | |
| Ludwigia alata | | | | 3.9 | 3.9 | .1 | .1 |
| Ludwigia peruviana | | | | | 9.8 | | .7 |
| Pluchaea purpurascens | | | | | 5.9 | | .1 |
| Polygonum hydropiperoides | | 41.2 | 82.4 | 23.5 | 7.8 | .9 | .1 |
| Polygonum punctatum | | 64.7 | | | 15.7 | | 2.0 |
| Amaranthus cannabinus | | | | | 11.8 | | .3 |
| Ferns | | | | | | | |
| Acrosticum danaeaefolium | 3.9 | 3.9 | | | | | |
| Blechnum serrulatum | 3.9 | | | | | | |
| Osmunda regalis | | 2.0 | | | | | |
| Total Mean Herb Cover | | | | | | 2.06 | 29.2 |
| Shrubs and Trees | | | | | | | |
| Cephalanthus occidentalis | 17.6 | 31.4 | 35.3 | 33.3 | 33.3 | 23.6 | 30.2 |
| Myrica cerifera | | 2.0** | | | | | |
| Salix caroliniana | 5.9 | 3.9 | 3.9 | 3.9 | 5.9 | 9.4 | 14.3 |
| Baccharis spp. | | | | | 7.8 | | .3 |
| Total Mean Woody Cover | | | | | | 33.0 | 44.5 |
| Total # Species | 14.0 | 25.0 | 17.0 | 18.0 | 27.0 | | |
| Avg. # Species/Quadrat | 2.0 | 4.1 | 3.5 | 3.4 | 4.5 | | |

* Cover for woody shrubs obtained by line intercept method.
**Seedlings only

**APPENDIX TABLE 3.**
**Frequency and Cover of Vegetation Species on Tree Islands in WCA-2A, 1980-1984.**

**Site: Tree Island #2**
Vegetation Composition

| | Pre-Drawdown | | Drawdown Years FREQUENCY (%) | | | MEAN COVER (%)* | |
|---|---|---|---|---|---|---|---|
| Species | 1980 | 1981 | 1982 | 1983 | 1984 | 1983 | 1984 |
| Aquatics | | | | | | | |
| Chara spp. | 19.2 | | 2.0 | | 2.0 | | .3 |
| Nymphaea odorata | 2.0 | | 2.0 | 2.0 | | .1 | |
| Typha spp. | 9.6 | 9.6 | | | | | |
| Utricularia spp. | 32.7 | | 3.8 | 2.0 | | .1 | |
| Paludal Herbs and Vines | | | | | | | |
| Mikania scandens | 15.4 | 28.9 | 32.7 | 30.8 | 57.7 | .2 | .4 |
| Peltandra virginica | 59.6 | 21.2 | 61.5 | 42.3 | 48.1 | .5 | 1.4 |
| Pontederia lanceolata | 34.6 | | 2.0 | 3.8 | 5.8 | .1 | .1 |
| Proserpinaca palustris | 9.6 | 7.7 | 9.6 | 5.8 | 9.6 | .1 | .1 |
| Sagittaria lancifolia | 80.8 | 88.5 | 88.5 | 84.6 | 84.6 | 9.8 | 9.7 |
| Sarcostemma clausa | 9.6 | 19.2 | 2.0 | 13.5 | 17.3 | .1 | .1 |
| Sedges and Grasses | | | | | | | |
| Cladium jamaicensis | 92.4 | 96.2 | 98.1 | 100.0 | 98.1 | 17.8 | 15.7 |
| Dichromena colorata | 2.0 | 23.1 | | 2.0 | 7.7 | .1 | .4 |
| Echinochloa spp. | | 9.6 | 2.0 | | | | |
| Leersia hexandra | | 7.7 | | | 2.0 | | .1 |
| Panicum dichotomum | | 30.8 | 7.7 | | 3.9 | | .1 |
| Sacciolepis striata | | 5.8 | 2.0 | | 3.8 | | .1 |
| Mesophytic Forbs | | | | | | | |
| Aster carolinianus | | 2.0 | 3.8 | 3.9 | 5.8 | .3 | .1 |
| Boehmeria cylindrica | 7.7 | 25.0 | 30.8 | 15.4 | 36.5 | .1 | .4 |
| Centella asiatica | 3.9 | 44.2 | 15.4 | 11.6 | 13.5 | .1 | .1 |
| Diodia virginiana | 3.9 | 19.3 | 5.8 | 5.8 | 9.6 | .1 | .1 |
| Eupatorium capillifolium | | 11.6 | 7.7 | | | | |
| Conoclinium colestinium | | 15.4 | 21.2 | 15.4 | 17.3 | .2 | .3 |
| Hydrocotyle umbellata | | 13.5 | 11.5 | 3.8 | 19.2 | .1 | .2 |
| Lactuca spp. | | 2.0 | | | | | |
| Ludwigia alata | 3.9 | 5.8 | 7.7 | 5.8 | 2.0 | .1 | .1 |
| Ludwigia repens | 3.9 | 3.8 | | | 3.9 | | .1 |
| Pluchaea purpurascens | | 2.0 | | | | | |
| Polygonum hydropiperoides | | 3.9 | 3.9 | 2.0 | 3.9 | .1 | .1 |
| Vicia acutifolia | | 26.9 | | | | | |
| Mitreola petiolata | | | | | 3.8 | | .1 |
| Ferns | | | | | | | |
| Acrosticum danaeaefolium | 2.0 | 2.0 | | | 7.7 | | .1 |
| Blechnum serrulatum | 53.9 | 57.7 | 55.8 | 59.7 | 55.8 | 1.5 | 1.9 |
| Thelypteris palustris | 30.8 | 28.9 | 30.8 | 38.5 | 40.4 | .8 | .9 |
| | | | | Total Mean Herb Cover | | 32.9 | 33.0 |
| Shrubs and Trees | | | | | | | |
| Cephalanthus occidentalis | 31.1 | 28.9 | 44.3 | 38.5 | 40.4 | 4.5 | 9.8 |
| Myrica cerifera | 30.8 | 44.2** | 25.0 | 26.9 | 23.1 | 6.6 | 15.7 |
| Persea borbonia | | | | | | 0.3 | 0.3 |
| Salix caroliniana | | | 2.0 | | | | 0.8 |
| Baccharis spp. | | | | 2.0 | 3.9 | | |
| | | | | Total Mean Wood Cover | | 11.4 | 26.6 |
| Total # Species | 22.0 | 30.0 | 27.0 | 23.0 | 28.0 | | |
| Avg. # Species/quadrat | 5.2 | 6.8 | 5.8 | 5.1 | 6.3 | | |

* Cover for woody shrubs obtained by line intercept method
** Includes seedlings

**APPENDIX TABLE 4.**
**Frequency and Cover of Vegetation Species on Tree Islands in WCA-2A, 1980-1984.**

**Site: Tree Island #3**
Vegetation Composition

| Species | Pre-Drawdown 1980 | Pre-Drawdown 1981 | Drawdown Years FREQUENCY (%) 1982 | 1983 | 1984 | MEAN COVER (%)* 1983 | 1984 |
|---|---|---|---|---|---|---|---|
| <u>Aquatics</u> | | | | | | | |
| Typha spp. | PR | PR | PR | PR | 2.0 | .1 | .1 |
| Utricularia spp. | | | 2.0 | | | | |
| <u>Paludal Herbs and Vines</u> | | | | | | | |
| Mikania scandens | 12.0 | 26.0 | 24.0 | 26.0 | 36.0 | .2 | .2 |
| Peltandra virginica | 56.0 | 82.0 | 100.0 | 90.0 | 92.0 | 3.7 | 3.9 |
| Pontederia lanceolata | 10.0 | 10.0 | 10.0 | 12.0 | 14.0 | .6 | .5 |
| Proserpinaca palustris | 20.0 | 20.0 | 36.0 | 40.0 | 34.0 | 1.8 | .9 |
| Sarcostemma clausa | 54.0 | 68.0 | 46.0 | 31.4 | 36.0 | .2 | .2 |
| Smilax laurifolia | PR | PR | PR | 4.0 | | .1 | |
| Bacopa carolinana | | | | | 2.0 | | .1 |
| <u>Sedges and Grasses</u> | | | | | | | |
| Chlois spp. | | | | | 2.0 | | .1 |
| Cladium jamaicensis | 4.0 | 4.0 | 6.0 | 6.0 | 8.0 | .1 | .2 |
| Cyperus odoratus | | 4.0 | | | 2.0 | | .1 |
| Dichromena colorata | 24.0 | 24.0 | 4.0 | 22.0 | 28.0 | .4 | 3.8 |
| Echinochloa spp. | | 56.0 | 56.0 | 62.0 | 62.0 | 7.0 | 15.7 |
| Panicum agrostoides | 26.0 | 16.0 | 22.0 | 22.0 | 24.0 | .2 | .3 |
| Panicum spp. | | | 10.0 | 12.0 | 2.0 | .1 | .1 |
| Panicum dichotomum | 40.0 | 40.0 | 34.0 | 26.0 | 38.0 | .1 | .4 |
| Panicum hemitomon | | 12.0 | 2.0 | 2.0 | 4.0 | .1 | .1 |
| Rhynchospora microcarpa | | | | | 2.0 | | .1 |
| Unknown grass | | PR | | | | | |
| Scleria spp. | | | 4.0 | 4.0 | 2.0 | .1 | .1 |
| Eleocharis vivipara | 16.0 | 16.0 | 4.0 | 11.8 | 10.0 | .4 | |
| <u>Mesophytic Forbs</u> | | | | | | | |
| Aster carolinianus | 20.0 | 28.0 | 38.0 | 32.0 | 32.0 | .2 | .2 |
| Boehmeria cylindrica | 42.0 | 76.0 | 68.0 | 54.0 | 74.0 | .5 | 2.5 |
| Centella asiatica | 28.0 | 28.0 | 28.0 | 32.0 | 38.0 | .3 | .2 |
| Cirsium horridulum | | PR | | | | | |
| Diodia virginiana | 12.0 | 24.0 | 30.0 | 18.0 | 20.0 | .1 | .1 |
| Eupatorium capillifolium | 10.0 | 40.0 | 10.0 | | 4.0 | | .1 |
| Eupatorium colestinium | 10.0 | 24.0 | 14.0 | 4.0 | 10.0 | .1 | .1 |
| Galium obtusum | 10.0 | 16.0 | 16.0 | 6.0 | 6.0 | .1 | .1 |
| Hydrocotyle umbellata | 75.0 | 72.0 | 68.0 | 56.0 | 58.0 | .4 | .3 |
| Ludwigia alata | 14.0 | 14.0 | 18.0 | 18.0 | 22.0 | .1 | .1 |
| Ludwigia microcarpa | | | | | 2.0 | | .1 |
| Ludwigia repens | 12.0 | 8.0 | 6.0 | 6.0 | 10.0 | .1 | .1 |
| Melothria pendula | | PR | | 2.0 | 14.0 | .1 | .1 |
| Pluchaea foetida | 12.0 | 24.0 | 14.0 | 16.0 | 22.0 | .2 | .3 |
| Pluchaea purpurascens | 4.0 | 22.0 | | | | | |
| Polygonum hydropiperoides | 33.0 | PR | 10.0 | 22.0 | 12.0 | .1 | .1 |
| Vicia acutifolia | 18.0 | 18.0 | | 8.0 | 8.0 | .1 | .1 |
| Mitreola petiolata | | | | 4.0 | 4.0 | .1 | .1 |
| Teucrium canadense | | | | | 4.0 | | |
| <u>Ferns</u> | | | | | | | |
| Acrosticum danaeaefolium | 2.0 | 4.0 | | 2.0 | 2.0 | .1 | .1 |
| Blechnum serrulatum | 80.0 | 86.0 | 84.0 | 68.0 | 64.0 | 1.3 | 1.3 |
| Osmunda regalis | 46.0 | 60.0 | 48.0 | 42.0 | 56.0 | 5.0 | 3.4 |
| Thelypteris interruptus | 28.0 | 28.0 | 20.0 | 20.0 | 18.0 | .8 | 2.6 |
| Thelypteris palustris | 66.0 | 80.0 | 74.0 | 56.0 | 60.0 | .8 | .6 |
| Woodwardia virginica | | | | 24.0 | 32.0 | .3 | .4 |
| | | | | Total Mean Herb Cover | | 25.6 | 40.3 |

APPENDIX TABLE 4. (Cont'd.)

| | | | | | |
|---|---|---|---|---|---|
| Shrubs and Trees + | | | | | |
| Cephalanthus occidentalis | | | | | 2.0 |
| Myrica cerifera (seedlings) | 28.0 | 60.0 | 10.0 | 6.0 | 20.0 |
| Persea borbonia (seedlings) | 2.0 | 2.0 | 8.0 | | 6.0 |
| Baccharis spp.(seedlings) | | PR | PR | PR | 2.0 |
| Total # Species | 35.0 | 33.0 | 33.0 | 37.0 | 46.0 |
| Avg. # Species/quadrat | 9.1 | 11.5 | 9.2 | 8.7 | 10.0 |

+ See Table for detailed information

APPENDIX TABLE 5.

**Discriminant Function Coefficients Separating Water Quality Site Groupings. Variables Listed Below were the Most Important Identifying Water Quality Differences Among Sites.**

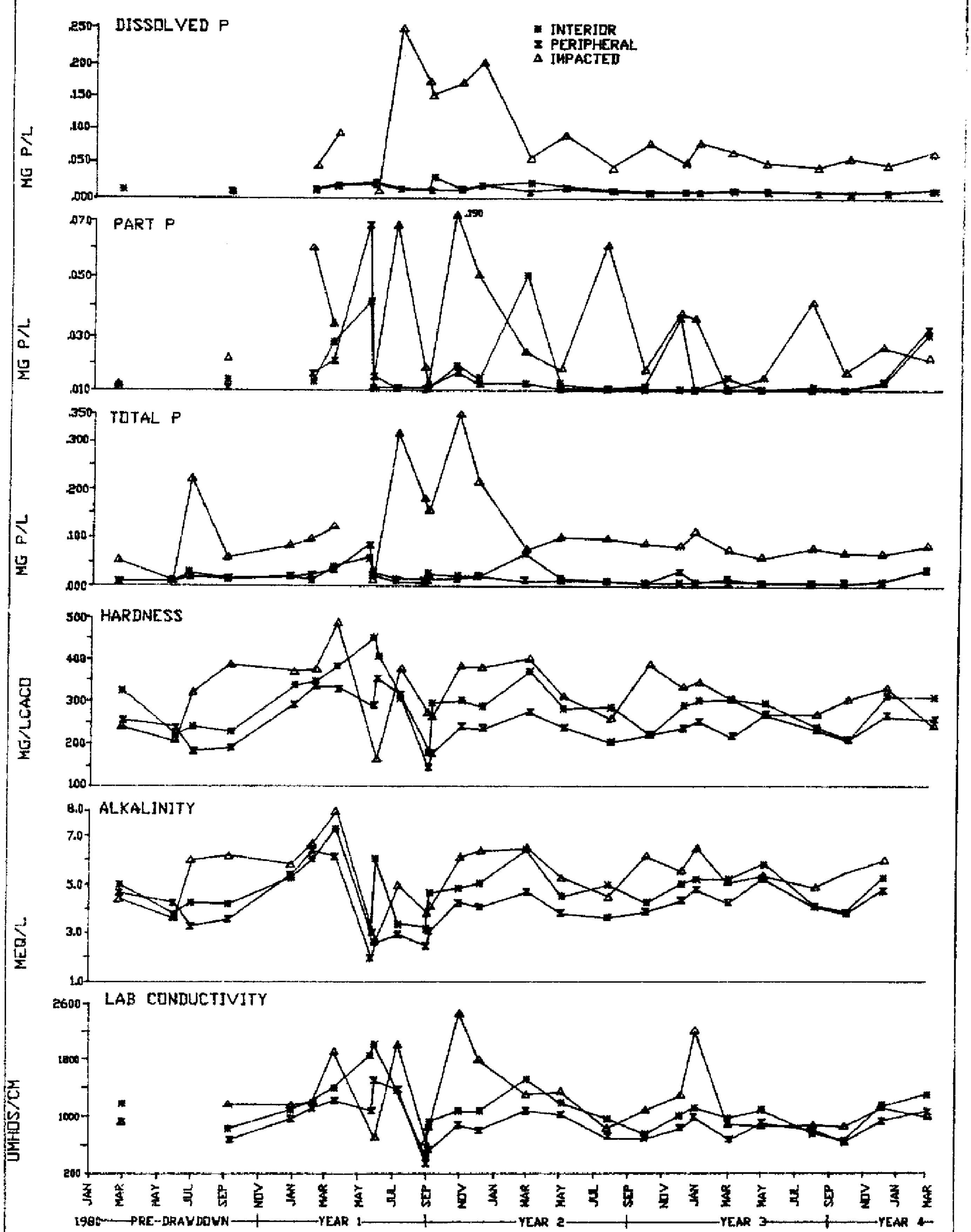
| Discriminant Function | I | II |
|---|---|---|
| Canonical Correlation | .758 | .280 |
| Explained Variation (%) | 94.1 | 5.9 |
| Cumulative Explained Variation (%) | 94.1 | 100.0 |
| **Discriminant Variables** | **Standardized Function Coefficients** | |
| Mg | .250 | .779 |
| Total N | -.246 | .366 |
| Total P | .236 | -.231 |
| $NO_3$ | .034 | -.093 |
| $PO_4$ | .237 | .103 |

**APPENDIX TABLE 6.**
**Discriminant Function Analysis Comparing Changes in Water Quality Over Time. Variables Listed Below Were the Most Important in Identifying Water Quality Differences Resulting from Marsh Drawdown and Reflooding.**

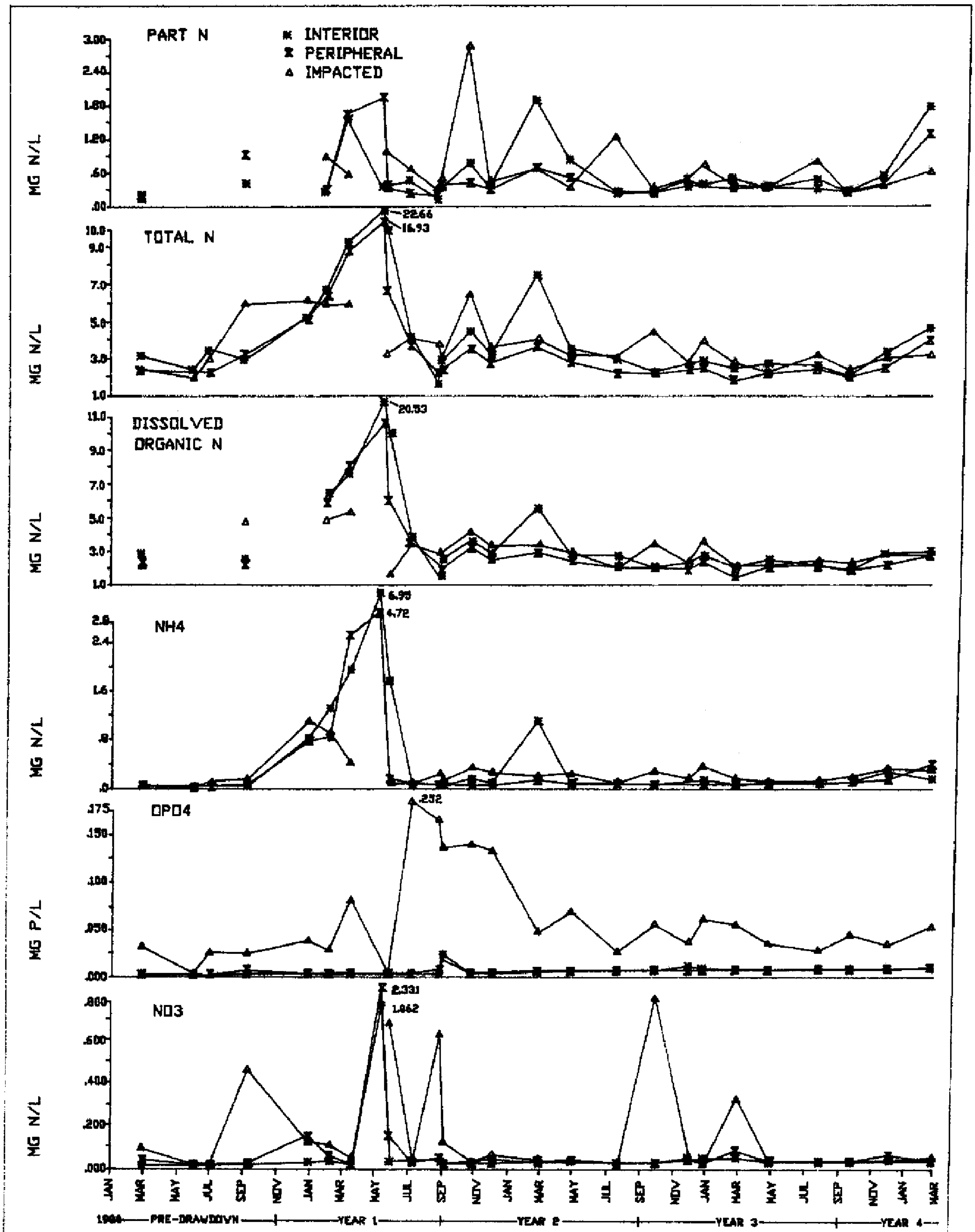
| | | |
|---|---|---|
| **Discriminant Function** | I | II |
| Canonical Correlation | .764 | .610 |
| Explained Variation (%) | 60.7 | 25.7 |
| Cumulative Variation (%) | 60.7 | 86.4 |
| | Function Coefficients | |
| **Discriminant Variables** | | |
| Total N | -.481 | -.853 |
| $NH_4$ | -.215 | .137 |
| Alkalinity | -.269 | 1.610 |
| Total P | .102 | -.070 |
| Cl | .014 | .689 |
| Ca | .139 | -1.101 |
| Mg | .221 | -.427 |

**APPENDIX TABLE 7.**
**Discriminant Function Coefficients (Standardized) Associated with Variables Separating Tree Island, Sawgrass, and Slough Soils over Time**

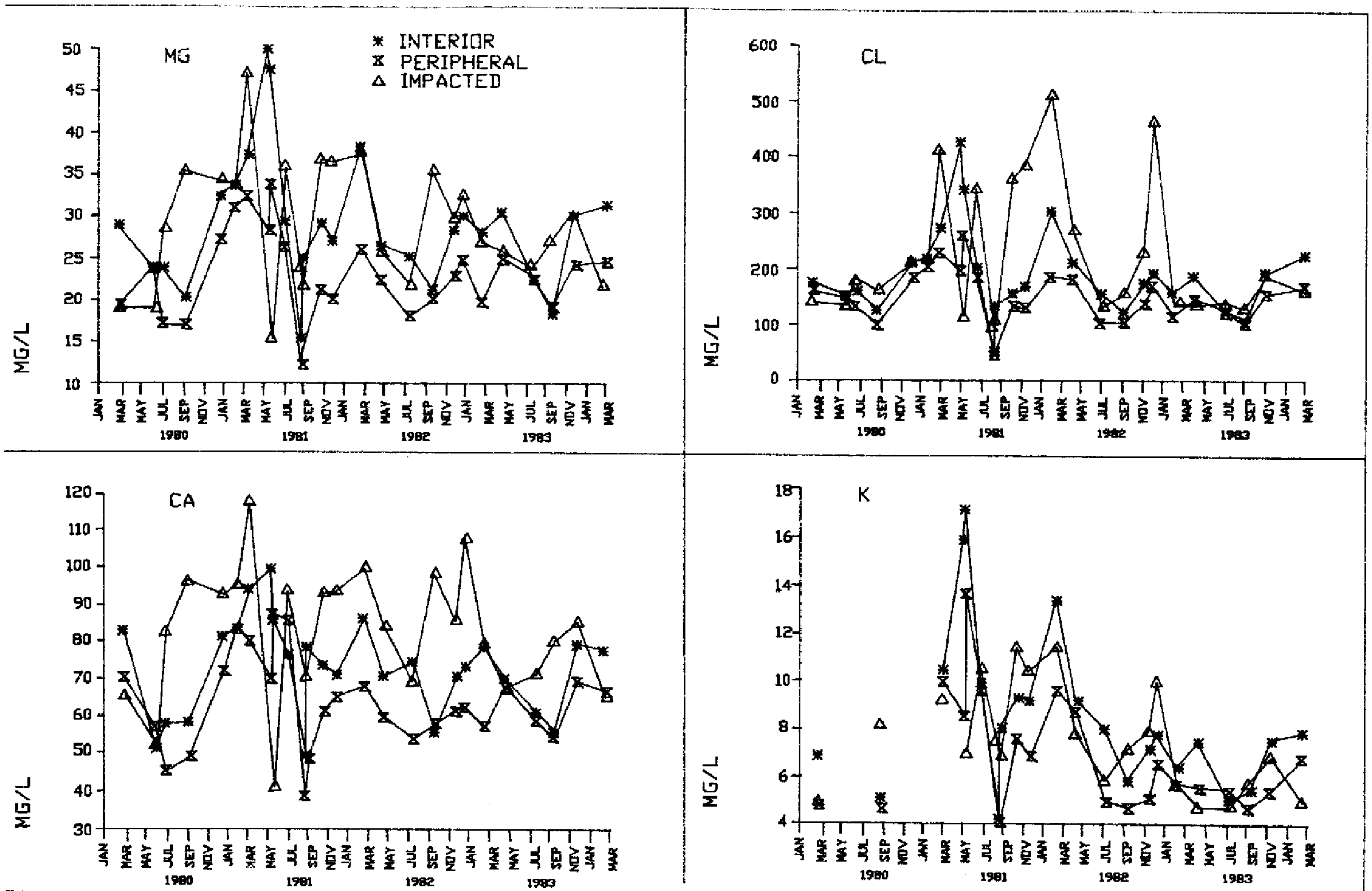
| Sites: | Tree Islands | | Sawgrass | | Sloughs | |
|---|---|---|---|---|---|---|
| **Discriminant Function** | I | II | I | II | I | II |
| Canonical Correlation | .952 | .629 | .921 | .781 | .900 | .600 |
| **Percent Variance** | | | | | | |
| Explained by Functions | 90.4 | 6.2 | 70.5 | 19.6 | 80.0 | 10.7 |
| Cumulative Variance Explained | 90.4 | 96.6 | 70.5 | 90.1 | 80.0 | 90.7 |
| | Standardized Function Coefficients | | | | | |
| **Discriminant Variables** | | | | | | |
| K | .558 | .004 | .462 | -.325 | .626 | .025 |
| Total N | -.014 | -3.085 | -.494 | -.549 | -.188 | -1.587 |
| Ca | .179 | .080 | -.230 | -1.373 | .124 | -.504 |
| Total P | -.050 | -.733 | .028 | .131 | .003 | -.450 |
| Mg | | | .055 | -.046 | -.361 | -.167 |




APPENDIX FIGURE 1. WATER CHEMISTRY PHYSICAL PARAMETERS: FEB 1980-MAR 1984.




APPENDIX FIGURE 2. WATER CHEMISTRY NUTRIENTS: FEB 1980–MAR 1984.




APPENDIX FIGURE 3. WATER CHEMISTRY CATIONS: FEB 1980–MAR 1984.