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November 1, 1980 - December 31, 1981

PRELIMINARY ENVIRONMENTAL RESPONSES TO MARSH DE-WATERING AND REDUCTION IN WATER REGULATION SCHEDULE IN WATER CONSERVATION AREA—2A

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PROGRESS REPORT

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NOVEMBER 1, 1980 - DECEMBER 31, 1981

By

DEWEY WORTH

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Environmental Sciences Division
Resource Planning Department
South Florida Water Management District

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EXECUTIVE SUMMARY

The hydrologic cycle of the Everglades has historically oscillated between extremes of flood and drought. Levee impoundment and effective surface water storage in Water Conservation Area 2A (WCA-2A) has altered this cycle by increasing water depth and duration of flooding. Resulting undesirable ecological changes include (1) loss of certain plant communities (wet prairies and tree islands), (2) accumulation of flocculent plant detritus (gyttja) in sloughs, (3) creation of more open water habitats, and (4) a decline in wildlife utilization (chiefly wading birds).

This study will evaluate alterations in WCA-2A stage regulation as a management tool for stimulating regrowth of certain marsh plant communities. The present 13.0-14.5 ft msl schedule would be reduced to 9.5-12.5 ft msl for a three year period. Under the revised schedule, an annual reduction of water levels would expose marsh soils and permit regrowth of certain plant species. This report discusses changes in plant community characteristics, soil nutrients and water quality following the first year of the revised regulation schedule.

Marsh dewatering began 1 November 1980 and continued into the spring of 1981. Of the total outflows, approximately 50% (62,803 acre-ft) was directed to WCA-3A, 22% (27,401 acre-ft) to WCA-2B and the remaining 28% (35,042 acre-ft) was used to meet water supply needs for the east coast.

Water levels at the centrally located 2-17 gauge receded below ground on 29 March 1981 and remained below ground approximately 100 days. While a large portion of WCA-2A was dry during this interval, drying was not complete in the south central section where water ponded in the center of sloughs or remained just below ground surface.

Reflooding of the marsh began gradually in July until arrival of tropical storm Dennis on 16 August. Heavy rainfall and inflows from WCA 1 caused stage to rise rapidly, reaching 12.65 ft msl on 10 September. Although the stage in WCA-2A at this time was well above the revised schedule, the schedule was not adhered to as water supplies were conserved due to a water shortage caused by the preceding year's drought.

Prior to dewatering, aquatic slough vegetation was dominated by bladderwort (Utricularia spp.) and white water lily (Nymphaea odorata). Emergent vegetation was sparse, and composed primarily of two flood tolerant species, slender spikerush (Eleocharis elongata) and Paspalidium paludivagum.

After initial drying, two new wet prairie species, beakrush (Rhynchospora tracyi) and maidencane (Panicum hemitomon) became established at one of the slough transects but were present in only 2% of the samples. Poor recruitment of these wet prairie indicator species may be attributed to inadequate drying throughout most of the interior marsh. Where drying was more complete, adjacent to L-35B and L-36, a number of terrestrial and annual plants colonized these areas, including some important waterfowl food plants. Other changes in slough vegetation composition included the temporary elimination of bladderwort and a substantial reduction in the white water lily standing crop.

Sloughs documented after marsh reflooding generally showed a resurgence in growth of aquatic vegetation. However, changes in emergent growth were most apparent in the southern portion of the marsh where soils had dried thoroughly. Dense monocultures of spikerush (Eleocharis cellulosa) and Paspalidium paludivagum developed in sloughs (adjacent to the S-11 structures) that were dominated by submergents prior to the drawdown.

Three tree island sites studied, represented (1) a drowned island, dominated by cattail (Typha sp.), (2) an island inundated for a shorter period annually, and dominated by shrubs and sawgrass (Cladium jamaicensis), and (3) a live tree island of dahoon holly (Ilex cassine) and wax myrtle (Myrica cerifera).

Following reduction in water levels, newly established plant species on tree islands consisted mainly of grasses and herbs. However, the majority of these species were drowned when tree islands reflooded.

To reduce the threat of wildfires during the initial drawdown, a controlled sawgrass burning program was implemented by Florida Game and Freshwater Fish Commission in October 1980. Regrowth of burned sawgrass was monitored at four sites representing a wide range of ground elevations, hydroperiod, and depth of flooding. Although the period of exposure and degree of soil drying differed among sites, regrowth following burning was similar. Average culm density increased after burning and was greatest during dry marsh conditions, partially attributed to new seedling growth. Reflooding drowned newly emerging sawgrass seedlings, but was later offset by new culm production through rhizomes and suckers. Culm density increased 60 percent after one year following burning and reduction in water level.

Several changes in soil fertility and water quality coincided with the drawdown and reflooding of the marsh. During the dry marsh phase, cations (Mg^{++}, Ca^{++} and K^{+}) and nutrients (N and P) in slough soils increased probably due to mineralization of gyttja. Following reflooding, soil nutrients and cations continued to remain higher in concentration than before the drawdown.

Surface water nutrients and ion concentrations increased as water levels declined during the initial drawdown. Dissolved organic nitrogen and inorganic ammonia increased substantially, together with major ions (Ca^{+}, Mg^{+}, and Cl^{-}), resulting in higher conductivities, alkalinity, and hardness. Immediately following reflooding, major ions and nutrients, particularly phosphorus, increased initially, but declined to pre-drawdown levels as the stage increased from rainfall and other inflows.

INTRODUCTION

Water Conservation Area 2 (WCA-2) is one of three large impoundment areas 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 which encompass about one half of the original Everglades. The ecology of this region has been altered through attempts to drain the land beginning in the 1900's (Davis, 1943). Although overdrainage occurred in many areas, the hydrologic cycle continued to include long periods of flooding with intermittent drying (Parker et al., 1955). More recently, impoundment of the marsh, together with the effective storage of surface water, has reduced the frequency of drying in WCA-2A. A shift in plant community composition to species favoring both longer hydroperiods and deeper water conditions has occurred. Other undesirable ecological changes that have occurred include an accumulation of flocculent plant detritus (gyttja), decline in wildlife utilization (principally wading birds), and creation of open water habitats replacing wet prairie communities.

The purpose of this study is to stimulate regrowth of wet prairie and tree island communities by simulating natural drying through alteration of the regulation schedule in WCA-2A. Simulating natural drying of the marsh would provide other benefits including 1) improved soil fertility by aeration of sediments, 2) compaction of organic debris, and 3) increased wildlife use. Similar techniques 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). Results of this study will be used to evaluate the applicability of drawdown, by alterations in stage regulation, as a management

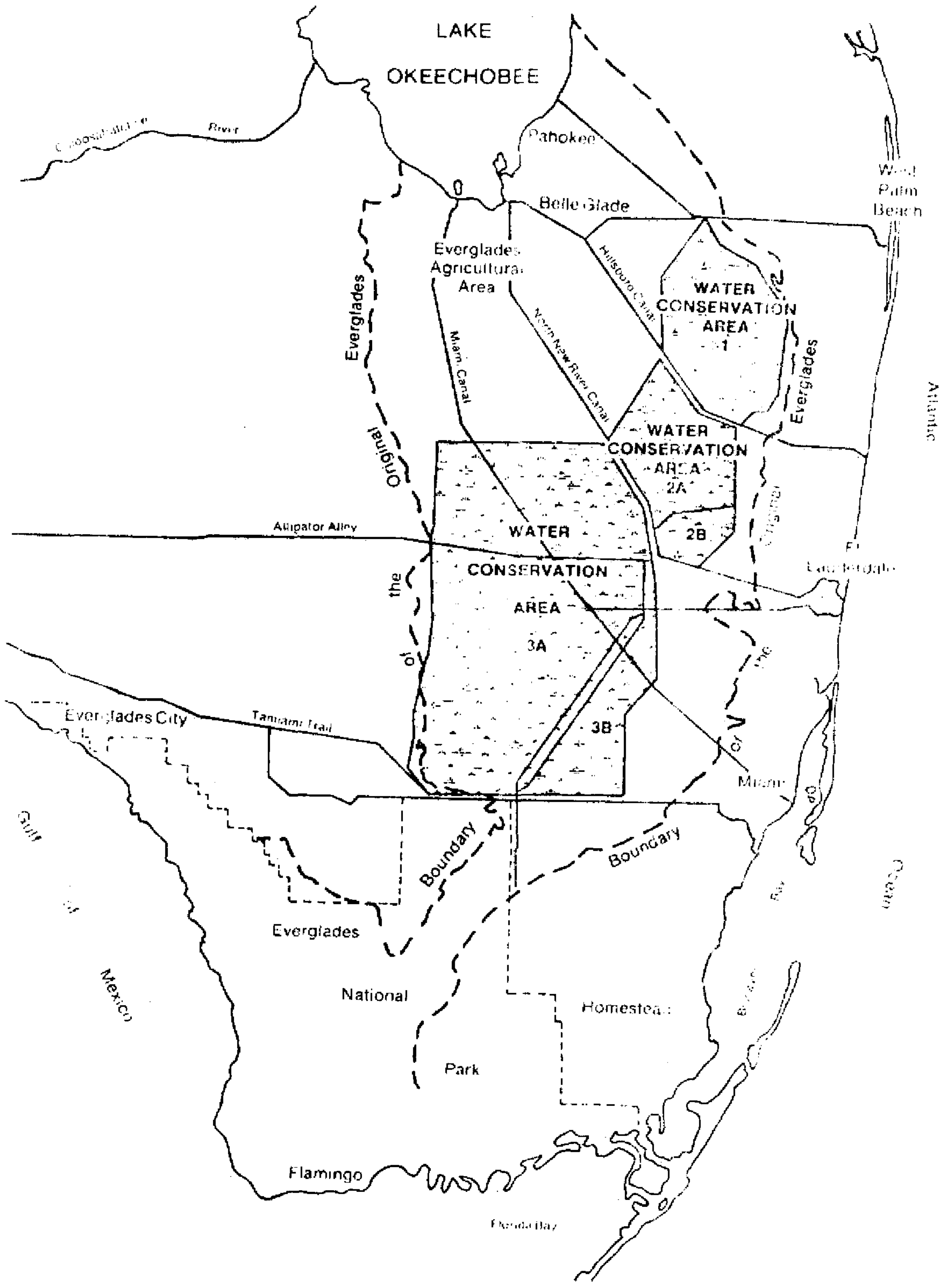


Figure 1 **LOCATION OF EVERGLADES WATER CONSERVATION AREAS AND BOUNDARY OF ORIGINAL EVERGLADES IN SOUTH FLORIDA. (Adapted From Smith, 1968)**

tool in maintaining or enhancing Everglades ecology. Consequently, a three year change in the water regulation schedule (from 13.0-14.5 ft msl to 9.5-12.5 ft msl) was initiated in November 1980.

BACKGROUND

Marsh Impoundment and Water Storage

Drainage attempts in the Everglades began in 1907 following formation of the Everglades Drainage District. Under legislative authorization, four major canals, the Hillsboro, South New River, North New River, and Miami, were completed by 1921. These canals traversed the Everglades interior, linking Lake Okeechobee with the coast, and provided a virtually uninterrupted drainage conveyance. During dry conditions these canals may have lowered ground water levels by as much as six feet throughout the Everglades and substantially increased surface water runoff (Leach et al., 1972).

As drainage of the Everglades basin proceeded, agricultural and urban development increased, resulting in greater flood risk during storm events and increased water demand during the dry season. In 1948, the Army Corps of Engineers proposed a comprehensive water control program which included the creation of three Water Conservation Areas within the Everglades basin. The system utilized levees and canals operating in conjunction with Lake Okeechobee to control and regulate water levels. With increased water demand from agricultural and urban development, the Water Conservation Areas have become vital water storage facilities.

Impoundment of the marsh creating WCA-2 was completed in 1958 (U.S. C.O.E., 1958). The eastern perimeter was formed by L-36, the northwest by L-6, and southern enclosures by L-35 and L-35A (Figure 2). The western enclosure made use of US Highway 27 while the northeast enclosure utilized the Hillsboro Canal. Later, in 1961, additional levees were completed paralleling US Highway 27 (L-38) and the Hillsboro Canal (L-39).

Initially, the water storage capability of WCA-2 was only moderately successful. A large portion of the area dried seasonally. Hydrologic studies revealed that high seepage losses occurred through a highly porous underlying rock strata (U.S.C.O.E., 1958) in the southern third of WCA-2. An additional levee (L-35B) was subsequently completed in 1961 to isolate this highly porous section. Construction of L-35B separated WCA-2 into two pools, the larger designated WCA-2A (247 km^2) and the smaller WCA-2B (91 km^2). Separating the "leaky" southern portion of the pool made it possible to better regulate the quantity of water stored in WCA-2A.

Changes in Hydrology and Vegetation

Water level records from two locations in WCA-2, gauge 2-17 (ground elevation 11.1 ft msl) and gauge 2-21 (ground elevation 6.4 ft msl) (see Figure 2), were compiled and hydrologic conditions expressed by stage exceedence curves for the period of record 1952-1979 (Figures 3a and 3b). A combination of climatic and man induced influences produced four distinct water regimes.

a. Period 1952-1960 (Pre-L-35B Hydrology)

During this period, levee construction around WCA-2 was proceeding but water levels were not well regulated or controlled. The hydroperiod at the centrally located 2-17 gauge was characterized by periodic drying with an inundation frequency of 78% and water depths $\leq$1.0 ft throughout most of the year (water depths $>$1.0 ft occurred 18% of the time).

In contrast, stage data from the 2-21 gauge, located in the extreme south end of WCA-2, shows ponding of water occurred after L-35 interrupted

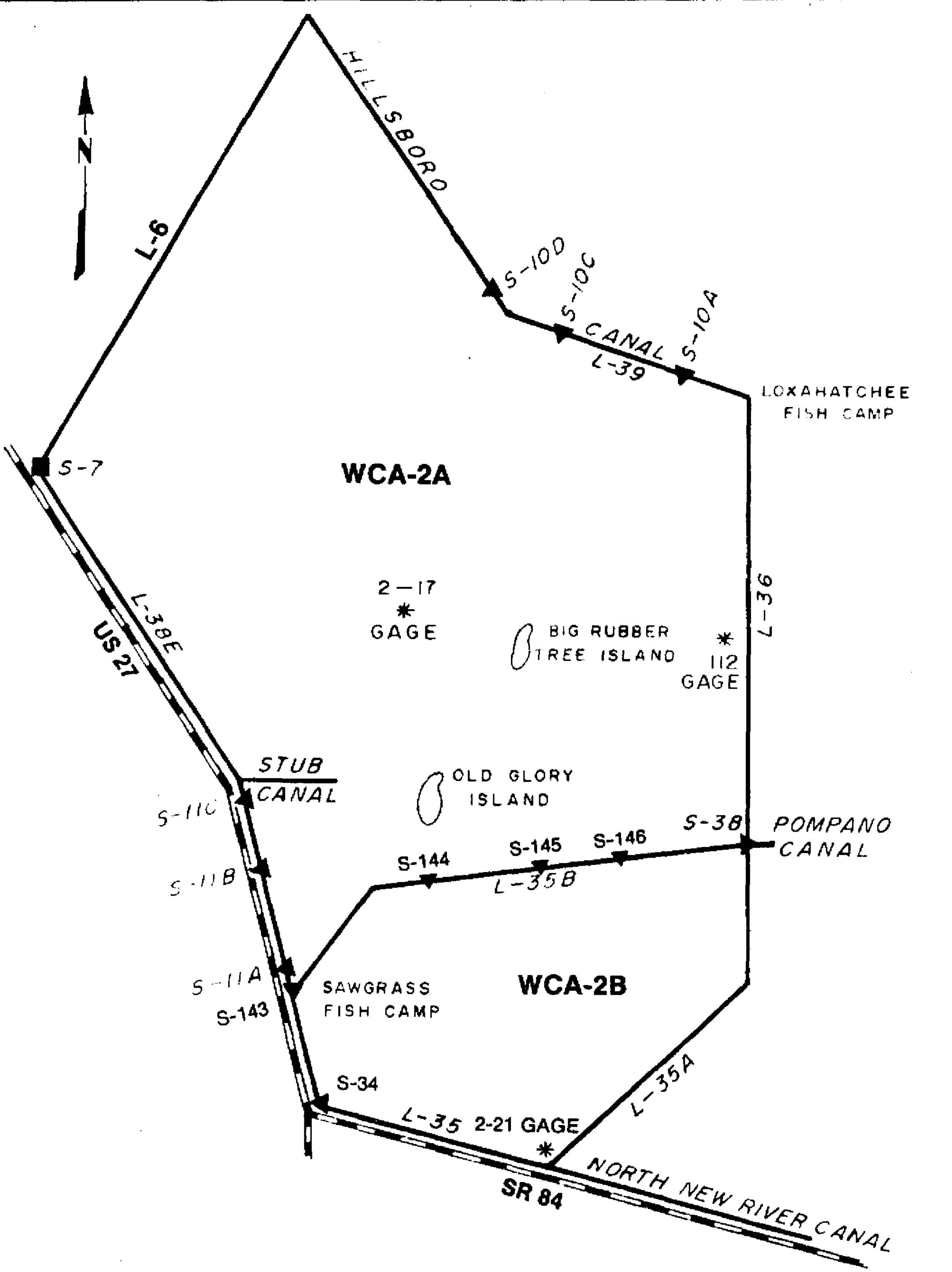
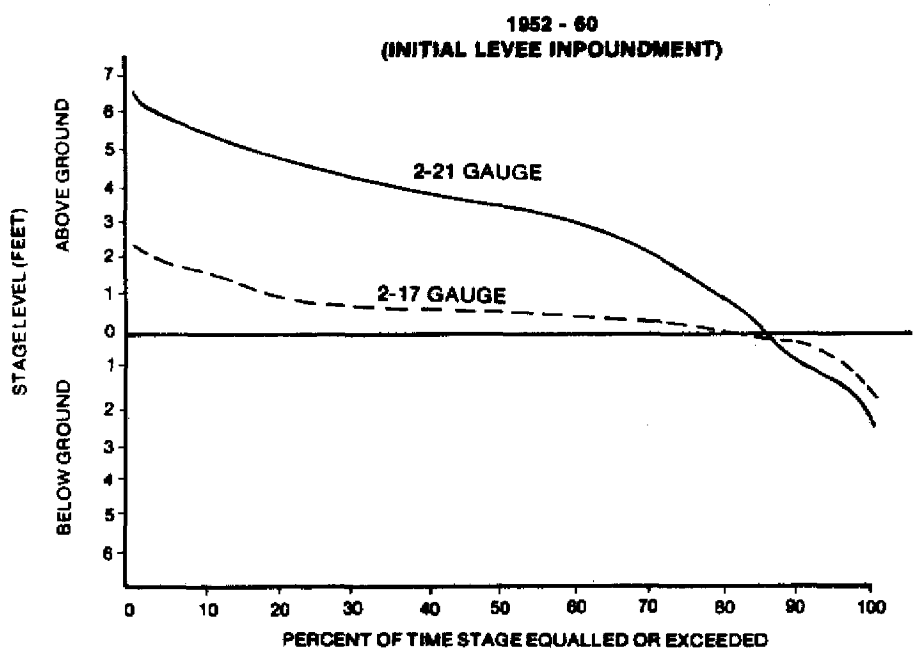
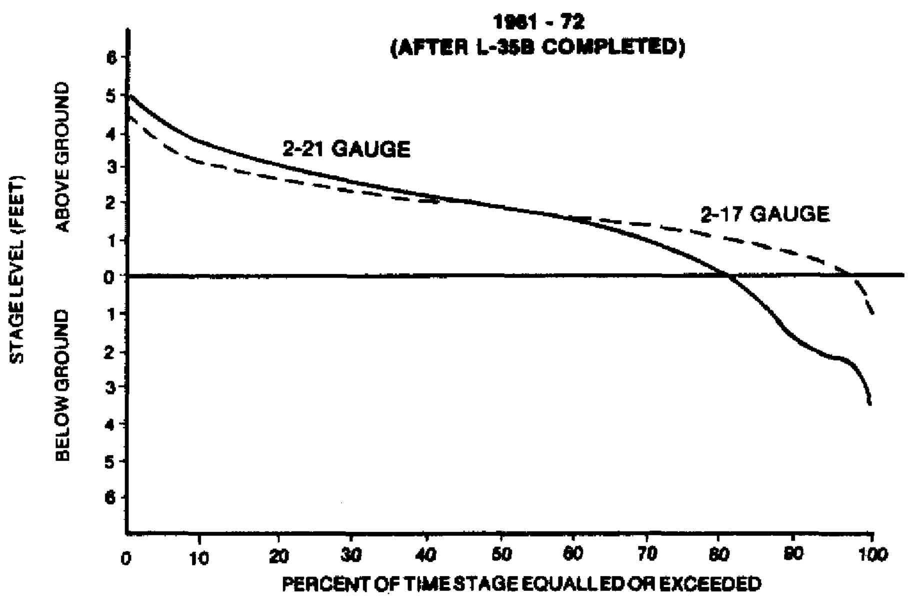


Figure 2 **LEVEES, WATER CONTROL STRUCTURES, AND STAGE RECORDING GAUGES OF WCA-2A AND WCA-2B**



NUMBER DAYS ANNUALLY STAGE AT OR BELOW GROUND

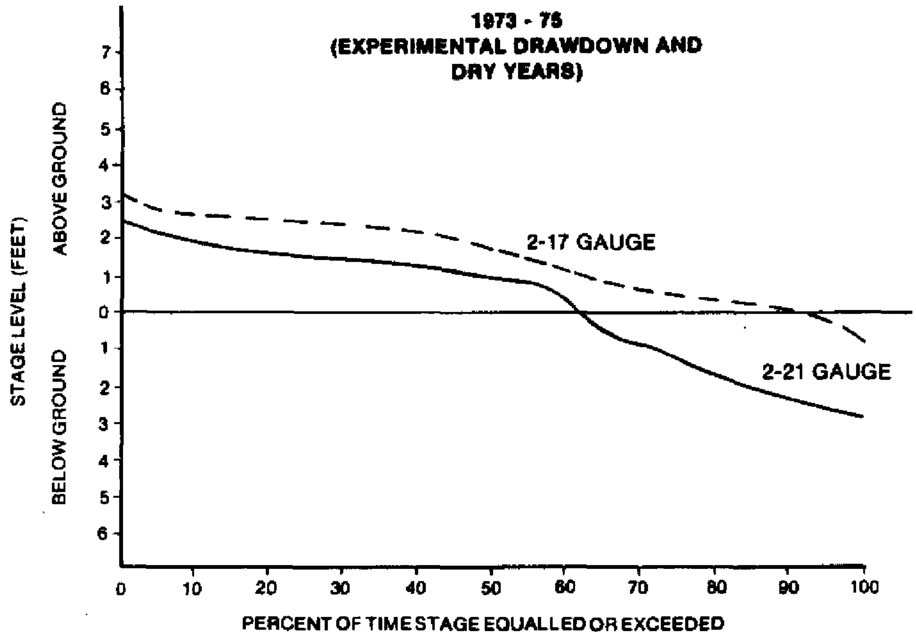
YEAR	GAUGE 2-21	GAUGE 2-17
1952	196	-
53	60	-
54	0	0
55	10	110
56	151	256
57	107	108
58	0	0
59	0	0
60	0	15



NUMBER DAYS ANNUALLY STAGE AT OR BELOW GROUND

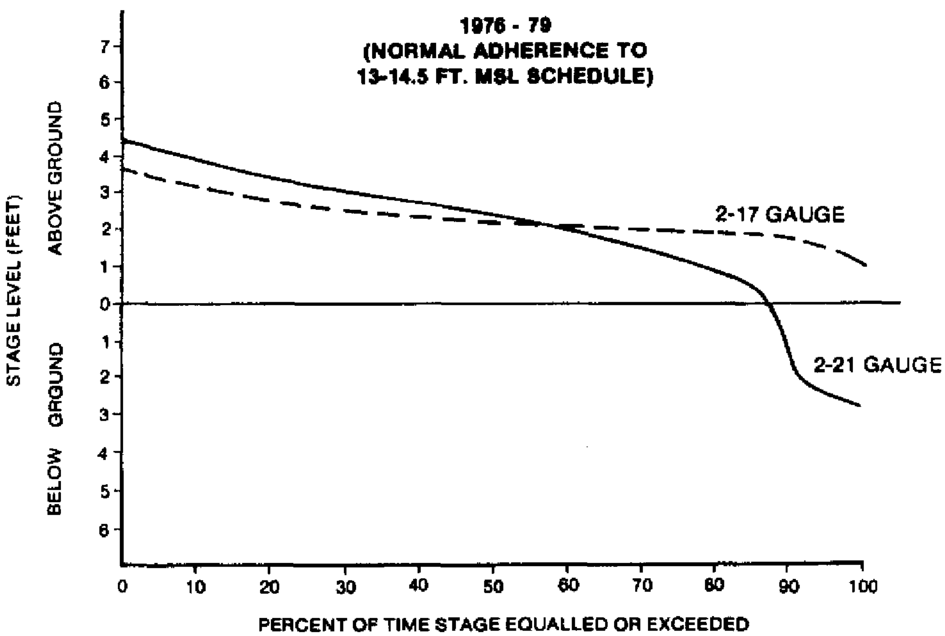
YEAR	GAUGE 2-21	GAUGE 2-17
1961	22	0
62	199	70
63	136	0
64	117	0
65	82	0
66	26	0
67	47	0
68	37	0
69	0	0
70	0	0
71	171	47
72	36	0

Figure 3a **STAGE LEVEL PERCENT EXCEEDENCE CURVES FOR WCA-2 FOR THE PERIOD OF RECORD 1952-75 AND 1961-79**



NUMBER DAYS ANNUALLY STAGE AT OR BELOW GROUND

	GAUGE	
YEAR	2-21	2-17
1973	180	71
74	157	13
75	127	12



NUMBER DAYS ANNUALLY STAGE AT OR BELOW GROUND

	GAUGE	
YEAR	2-21	2-17
1976	100	0
77	123	0
78	18	0
79	0	0

Figure 3b **STAGE LEVEL PERCENT EXCEEDENCE CURVES FOR WCA-2 FOR THE PERIOD OF RECORD 1973-75 AND 1976-79**

surface water flow to the south. The surrounding marsh at this gauge was inundated 85% of the time during this period and extreme water depths >5.0 ft occurred 20% of the time.

The impact of levee construction and initial ponding of water on vegetation during this period is not known. Loveless (1959) described four basic plant communities present in WCA-2; sloughs, wet prairies, tree islands and sawgrass marsh. Each of these plant communities occurred throughout the Everglades more or less dependent on inundation frequency, although soil type and water quality were also considered important to their development (Davis, 1943).

Extensive wet prairies characterized by either maidencane (Panicum hemitomon), spikerush (Eleocharis cellulosa), or beakrush (Rhynchospora tracyi), were present in the east-central portion of WCA-2 where periodic drying occurred. Loveless (1959) noted that some of these wet prairie communities might have resulted from lowered water tables following previous drainage attempts.

Sloughs were characterized as natural drainage channels that remained wet throughout the year. Water lily (Nymphaea odorata) or floating heart (Nymphoides aquatica) generally dominated with wet prairie species present near the margins. The submergent bladderwort (Utricularia sp.) was also prominent.

Tree islands, formed on peat mounds or rock outcrops above the surrounding marsh, were dominated by dahoon holly (Ilex cassine), wax myrtle (Myrica cerifera), and red bay (Persea borbonia).

Sawgrass (Cladium jamaicensis) comprised the majority of plant cover, occurring in pure stands or intermixed with other emergents like flag (Sagittaria lancifolia), pickerelweed (Pontederia lanceolata), and arrow-arum (Peltandra virginica).

b. Period 1961-1972 (Post L-35B Hydrology)

Following completion of L-35B in 1961, water management guidelines were adopted for the two newly created areas (WCA-2A and WCA-2B). WCA-2A was principally used for water storage, since more effective water regulation was possible with the porous rock strata isolated in WCA-2B. The initial stage regulation schedule for WCA-2A varied seasonally between 12.0-14.5 ft msl (Figure 4). In 1972, the minimum was increased from 12.0 to 13.0 ft msl to enhance fisheries potential (U.S. C.O.E., 1972). Because of the high seepage losses in WCA-2B, no attempt was made to strictly regulate water levels, although a regulation schedule was adopted which varied seasonally between 8.0 - 10.5 ft msl (Figure 4).

Stage exceedence curves for this time period show that inundation frequency increased from 76% to 97% at the 2-17 gauge, with a corresponding increase in water depth. During this time, the marsh dried briefly in 1962 and 1971, but otherwise remained continuously flooded throughout the intervening eight years. In contrast, the impounded marsh in WCA-2B frequently dried after it was separated from the upper watershed, with rainfall the primary source of water. Inundation frequency at the 2-21 gauge declined during this period from 85% to 81%.

The greater frequency of inundation in WCA-2A had a significant impact on the area plant communities. Dineen (1972; 1974) summarized changes that had taken place, which 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.

Period 1973-1975 (Experimental Drawdown)

An experimental drawdown of WCA-2A water levels was undertaken in February 1973 to reverse or alleviate undesirable effects of prolonged

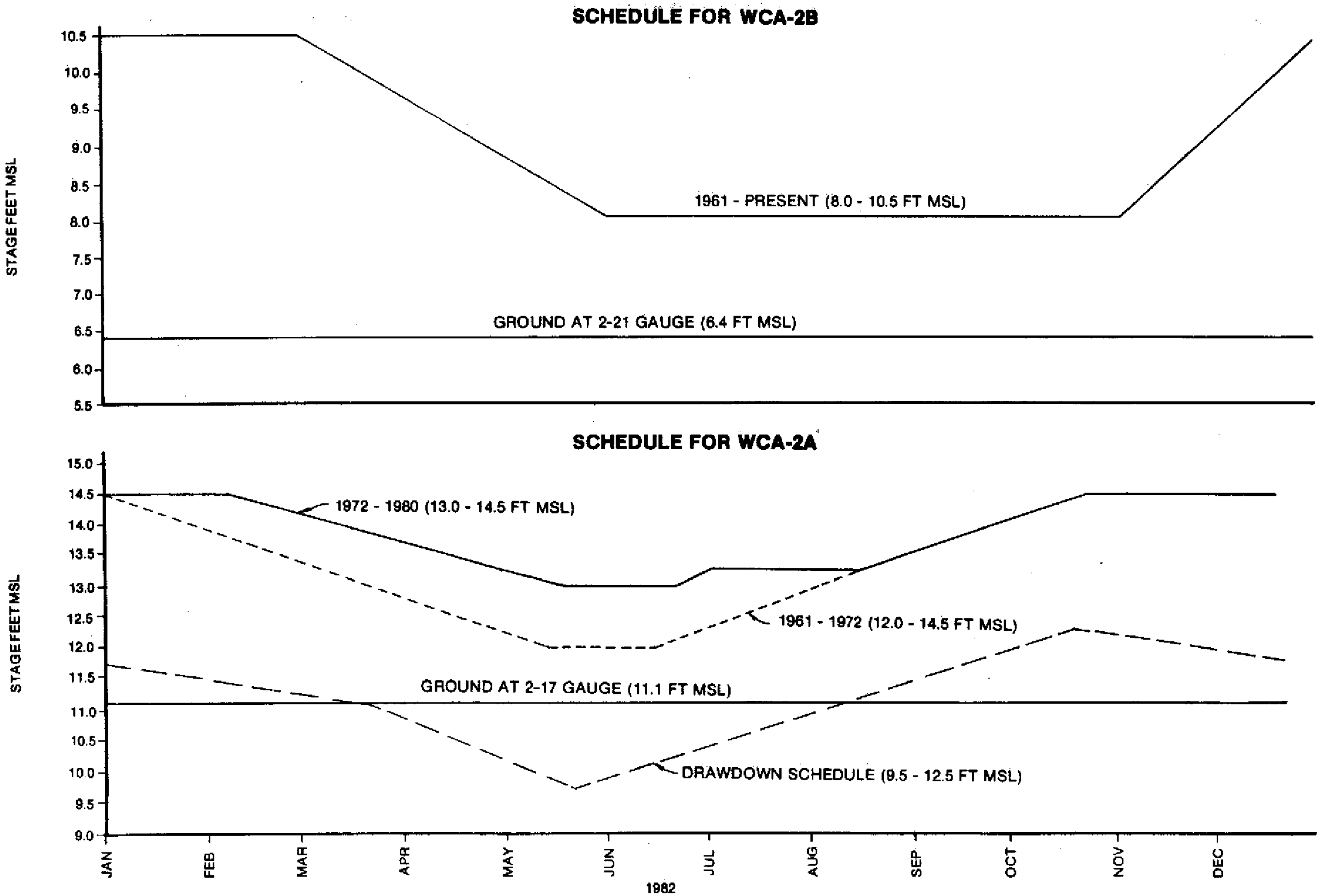


Figure 4 HISTORICAL AND MODIFIED SEASONAL REGULATION SCHEDULES FOR WCA-2A AND WCA-2B.

flooding. The purpose of the drawdown was to simulate natural drying conditions that occurred prior to L-35B construction and promote regrowth of wet prairies and tree islands. Water level at the 2-17 gauge first receded below ground in May, where it remained for approximately 71 days.

Following the 1973 drawdown, low rainfall amounts over the next two years (1974-1975) resulted in lower water levels and the marsh again dried briefly. Figure 3b shows the stage duration curves for this period.

The 1973 drawdown began too late in the year for the marsh to dry sufficiently before reflooding by summer rains. However, the drawdown was partially successful in stimulating regrowth of some wet prairie species (beakrush and maidencane) on drier sites and woody species (willow, buttonbush, and wax myrtles) on tree islands (Dineen, 1974). Partial drying also helped to consolidate accumulated detritus (gyttja) within sloughs in many areas. Other drawdown benefits included reappearance of Everglade kites in WCA-2A, and a large number of wading birds were observed feeding on small fish as water levels receded (Kushlan, 1974).

d. <u>Period 1976-1979</u> (Post-Drawdown)

Between 1976-79, water levels in WCA-2A remained above ground level throughout most of the pool; the depth and duration of flooding resembling conditions that followed completion of L-35B. Figure 3b compares the stage duration curves during this period at the 2-17 and 2-21 gauge.

Prolonged inundation and increased water depth continued to influence marsh plant communities. Regrowth of wet prairie species that occurred after marsh drying from 1973-1975, declined during the following years. Sloughs were dominated by water lily and bladderwort. Gyttja again accumulated several inches deep, overlying bottom soils. Live tree island communities remained restricted to the highest elevations in the northern apex of the area

(McPherson, 1973; Alexander and Crook, 1974; Gleason et al., 1975; Stone, 1978), while most of the drowned tree islands primarily supported a dense growth of cattail. Although sawgrass plant cover remained extensive throughout WCA-2, cattail had become more prominent in several localities.

In WCA-2B, wet prairie communities have continued to thrive under the alternating wet and dry periods. This area also supports large wading bird populations attracted by the concentration of forage food within small pools as water levels recede annually. However, the shorter hydroperiod has also permitted the exotic tree, Melaleuca quinquenervia, to establish and it is now prominent in WCA-2B.

Study Objectives

Results of the 1973 drawdown indicated that alterations in the water regulation schedule could be a successful management tool for restoration or enhancement of WCA-2A marsh. This study will implement a similar change in regulation schedule with the following objectives: (1) consolidate and oxidize sediments by drying marsh soils, (2) stimulate seed germination of certain "wet prairie" plant species, (3) maintain a hydroperiod suitable for wet prairie development, (4) promote regrowth of woody species on drowned tree islands, and (5) wildlife habitat enhancement.

To accomplish these goals a lower regulation schedule was adopted for a three year period, with annual drawdown of water levels to begin each November. The new schedule will follow a seasonal regulation, proposed by Dineen (1974), varying from 9.5 - 12.5 ft msl (Figure 4) as a hydroperiod associated with former wet prairie development. A lower schedule would also promote regrowth of woody species on drowned tree islands and enhance sawgrass. Water levels would decline throughout the normal dry winter season and expose marsh soils by early spring. The marsh would then remain dry until the rainy season begins. Water normally stored in WCA-2A will be routed to WCA-3 or WCA-2B.

As water levels recede annually under the new schedule, a reduction in sport fish abundance within the marsh is expected; however, wading birds will be attracted to the shallow waters as small fish and other forage organisms concentrate in pools. Larger fish will find refuge in peripheral canals and redistribute over the area as the marsh refloods. Improved spawning habitat by the compaction of flocculent plant detritus should promote increased small fish populations, providing a renewed food supply for wading birds as water levels recede again the following spring.

A monitoring program was established to document changes in vegetation composition and other components of the WCA-2A ecosystem commensurate with the stage regulation change. Slough and tree island plant communities were documented prior to the drawdown as a baseline for comparisons. Slough/wet prairies in WCA-2B were additionally monitored to compare the community structure associated with a "wet prairie" hydroperiod. Regrowth of burned sawgrass was also monitored. Other monitoring programs including fish populations, benthic and aquatic macroinvertebrates, as well as attempts to control Melaleuca, have been undertaken. These results will be presented in later reports.

GENERAL STUDY AREA DESCRIPTION

Water Inflows, Outflows and Quality

The largest single source of water to WCA-2A is rainfall which accounts for 43% of the total annual input (Millar, 1981). Other inflows include Everglades agricultural area basin runoff conveyed through S-7 and discharges from Water Conservation Area 1 through the S-10 structures (Figure 2). Outflows are made through the S-11 structures located in the south end of L-38E, S-143, the culvert structures in L-35B (S-144, 145, 146), and S-38.

Inflows into WCA-2B, other than rainfall, are through S-141 and L-35B culvert structures. Major outflows are evapotranspiration and percolation through the porous rock strata.

Water quality of WCA-2A surface inflows is characterized by high concentrations of both nitrogen and phosphorus. Where inflow water is forced across marshland, nutrient concentrations are rapidly reduced over a short distance from the entry source (Gleason, 1974; Millar, 1981; Swift, 1981). 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).

Topography and Soils

Ground elevations in WCA-2A range from approximately 13 ft msl at the north end to 10 ft msl adjacent to L-35B, with slightly lower elevations (8 ft msl) adjacent to the S-11 structures at the south end (Figure 5). Surface elevations in WCA-2B also decline from north to south ranging from 10 to 6 ft msl.

Two distinct peat soil types are prevalent in WCA-2: Everglades and Loxahatchee peats. Decomposition products of sawgrass comprise the bulk of Everglades peat, while derivatives of slough vegetation (*Nymphaea* and *Eleocharis*) form Loxahatchee peat (Davis, 1943; Gleason et al., 1974). A third less common peat deposit called Gandy is found exclusively on tree islands overlying either Loxahatchee or Everglades peats. This peat is derived from vegetation associated with tree islands (Davis, 1943).

METHODS AND MATERIALS

Vegetation Sampling

Ten sites were selected in WCA-2A to monitor plant community changes associated with the reduced water level. Three sloughs, three tree islands, and four sawgrass study sites were selected along a decreasing ground elevation gradient from north to south. Three slough-wet prairie habitats were selected in WCA-2B for comparison. Figure 5 shows sample sites and ground elevations in relation to generalized contour intervals within the area.

Pre-drawdown samples from sloughs and tree islands in WCA-2A and slough-wet prairie sites in WCA-2B were collected from June-August 1980. Vegetation sampling was repeated in WCA-2A during May-June 1981 while the area was dry and in November 1981 after three months of reflooding.

To reduce the possibility of wildfires during dry marsh conditions, controlled burning of sawgrass litter was implemented in winter 1980-81 by the Florida Game and Freshwater Fish Commission. Following burning, sawgrass regrowth was monitored to determine relationships between density and inundation frequency and to establish when density and standing crop stabilize. Sawgrass samples were initially collected in April 1981 and were repeated at four month intervals.

Due to the variety of plant communities sampled, a number of different documentation and collection techniques were employed.

Sloughs

A 183 m transect was established along the longitudinal (north-south) axis of each slough. A total of 51 quadrats, 0.25 m^2, were examined at 3.7 m intervals, offset 3 m west of the transect line. Within each quadrat, species presence and gyttja (unconsolidated sediment) depth were recorded, and ground elevation was determined from water depth. Other species observed

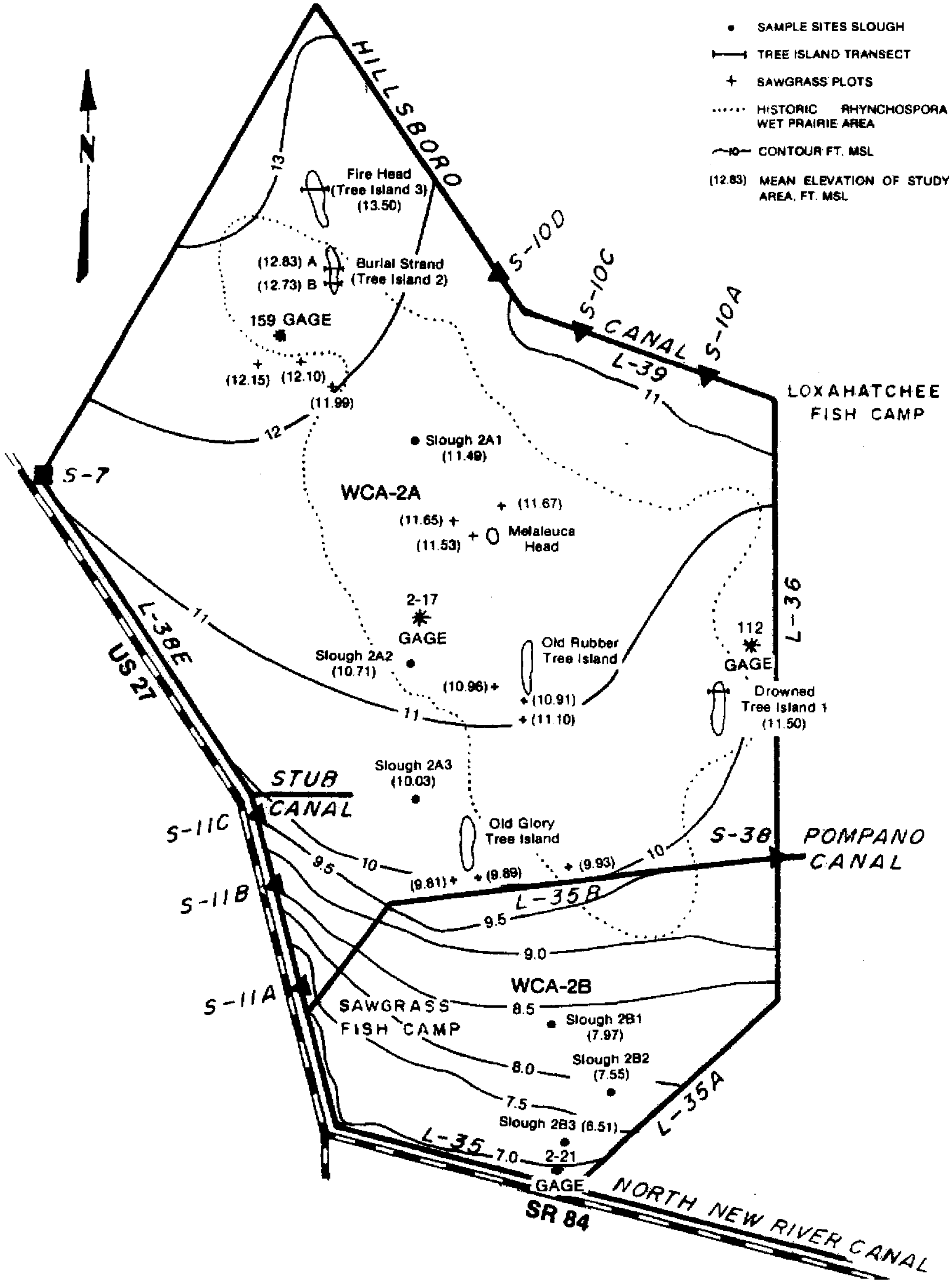


Figure 5 VEGETATION SAMPLE SITE LOCATIONS AND GROUND ELEVATION IN RELATION TO GENERALIZED SURFACE GROUND CONTOURS IN WCA-2A AND WCA-2B.

along the transect, but not occurring within quadrats, were also noted. Quantitative vegetation samples were collected with 10 randomly placed 0.25 m^2 quadrats offset 3 m east of the transect line. All vegetation within these quadrats was clipped at ground surface and sorted by species. Total stem density for each species was determined by the number of live shoots. Biomass was based on oven dry weight at 90°C for 48 hours.

An additional 18x3 m plot was established at higher ground elevation along the slough margin. This edge plot was monitored for possible changes in vegetation which might not occur along the transect due to incomplete drying. This plot was subdivided into a grid containing 216 quadrats each $0.25m^2$. A total of 6 quadrats were randomly selected and all vegetation clipped at ground surface. Samples were treated as above for estimates of density and biomass.

Tree Islands

A 183 m transect at tree island 1 was established, traversing east to west, approximately 150 m south of the northernmost edge of the island. A total of 51 quadrats $1.0m^2$ were offset 3 m north of the transect line at 3.7 m intervals. Plant species present and water depth were recorded in each quadrat. Other plant species encountered along the transect were also noted. An additional plot was established midway through the island to monitor drowned tree regrowth. This plot was defined by extending a line out 7.6 m from a fixed point in an arc of 180°. All live and dead woody plants were tagged and enumerated. Canopy height was measured for all live trees.

The identical procedure for obtaining species presence was employed at tree island 2; however, some difficulty was encountered delineating the island boundaries in relation to surrounding sawgrass. To avoid over representing the surrounding sawgrass community, two 91 m transects were established toward the island center. The first transect (A) was located about 150 m south of the island northern edge. The second transect (B) was located about 600 m south of Transect A in the broadest section of the island. No attempt was made to monitor drowned tree regrowth at this site due to the scarcity of stumps.

The density of live trees and understory vegetation at tree island 3 precluded using a continuous line transect. Five rectangular plots measuring 9x3 m were staked, beginning at the tree island margin, and spaced to include all visually distinguishable transitions in vegetation composition. This resulted in two plots, one each, located on the east and west boundaries of the island with the remaining three distributed within the island interior.

All woody plants greater than 1 m in height within these plots were enumerated. Basal diameter and stem or canopy height was also measured. Canopy closure was visually estimated. Presence of herbaceous vegetation was determined within each plot using ten randomly placed 1.0 m^2 quadrats. Any additional plant species occurring within the larger plot but not found in the subsampled quadrats were noted.

Sawgrass

Each sawgrass study site was comprised of three separate stands with similar ground elevations. Each stand was sampled with five randomly placed 1.0 m^2 quadrats. Open areas within the stand were intentionally avoided to reduce variability. Within each quadrat, all live vegetation was clipped at ground level and all culms removed. Where tussock growth was prevalent, only culms were removed. Maximum leaf length and total number of leaves were determined after removal of all dead leaf material. Total sawgrass biomass for each quadrat was weighed after 72 hours drying at 90°C.

Biological Indices

Species percent presence (frequency) was calculated for slough and tree island sites and is based on the number of quadrats in which a species occurred divided by the total number of quadrats examined. Importance values were calculated for slough vegetation as an aid in differentiating species importance in community structure and dominance. The method for calculating this index is based on a modified technique used by Curtis and McIntosh (1951) which combined measures of relative percent presence and relative percent biomass ascribed to a particular species. Relative percent presence is defined as the percentage presence for a species divided by the sum of the percent presence for all species. Relative percent biomass is the biomass of a species divided by the total species biomass. Calculation of this importance value is represented by:

$$\text{Importance Value} = \frac{\text{Species \% presence}}{\text{Sum of species \% presence}} \times 100 + \frac{\text{Species biomass}}{\text{Sum of species biomass}} \times 100$$

Value of this index ranges from 0 to 200. Values approaching 200 indicate greater species dominance relative to other species within the community. A percentage community dominance index for slough vegetation is expressed as the sum of the percentage biomass ascribed to the two dominant species (McNaughton, 1968).

Species diversity for slough and tree island sites is represented as total species richness (Whittaker, 1972), based on an average number species per replicate and total number species for the community.

Soil and Water Chemistry Collections

Soils

Soil samples were collected from each vegetation community on each sample date. Six replicate cores were collected from each tree island and slough site, while three replicates were collected from each sawgrass stand. Surface soil cores were collected to a depth of 20 cm with an aluminum cylindrical tube 7.5 cm in diameter. Two additional replicate cores of the entire peat depth were collected at each slough and sectioned at 20 cm intervals to provide a vertical profile. Following collection, all samples were immediately iced in the field and frozen until analyzed.

Nutrient analyses included total nitrogen, total phosphorus, available phosphorus (Bray P-2 phosphorus), potassium (K), calcium (Ca), and magnesium (Mg). All analyses were performed by the South Florida Water Management District Soil Chemistry Laboratory. Soil samples were air dried and ground in a Wiley Mill until the entire sample passed through a #10 mesh sieve (U.S. Standard Sieve Series). A representative subsample was further ground until 5 gm were obtained after passing through a #35 mesh sieve. This subsample was analyzed for nutrient content. Total nitrogen (Kjeldahl) and phosphorus samples were prepared following procedures outlined by Jackson (1958) and measured using modified Technicon Auto Analyzer methods. Potassium, calcium, and magnesium were digested using a lithium metaborate fusion method (Medlin et al., 1969) and measured by Atomic Absorption Spectrophotometry. Available phosphorus analysis (Bray P-2 phosphorus) was conducted as outlined by Jackson (1958) with the following modification. The sample volume used for extraction was obtained by approximating a 2 gm dry weight equivalent from wet samples based on a calculated average percent moisture content. Extracted solutions from wet samples were then analyzed by the Technicon as above.

Water Quality

Surface water at 21 interior marsh stations (Figure 6) was sampled at approximately six week intervals from February 1980 to December 1981. Collection techniques and analytical methods are outlined by Millar (1981). The parameters monitored during this study were:

Nutrients	Ions	Other Quality Measures
Total Nitrogen	K	Alkalinity
Total Kjeldahl Nitrogen	Ca	Hardness
NH_4	Mg	Conductivity
NO_3	Cl	Total Organic Carbon
$o\text{-}PO_4$	SO_4	Color
$T\text{-}PO_4$		

A nutrient budget(excluding rainfall contributions) was calculated throughout the drawdown for total nitrogen, phosphorus, and chloride, based on procedures also outlined by Millar (1981). Water samples were collected at two week intervals upstream from inflow (S-10A, 10C, 10D and S-7) and outflow (S-11A, 11B, 11C, S-38) structures during periods of operation.

RESULTS

Marsh Dewatering and Reflooding

Figure 7 depicts changes in stage levels during marsh drawdown and reflooding from 1 November 1980 to 31 December 1981 at three locations in WCA-2A, the marsh interior (gauge 2-17), the peripheral marsh (gauge 112), and within the L-35B borrow canal (S-38 headwater). Large discharges through the S-11 structures in November and December 1980 rapidly lowered the L-35B canal stage, creating a gradient (approximately 2 ft) between the marsh and

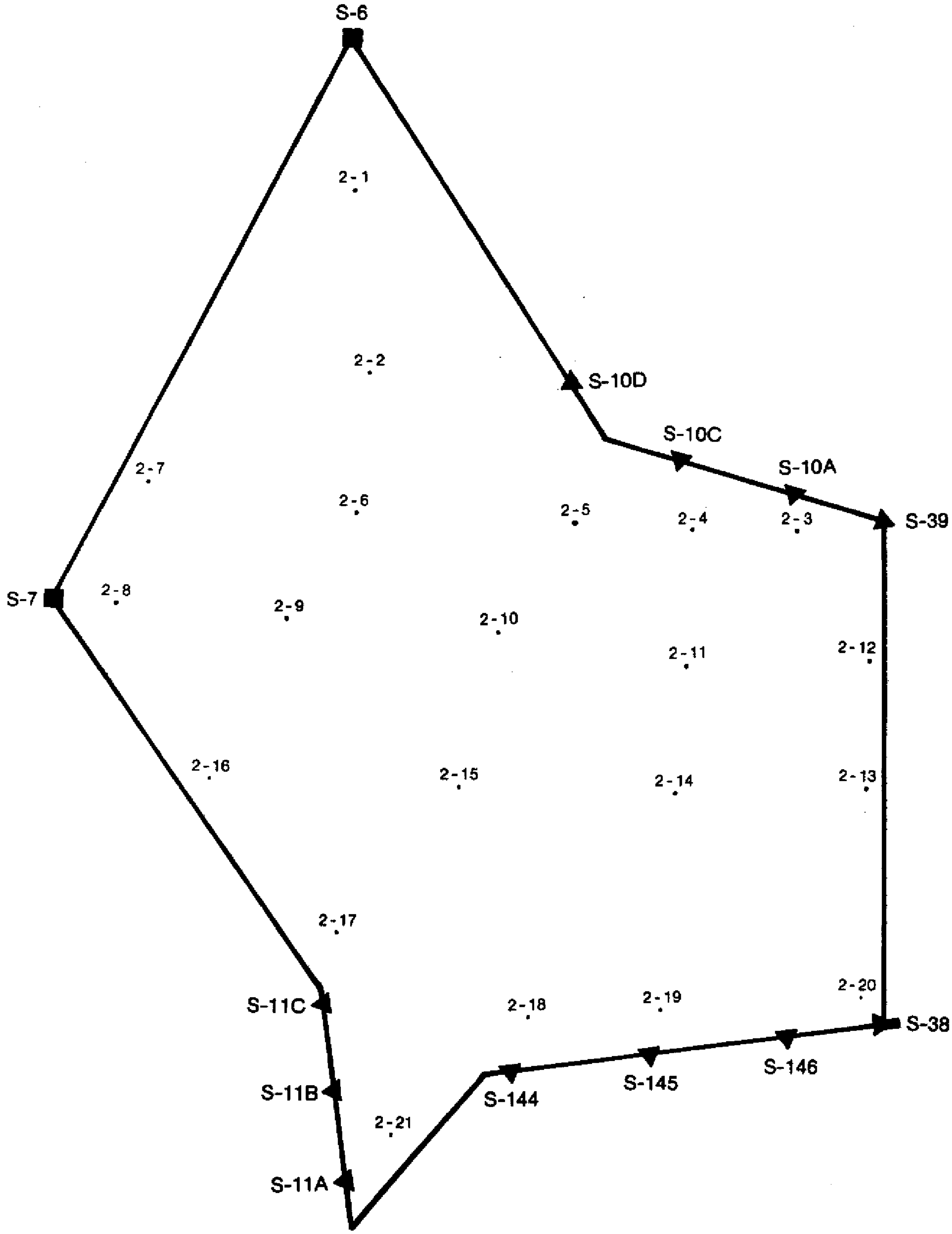
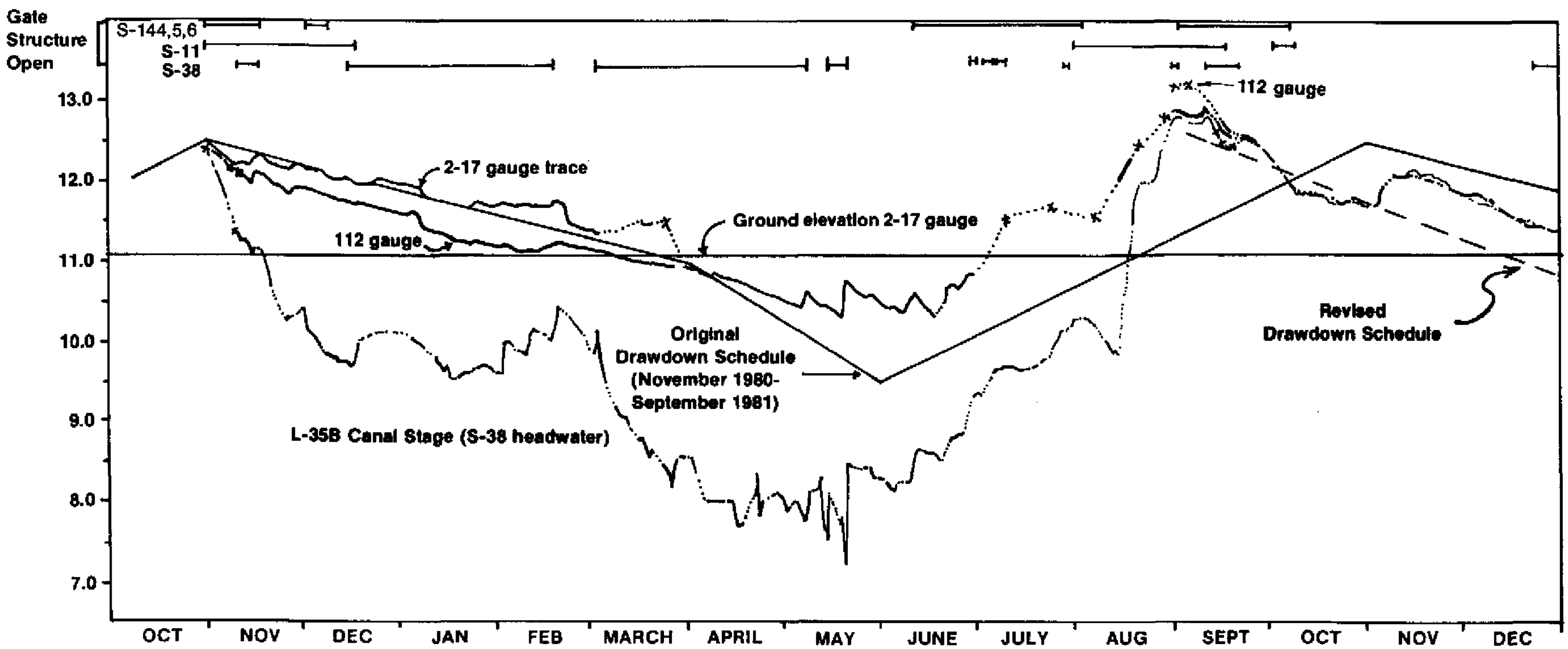


Figure 6 WCA-2A INTERIOR WATER QUALITY STATIONS



X INDICATE SINGLE OBSERVATION POINTS

* NOTE: INCOMPLETE RECORD FOR 2-17 AND 112 GAUGES DUE TO EQUIPMENT MALFUNCTION

Figure 7 Daily stage * recorded at the 2-17 gauge (111), 112 gauge and S-38 headwater (L-35B canal) during drawdown together with the outflow structure gate status, November 1, 1980 - December 31, 1981.

canal which allowed the interior stage level to slowly decline. By regulating discharges from WCA-2A, this gradient was maintained and the marsh continued to dewater effectively through February 1981. A monthly water budget (excluding rainfall and evapotranspiration losses) for the drawdown period (November 1980-July 1981) summarizes changes in inflows and outflows for WCA-2A (Table 1). Approximately 50% (62,803 acre ft) of the total outflow was discharged to WCA3A while WCA-2B received 22% (27,401 acre-ft).* The remaining 28% (35,042 acre-ft) was used to meet water supply needs for the east coast.

The presence of airboat trails and natural flow ways (sloughs) influenced recession rates in the marsh. This can be seen by comparing stage levels of the peripheral marsh (gauge 112) and interior marsh (gauge 2-17). Water level at the 112 gauge receded at a faster rate due to the close proximity of an airboat trail and adjacent sloughs paralleling L-36.

Airboat trails became increasingly important drainage streams as stage levels declined. Trails which follow the north-south alignment of sloughs and cut through the higher elevated sawgrass ridges provided a pathway for water when overland flow through sawgrass ceased. However, by mid-March, as the 2-17 gauge reached 11.40 ft msl (0.30 ft above ground surface), surface drainage from the marsh ceased and airboat trails were no longer effective conveyance ways. Further marsh drying was dependent on evapotranspiration losses.

By 30 April, WCA-2A contained only small isolated pockets of standing water with soil surfaces dry throughout most of the marsh. Shallow wells dug along the marsh perimeter indicated the ground water level was 15-25 cm below the soil surface. Drying was not as complete in the south central

*Estimate includes inflows from S-141 in addition to the L-35B culvert structures (S-144, 145, and 146). Inflows through S-141 are based on calculated discharge volumes passing through the upstream structure (S-143) while the downstream structure (S-34) remained closed.

TABLE 1. TOTAL MONTHLY INFLOWS (EXCLUDING RAINFALL) AND OUTFLOWS OF WCA-2A THROUGHOUT THE DRAWDOWN ENDING JULY 1981. UNITS ARE ACRE FT.

	Total Inflows		Total Outflows				
Month/ Structure	S-10's	S-7	S-11's	S-38	S-143*	S-144 S-145 S-146	Inflow-Outflow
Nov. (drawdown)	0	3872	43127	771	1838	8251	-50115
December	0	1160	19676	1757	4292	783	-25348
January 1981	0	0	0	1553	6644	0	-8197
February	0	3068	0	1053	2578	0	-563
March	0	809	0	2330	2036	0	-3557
April	60	9453	0	7067	7329	0	-5003
May	355	6335	0	3697	3592	0	-599
June	0	0	0	0	0	0	0
July	0	0	0	0	1321	5554	-6875
Total for Period	295	24697	62803	18228	29630	14588	-100257

*Estimates based on ACE recorded volume discharged through S-34 when structures simultaneously open. Estimates for November, December and March are based on theoretical discharge volumes derived from recorded head differences across S-143. Discharge volumes during these months were not reported while gates were open.

section, where water ponded in the center of the sloughs or remained just below ground surface. Surface water levels at the 2-17 gauge receded below ground (11.10 ft msl) around 29 March and remained below ground until approximately 6 July, a total of about 100 days. Lowest stage level recorded was 10.25 ft msl on 18 June.

Rainfall in July gradually reflooded the marsh at the 2-17 gauge to a depth of 6-8 inches prior to tropical storm Dennis on 16 August. Heavy rainfall combined with S-10 discharges from WCA-1, caused the stage to rise rapidly, finally culminating at 12.65 ft msl on 10 September.

To achieve more complete drying of the marsh during the second and third years of the program, timing of the drawdown was advanced by two months, beginning in September 1981. Advancing the schedule would allow the marsh to dry in December and remain exposed throughout the normal dry winter season. However, because of continued low water levels in Lake Okeechobee, water releases from WCA-2A were suspended to conserve water supplies depleted by the previous year's drought. As a result, WCA-2A water levels remained above the revised schedule and delayed the second year drawdown.

Changes in Vegetation

a. Sloughs

Pre-drawdown

Table 2 lists the environmental characteristics and associated vegetation structure of slough transects in WCA-2A prior to the drawdown. Samples collected from the slough edge plots contained a similar species composition, although emergent species density and biomass were generally higher than the transects (Appendix Table 1). Most species were represented in qualitative samples (percent presence), but some were absent in quantitative collections due to variability in distribution and abundance. However, the two sampling

TABLE 2. ENVIRONMENTAL CHARACTERISTICS AND ASSOCIATED VEGETATION STRUCTURE OF WCA2A SLOUGHS PRIOR TO THE DRAWDOWN (June-July 1980)

SLOUGH SITES

Environmental Characteristics	2A1	2A2	2A3
Avg. Ground Elevation (ft. msl)	11.49	10.71	[illegible]
% Inundation +	94.1	99.3	[illegible]
Avg. Soil Depth (inches)	62.7	60.5	[illegible]
Avg. Gyttja Depth (cm)	14.5	17.1	[illegible]

Vegetation Structure	2A1	Stem Density**		Biomass**		2A2	Stem Density**		Biomass**		2A3	Stem Density**		Biomass**	
Species Composition	% Present*	#/m²	%	g/m²	%	% Present*	#/m²	%	g/m²	%	% Present*	#/m²	%	g/m²	%
Floating															
Nymphaea odorata	47.1	17.2	6.6	40.0	57.8	54.9	11.0	15.9	10.4	58.6	[illegible]	[illegible]	0.9	1.5	4.4
Submergent															
Utricularia sp.	92.0	ND		13.5	19.4	92.2	ND		18.0	34.7	[illegible]	[illegible]		[illegible]	50.[illegible]
Emergent															
Eleocharis elongata	33.[illegible]	225.5	86.4	7.8	11.3	23.5	53.0	76.3	[illegible]	2.2	[illegible]	[illegible]	95.[illegible]	4.5	13.6
Eleocharis cellulosa	23.5	12.0	4.6	3.0	4.3	7.8	2.5	3.6	1.4	2.7	[illegible]	[illegible]		NR	
Paspalidium paludivagum	2.0	2.5	1.0	3.3	4.7	7.8	0.5	0.7	0.1	1.2	[illegible]	[illegible]	[illegible]	10.5	3[illegible].5
Sagittaria lancifolia	2.0	4.0	1.5	1.7	2.5	5.9	2.0	2.2	0.8	1.6					
Pontederia lanceolata	2.0	NR		NR											
Cladium jamaicensis	2.0	NR		NR		2.0	NR		NR						
Woody Species															
Cephalanthus occidentalis	2.0	NR		NR											
Totals		261.2		69.3			69.0		51.8			[illegible]		33.3	

+Period or Record 1961-1979
*Percent Presence in 51 Quadrats
**Estimate from 10 Quadrats 0.25 m²

ND = No Data Obtained
NR = Species Not Represented in Samples

TABLE 3. ENVIRONMENTAL CHARACTERISTICS AND ASSOCIATED VEGETATION STRUCTURE OF SLOUGHS IN WCA-2B.

SLOUGH SITES

Environmental Characteristics	2B1	2B2	2B3
Avg. Ground Elevation (ft. msl)	7.97	7.55	[illegible]
% Inundation +	56.9	65.9	[illegible]
Avg. Soil Depth (inches)	29.2	30.3	[illegible]
Avg. Gyttja Depth (cm)	0	0	

Vegetation Structure	2B1	Stem Density**		Biomass**		2B2	Stem Density**		Biomass**		2B3	Stem Density**		Biomass**	
Species Composition	% Present*	#/m²	%	g/m²	%	% Present*	#/m²	%	g/m²	%	% Present*	#/m²	%	g/m²	%
Floating															
Nymphaea odorata	64.1	31.5	7.1	44.9	22.8	39.2	6.5	[illegible]	13.0	8.6					
Submergent															
Utricularia sp.	92.2	ND		11.9	6.0	15.7	ND		0.1	0.05	92.[illegible]	[illegible]		11.6	16.6
Chara sp.						90.2	ND		56.4	37.7	52.[illegible]	[illegible]		13.0	18.6
Bacopa caroliniana						15.7	69.2	9.7	15.6	10.4					
Potomogeton sp.											19.[illegible]	[illegible]		1.9	2.[illegible]
Emergent															
Eleocharis elongata	52.9	131.0	29.7	6.3	3.2	11.8	564.0	79	20.8	13.9					
Eleocharis cellulosa	98.0	202.0	45.8	63.9	32.9						3.[illegible]	[illegible]	23.6	2.7	3.8
Paspalidium paludivagum	11.8	10.0	2.3	8.8	4.5	39.2	6.0	[illegible]	4.9	3.3	5.[illegible]	[illegible]	1.0	0.1	0.1
Sagittaria lancifolia	21.6	22.0	5.0	29.6	15.0	54.9	20.8	[illegible]	17.6	11.8	52.[illegible]	[illegible]	19.6	21.2	30.3
Pontederia lanceolata						2.0	NR		NR		3.[illegible]	NR		NR	
Panicum hemitomon	47.1	36.0	10.1	22.5	11.4	70.6	42.4	5.9	18.9	12.6	72.[illegible]	44.4	55.8	19.4	27.8
Leersia hexandrus						17.6	1.6	0.2	0.2	0.3					
Crinum americanum	2.0	NR		NR		NR	2.0	0.[illegible]	2.0	1.3					
Woody Species															
Cephalanthus occidentalis						2.0	ND		ND						
Totals		432.5		187.9			712.8		149.5			79.6		69.9	

+Period or Record 1961-1979

ND = No Data Obtained

techniques together reflect the overall heterogeneity of plant cover and abundance.

Bladderwort and white water lily were prevalent throughout the sloughs and comprised the majority of vegetation standing crop. Emergents, like arrowhead (Sagittaria lancifolia) and spikerush, generally occurred in isolated clumps on raised soil elevations. Two more common emergents, Eleocharis elongata and Paspalidium paludivagum, are particularly flood tolerant and occurred throughout a wide range of water depths.

WCA-2B sloughs exhibited a greater mixture in species composition and structural complexity (Table 3). Emergents were prevalent and comprised the highest percentage of community density and biomass. Wet prairie species like spikerush and maidencane were important contributors to community standing crop and density in all transects. Both species occured in dense patches scattered throughout the slough and interspersed with other emergents. Submergent and floating species were also common, but accounted for a smaller proportion of community standing crop than the emergents.

Differences between WCA-2A and WCA-2B sloughs in species composition and dominance were evident. Dominance was evaluated by comparing importance values for the more common species occurring at slough transects (Table 4). A shift in dominance can be seen among several species as inundation frequency increases.

Slough transects in WCA-2A are dominated by either white water lily or bladderwort. As a result, percent community dominance (% CD) is correspondingly high (Table 4). Dominance diversity curves for WCA-2A exhibit a sharp downward slope, indicative of a floristically poor community, dominated by a few species (Figure 8).

In WCA-2B sloughs, species dominance is less clearly defined and not restricted to a single species. As a result, community dominance is lower

TABLE 4. COMPARISON OF SPECIES RELATIVE IMPORTANCE VALUES (RELATIVE % OCCURRENCE + RELATIVE % BIOMASS) AND CORRESPONDING RANK DOMINANCE IN RELATION TO INUNDATION FREQUENCY AT THE SLOUGH STATIONS (PRE-DRAWDOWN CONDITIONS).

	Slough Sites					
	WCA-2A			WCA-2B		
Inundation Frequency	94.1	99.3	100.0	56.9	65.9	79.5
Species / Slough Site:	A1	A2	A3	B1	B2	B3
Utricularia sp.	65.4 (2)	82.7 (2)	103.8 (1)	29.7 (3)	4.4 (8)	46.4 (3)
Numphaea odorata	81.4 (1)	87.2 (1)	6.6 (4)	39.5 (2)	19.6 (4)	0
Eleocharis elongata	28.0 (3)	14.4 (3)	44.7 (3)	16.8 (6)	17.2 (5)	0
E. cellulosa	16.1 (4)	6.8 (4)	0	58.0 (1)	0	7.0 (6)
Sagittaria lancifolia	3.5 (6)	4.6 (5)	0	20.6 (5)	27.3 (3)	47.4 (2)
Paspalidum paludivagum	5.7 (5)	4.3 (6)	44.8 (2)	7.5 (7)	14.3 (7)	2.0 (7)
P. hemitomon				23.5 (4)	32.5 (2)	51.2 (1)
Bacopa caroliniana					14.4 (6)	0
Chara vulgaris					63.1 (1)	35.7 (4)
Potomogeton sp						9.0 (5)
% Community Dominance	77.2 (Nymphaea odorata-Utricularia sp.)	93.4 (Nymphaea odorata-Utricularia sp.)	82.0 (Utricularia sp.-Paspalidium paludivagum)	57.9 (Eleocharis cellulosa-Nymphaea odorata)	50.2 (Chara sp. Panicum-hemitomon)	58.2 (Panicum hemitomon-Sagittaria lancifolia)

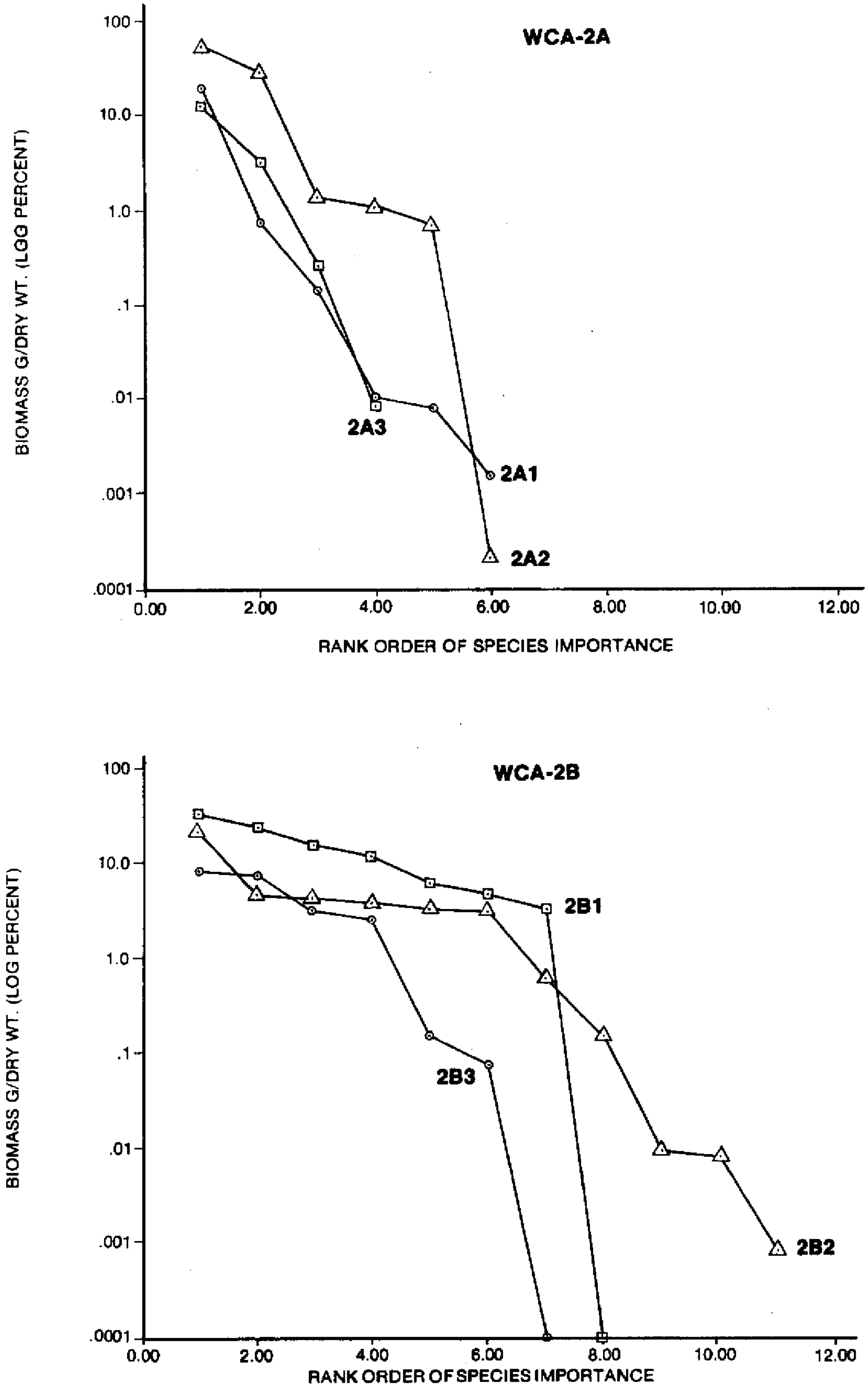


Figure 8 DOMINANCE-DIVERSITY CURVES BASED ON RELATIVE BIOMASS FOR SLOUGH STATIONS WCA-2A (Upper Graph) AND WCA-2B (Lower Graph)

(Table 4) and species richness is slightly greater. Dominance diversity curves show a more equitable distribution of biomass among species (Figure 8).

Initial drying

Two new wet prairie species (maidencane and beakrush) were found in WCA-2A slough transects following the initial drawdown in June 1981. Both species occurred exclusively at slough site 1, but were rare in percent presence (2% of quadrats examined).

Drying of sloughs temporarily eliminated bladderwort and substantially reduced the standing crop of white water lily, although the percent presence of the latter species increased due to seed germination. Large numbers of sawgrass seeds also germinated within sloughs when soils were exposed, but other emergent species declined slightly in abundance and percent presence. Sawgrass seedling densities averaged 29.2, 34.4, and 4.0 culms/m^2 at slough transects 1, 2, and 3, respectively. (Appendix Table 2 shows the results of the June 1981 sampling).

Observations made throughout WCA-2A showed that many new species occurred in predominately open areas along L-36 and adjacent to L-35B. During the drawdown process, water levels receded quickly in these areas, exposing soils in late March, and provided a thorough drying of surface soils. Exposed soils were quickly colonized by a variety of sedges, grasses, and herbaceous species. Some of the early invading species were Cyperus spp., sprangle top grass (Leptochloa domingensis), marsh fleabane (Pluchea spp.), and pigweed (Amaranthus cannabinus). Later in June and July, giant bristle grass (Seteria magna) and two species of millet grasses (Echinochloa walteri and E. crusgalli) were abundant, particularly along the marsh adjacent to L-35B.

Marsh Reflooding

As the marsh began reflooding in July 1981, grasses and other annuals were drowned, while vigorous emergent regrowth occurred where marsh drainage was most complete. This was dramatically demonstrated in the marsh adjacent to the S-11 structures. Prior to the drawdown, submergents like bladderwort and pondweed (Potomageton sp.) were predominant. When the S-11 structures were opened in November and December, the adjacent marsh quickly drained exposing large flats of barren peat soil. After reflooding, dense monocultures of spikerush and Paspalidium paludivagum were evident with lush beds of the algae Chara spp. growing between these emergent stands. Similar changes, although not as extensive, were observed in many sloughs located within about one mile of the L-35B canal. An additional wet prairie indicator species, beakrush (Rhynchospora inundata), was found scattered throughout this area.

Slough transects were resampled in November, but results indicated relatively little change in vegetation occurred in the marsh interior. While sawgrass seedlings were drowned by the increase in water depth, there was no substantial change in density, biomass, or percent presence of the remaining emergents. Bladderwort reappeared but the algae Chara spp. was the more prominent submergent (Appendix Table 3).

b. Tree Islands

Pre-drawdown

A comparison of the composition and percent presence of plant species at WCA-2A tree island study sites is presented in Table 5. Differences in the physiognomic diversity of the tree island transects are summarized in Figure 9. The transect at tree island 1 (average ground elevation 11.50 ft msl) is dominated by cattail (Typha sp.). Floristic composition of this island is typical of the drowned tree islands occurring in the southern third

TABLE 5. SPECIES COMPOSITION AND PERCENT PRESENCE AT WCA-2A TREE ISLAND STUDY SITES PRIOR TO DRAWDOWN (AUGUST 1980)

	Tree Island			
	1	2A	2B	3
	N = 51	26	26	50
Aquatics				
Chara sp.		19.2	19.2	
Nymphaea odorata	11.8		3.8	
Typha sp.	88.2	19.2		PR
Utricularia sp.	13.7	23.1	42.3	
Paludal Herbs and Vines				
Ipomea sagittata	2.0			
Mikania scandens		7.7	23.1	12.0
Pelandra virginica	3.9	53.8	65.4	56.0
Pontederia lanceolata	2.0	34.6	34.6	10.0
Prosperpinaca palustris			19.2	20.0
Sagittaria lancifolia	11.8	88.5	73.1	
Sarcostemma clausa	25.5	3.8	15.4	54.0
Smilax laurifolia				PR
Sedges and Grasses				
Cladium jamaicensis	25.5	96.2	88.5	4.0
Dichronema colorata			3.8	24.0
Eleocharis baldwinni				16.0
Eleocharis elongata	5.9			
Panicum agrostoides				26.0
Panicum dichotomum				40.0
Mesophytic Forbs				
Aster carolinianus				20.0
Boehmeria cylindrica			15.4	42.0
Centella asiatica			7.7	28.0
Diodia virginiana			7.7	12.0
Eupatorium coelestinum				10.0
Eupatorium sp. (dog fennel)				10.0
Galium sp.				10.0
Hydrocotyle umbellata				75.0
Ludwigia alata			7.7	14.0
Ludwigia repens			7.7	12.0
Pluchaea foetida				12.0
Pluchaea purpurascens				4.0
Polygonum hydropeperoides				33.0
Vicia acutifolia				18.0

TABLE 5. (Con't).

	Tree Island			
	1	2A	2B	3
Ferns				
Acrostichum danaeaefolium	3.9	3.8		2.0
Blechnum serrulatum	3.9	26.9	80.8	80.0
Osmunda regalis				46.0
Thelypteris interrupta				28.0
Thelypteris palustris		15.4	46.1	66.0
Shrubs and Trees				
Cephalanthus occidentalis	17.6	42.9	19.2	
Ilex cassine				*
Myrica cerifera		3.8	57.7	*
Myrica seedlings				28.0
Persea borbonia				2.0
Salix caroliniana	5.9			
Total # Species	14	15	21	35
Avg. # Species/Quad.	2.0	4.0	6.3	9.1+

*See Table 6 for detailed information
PR = Present but rare
+Excluding mature Myrica and Ilex tree spcies

		GROUND ELEVATION FT. MSL	PERCENT INUNDATION	TOTAL SPECIES
TREE ISLAND 1		11.50	94.0	14
TREE ISLAND 2	TRANSECT A B	12.83 (A) 12.73 (B)	65.1 (A) 68.3 (B)	15 (A) 21 (B)
TREE ISLAND 3		13.50	36.5	35

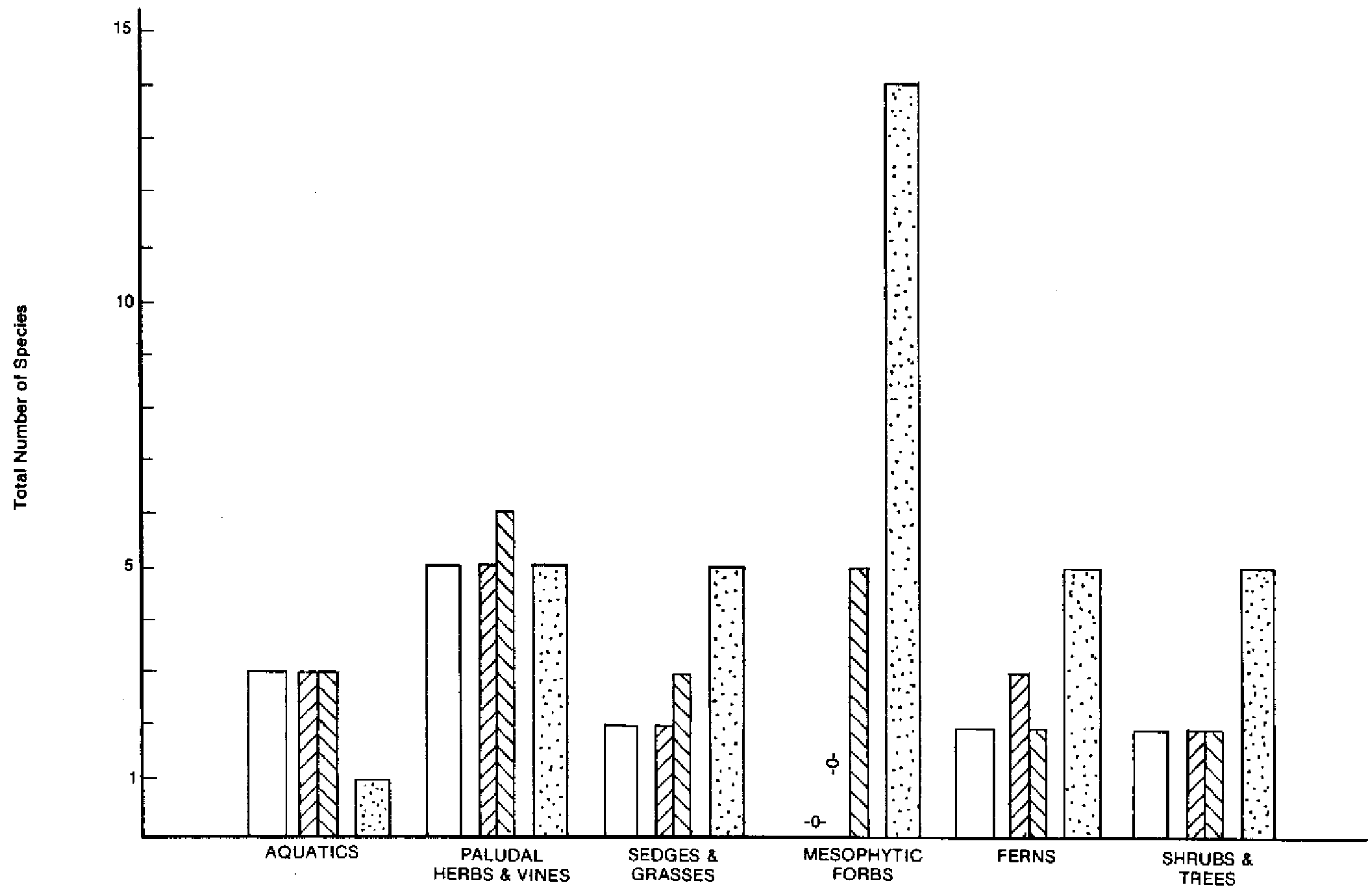


Figure 9 PHYSIOGNOMIC DIVERSITY OF TREE ISLANDS SAMPLED IN WCA -2A, PRE-DRAWDOWN CONDITIONS.

of WCA-2A. A cross-section of the island shows a marked zonation in plant community composition. At the peripheral margin of the island is a distinct ecotone between the island vegetation and adjacent slough. Within the interior of the island, cattail dominates the higher ground elevations and a decline in species richness occurs, averaging only 2.0 species/quadrat (Table 5). However, species richness was higher in a zone of buttonbush (Cephalanthus occidentalis) concentrated on the eastern half of the island. Associated species are the vine Sarcostemma clausa and swamp fern.

Tree canopy cover is virtually non-existent on this island. The only live tree species is willow (Salix caroliniana), which occurred in a small head at the north end of the island. Live willows were scattered along the transect but occurred in only 5.9% of the quadrats sampled and ranged from 1-3 m in height. A large number of dead willow stumps indicated that willow density was probably greater than at present.

Tree island 2 is located in the north central portion of WCA-2A, with an average ground elevation about one foot higher than island 1. Although subjected to less severe flooding, the floristic structure of this island has also been altered by frequent inundation. The dominant ground cover is sawgrass (Cladium jamaicensis) interspersed with low stature shrubs and willows. There is a live willow head at the northern apex of the island, similar to tree island 1.

Slight differences in species composition exist between the two transects at tree island 2 (Table 5). Transect A (average elevation 12.83 ft msl) contained cattail and a high frequency of buttonbush while Transect B (average elevation 12.73 ft msl) had a high frequency of wax myrtles. However, due to differences in shrub abundance, average species richness was higher on Transect B (6.3 species/m^2) than Transect A (4.0 species/m^2).

Tree island 3 (ground elevation 13.50 ft msl) is one of only a few live tree islands remaining in WCA-2A. Live tree islands occur only in the northernmost portion of WCA-2A, generally above the 13 ft msl elevation contour (see Figure 5). All of the living tree islands, including study site 3, are dominated by dahoon holly.

Vegetation plots transversing tree island 3 show distinctive zonations in floristic structure corresponding to canopy closure (Table 6). Canopy closure affects the amount of light transmitted to the tree island floor, influencing ground cover and distribution of plant species. Surrounding the tree island is a dense margin of sawgrass. Where the sawgrass marsh and tree island converge, there is an ecotone of grasses, sedges, ferns, forbs, and wax myrtle (Plots 1 and 5). Height of the wax myrtle ranges from 2-5 m and averages 3 m. Because of the scattered shrub distribution and relatively sparse foliage, canopy closure in the wax myrtle zone is <5%, resulting in slightly greater species richness.

Plots 2-4 represent the island interior. Floristic differences related to canopy cover are also noted between these plots (Table 6). Density of wax myrtle declines as they become dwarfed by taller dahoon holly (7 m in height). Canopy closure increases from both margins of the island toward the island center (Plot 3). As shading of the tree island floor increases, ground cover is dominated by ferns, particularly swamp fern, and species richness declines. Cattail is also present but is relatively rare, occurring only in plot 4.

Drawdown

Several new species of mesophytic forbs, sedges and grasses became established at each of the tree island sites following the drawdown (Table 7). New species composition on tree island transects varied due to the influence of fire and pre-drawdown species richness.

TABLE 6. CHARACTERISTICS OF DOMINANT WOODY SPECIES OCCURRING ON TREE ISLAND 3. ALL WOODY SPECIES 1.0 m IN HEIGHT INCLUDED.

		West				East
	Plots:	1	2	3	4	5
Distance Between Plots (m)		33 (1–2)	50 (2–3)	49 (3–4)	80 (4–5)	
Statistics	Species					
Stem Density/27 m^2	Myrica	14	13	2	0	15
	Ilex	0	10	6	17	0
Avg. Ht. (m)		2.38	3.48	3.09	----	1.92
		----	7.15	8.30	7.91	----
Avg. Basal Area (cm^2)/stem		3.1	7.2	4.1	----	1.4
		----	39.0	85.8	42.0	----
Cum. Basal Area (cm^2)/species		43.3	94.1	8.2	----	20.6
		----	390.2	514.8	714.5	----
Dominant Ground Cover %		Sedge-50% (Eleocharis baldwinni)	Ferns-25% (Blechnum-Thelypterus interruptus)	Ferns-90% (Blechnum serrulatum)	Ferns-50% (Blechnum serrulatum)	Sedge-40% (Dichromena colorata)
Tree Canopy Height		3 m	6 m	8 m	8 m	3 m
% Canopy Closure		5%	30%	70%	50%	5%
Soil Depth (m)		1.89	1.89	2.30	1.98	2.40
Total Species		29	23	19	24	17

TABLE 7. CHECKLIST OF NEW SPECIES FOUND ON TREE ISLAND TRANSECTS FOLLOWING THE DRAWDOWN OF WATER LEVELS.

	Tree Island Transect			
	1	2A	2B	3
Sedges and Grasses				
Cyperus odoratus	X			X
Dichromena colorata		X		
Echinochloa sp.	X	X	X	
Echinochloa walteri	X			
Eleocharis baldwinii	X			
Panicum dichotomum		X	X	
Panicum hemitomon	X		X	X
Paspalidium paludivagum	X			
Seteria magna	X			
Unknown grass sp. #1				X
Unknown grass sp. #2				X
Mesophytic Forbs				
Aster caroliniensis		X		
Boehmeria cylindrica		X		
Centella asiatica		X		
Crisium horridulum				X
Diodia virginiana	X	X		
Eupatorium coelestinum	X	X	X	
Eupatorium sp.	X		X	
Hydrocotyle umbellata		X	X	
Lactuca sp.			X	X
Ludwigia alata	X			
Ludwigia repens		X		
Melothria pendula				X
Pluchea purpurascens		X		
Polygonum hydropiperoides	X	X		
Polygonum punctatum	X			
Vicia acutifolia		X		
Ferns				
Osmunda sp.	X			
Trees and Shrubs				
Baccharis sp.		X		X
Myrica cerifera (seedlings)	X	X	X	
Total New Species	15	15	8	8

Tree island 1 was burned in early March 1981. As a result, many changes in herbaceous plant species are associated with post-fire succession. Burning reduced the cattail to ground level and greatly reduced accumulated litter. Dryer soil conditions combined with increased availability of light on the tree island floor facilitated new species exploitation. Smartweeds (Polygonum punctatum and P. hydropiperiodes) were particularly abundant, occurring in 64% of the quadrats (Appendix Table 4). Burning temporarily eliminated some species, such as the vine Sarcostemma clausa, the swamp fern, arrow-arum and pickerelweed. Tree islands 2 and 3 were not burned; thus, new species occurrence at these locations was directly related to soil drying.

Woody species regrowth also differed among tree islands. Buttonbush and willow are both fire tolerant and regrew quickly at tree island 1, producing a lush, new growth of leaves following burning. However, no regrowth was noted from drowned willow stumps monitored in a separate plot. Foliage of live willow trees at tree island 2 also increased substantially under dryer soil conditions, although some of the increase may reflect seasonality. Wax myrtle seedlings sprouted in all transects, but only a single individual was found at tree island 1. An additional woody species, saltbush (Baccharis sp.), grew at tree islands 2 and 3. This shrub is characteristic of mesic terrestrial habitats.

Reflooding

Due to marsh reflooding and senescence, many species established after the drawdown were absent when transects were examined in November 1981. Some of the more persistent species established during the drawdown that still survived in November were maidencane, smartweed (Polygonum hydropiperoides), pennywort (Hydrocotyle umbellata), climbing aster (Aster caroliniana), and creeping cucumber (Melothria pendula).

Woody species showed signs of reduced vigor following marsh reflooding. Buttonbush was completely defoliated at tree islands 1 and 2 and within the sawgrass stands throughout the marsh. Wax myrtles and willow trees were partially defoliated as well. It is uncertain whether changes in foliage cover were attributed to flood stress or reflect normal seasonality. Wax myrtle seedlings were absent from tree islands 1 and 2 and declined in percent presence at tree island 3 (from 60% to 36%, Appendix Table 4).

c. Sawgrass

Controlled burning of sawgrass communities in WCA-2A began on 30 October 1980. Figure 10 shows the sawgrass sample site locations in relation to the areas burned and initial date of burning.* Sawgrass sites were sampled during April, August, and December 1981. A second burn along the northwest margin of the area in May 1981 affected site 159G. This fire consumed new sawgrass growth and completely burned several small tree islands. A few minor peat fires resulted from this second burn.

Differences in hydroperiod were noted among sawgrass sites. Sawgrass sites 159G and OLDG were rapidly drained of surface water in early March, the former because it lies at a higher elevation than the other sites, and the latter due to its proximity to the L-35B canal. The MELH site dried sometime after the first two sites. Site RUBT is surrounded by sloughs and is located in the south central portion of the marsh where some water remained throughout the drawdown. By comparison, this was the wettest of sawgrass sites.

Regrowth of burned sawgrass during drawdown, dry marsh, and flooded marsh conditions is depicted in Table 8. Average culm density increased sharply after burning, and reached a maximum while the marsh was dry (May-August).

*Information courtesy of Florida Game and Freshwater Fish Commission.

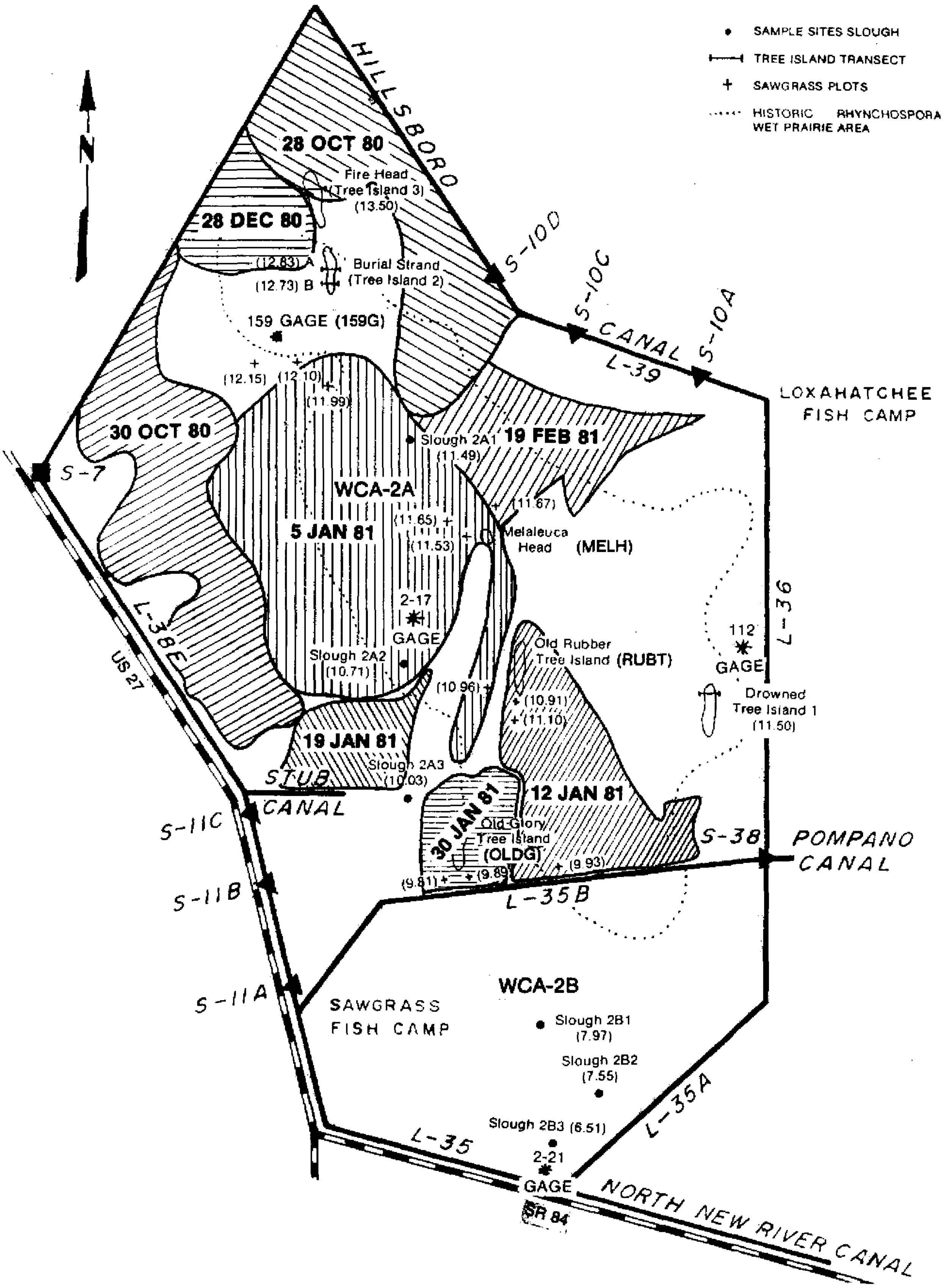


Figure 10 **SAWGRASS STUDY SITES IN RELATION TO CONTROLLED BURN AREAS IN WCA-2A DURING THE DRAWDOWN.**

TABLE 8. GROWTH OF BURNED SAWGRASS DURING DRAWDOWN, DRY MARSH AND REFLOODED MARSH CONDITIONS. ESTIMATES OF DENSITY, BIOMASS AND CULM HEIGHT BASED ON n=15 QUADRATS FOR EACH SITE (REPLICATE STANDS POOLED). NET BIOMASS ACCUMULATION IS BASED ON AN AVERAGE OF REPLICATE STANDS (n=3 FOR EACH SITE).

Hydrologic Condition:	Drawdown				Dry Marsh				Flooded Marsh			
Growth Interval:	(Jan.-Apr.)				(May-Aug.)				(Sept.-Dec.)			
Sites	Density (m^2)	Biomass (gm/m^2)	Height (cm)	Net Biomass Accumulation***	Density (m^2)	Biomass (gm/m^2)	Height (cm)	Net Biomass Accumulation***	Density (m^2)	Biomass (gm/m^2)	Height (cm)	Net Biomass Accumulation***
159G	41.4± 8.9	189.1±41.2	95.6±7.0	.037±.009	66.5±16.0 (61%)*	148.1±41.2 (-19.5%)*	75.3±4.9 (-21.2%)*	.019±.003	59.5±20.8 (-10.5%)	222.8±111.7 (50.4%)	91.7±8.1 (21.8%)	.015±.011
MELH	31.2±5.7	205.7±59.9	97.0±10.3	.065±.014	52.1±21.0 (67%)	322.6±97.5 (56.8%)	125.5±10.6 (29.4%)	.022±.021	54.5±11.9 (4.6%)	383.4±147.4 (18.8%)	116.6±20.3 (-7.1%)	.010±.006
RUBT	21.0±4.9	149.0±27.2	105.3±11.5	.067±.009	35.1±9.9 (67%)	223.1±62.0 (49.7%)	113.5±12.0 (7.9%)	.024±.004	35.3±8.5 (0.6%)	243.8±58.0 (9.3%)	122.5±16.3 (7.9%)	.006±.008
OLDG	25.5±8.8	81.9±24.6	77.6±15.0	.036±.015	43.1±17.0 (69%)	195.6±65.8 (138.8%)	95.6±19.3 (23.2%)	.035±.017	41.3±15.9 (-4.2%)	282.1±104.1 (44.2%)	109.3±11.6 (14.3%)	.013±.001
Average of All Sites	29.8	155.2	93.9	.051	49.2	247.1**	111.5**	.027**	47.7	303.1**	116.1**	.010**
% Increase for All Sites					65%	59.2%	18.7%		-3.1%	22.7%	4.1%	

* Percent increase or decrease over previous collection.
** 159G site excluded from site averages.
*** Units in gms/day/individual.

Seedlings accounted for a major portion of this density increase at some sites (Table 9). Seedlings first appeared in late April as soils in sawgrass stands were exposed. Highest densities generally occurred in more open areas of the stand (43/m^2 in one quadrat). At site 159G, seedling density was particularly low, presumably due to effects of the second fire coinciding with seedling emergence. Vegetative production of new culms from the bases of older culms and rhizomes was unaffected by this second fire, as evidenced by the continued increase in density.

As the marsh reflooded, sawgrass seedlings were drowned and a corresponding decline occurred in average culm density. However, the decline was not significant (P=.05) at any site, indicating seedling mortality was offset by continued new culm production.

To compare the rate of regrowth under different hydrologic conditions, net accumulation in culm biomass was calculated for each site (Table 8). This estimate was made by dividing the biomass accumulated between each sampling period by the total density present at the time of collection and by the number of days elapsed between sampling periods. For the first regrowth interval (January-April), it was assumed that live standing crop measured in April represented biomass accumulated after the fire (e.g. a negligible quantity of pre-burn live standing crop biomass survived the fire and was present at the time of collection). Seedlings were also excluded in computations of growth rates due to their negligible biomass.

Preliminary results indicate the rate of culm regrowth was most rapid during the first four months following burning (Table 8). After this initial surge in regrowth, the rate of increase generally declined. However, a sustained rate of growth was maintained at the OLDG site until after reflooding of the marsh. It was also apparent that a slower rate of regrowth occurred at the 159G site following the second burn.

TABLE 9. AVERAGE SAWGRASS SEEDLING DENSITY AND CORRESPONDING PERCENTAGE OF TOTAL CULM DENSITY OBSERVED AT STUDY SITES DURING DRY MARSH CONDITIONS.

Site	Plot #	Avg. # Seedlings/m^2**	Seedlings as % Total Density
159G*	1	0	0
	2	0.2 ± .4	0.4
	3	0.2 ± .4	0.3
MELH	1	16.0 ± 18.9	33.5
	2	11.2 ± 14.2	21.8
	3	10.0 ± 10.1	27.1
RUBT	1	6.2 ± 8.4	16.1
	2	1.6 ± 1.8	5.1
	3	0.6 ± 0.5	1.7
OLDG	1	0.6 ± 0.9	1.1
	2	5.2 ± 6.1	19.4
	3	9.0 ± 18.5	19.7

*Site burned a second time 2 May 1981

**Means based on 5 replicates/plot with standard deviation as indicated

Soil and Water Fertility

Soils

Nutrient and metal concentrations (% by weight) of marsh soils within each of the plant community sample sites are presented in Table 10a. Total nitrogen and calcium were the most abundant soil nutrient and metal, respectively. Available phosphorus (Bray P-2 phosphorus) was least abundant. This phosphorus fraction is considered the best indicator of readily available phosphorus for plant uptake (Patrick and Mahapatra, 1968; Klopatek, 1975). Results of this study indicate available phosphorus comprised approximately 10% of the total phosphorus in WCA-2A peat soils. Potassium was also present in low quantity. Soil nutrient profiles obtained at slough sites indicate highest concentrations of nitrogen and phosphorus occurred within the upper 20 cm of peat depth, while potassium and calcium remained relatively uniform throughout the profile (Table 11).

Changes in soil fertility were evident within each plant community following drawdown and reflooding of the marsh (Table 10a). Total phosphorus, calcium, and magnesium increased appreciably after drainage and exposure of slough soils. Mineralization of flocculent gyttja and subsequent incorporation into the surface soil horizon probably contributed to the increased concentration of these elements. Gyttja deposits measured 5 cm in thickness in some localities and contained substantially higher concentrations of these elements than underlying peat soils (Table 10b).

With the exception of phosphorus, soil fertility of tree islands and sawgrass communities generally declined while the marsh was dry. Soil exposure and subsequent drying appeared to increase the available phosphorus supply in these communities. Following reflooding, soil nutrients and cations increased above pre-drawdown levels in each of the plant communities sampled.

TABLE 10a. COMPARISON OF NUTRIENT AND METAL CONCENTRATIONS (% BY WEIGHT) IN MARSH SURFACE (0-20 cm) SOILS FOLLOWING DRAWDOWN AND REFLOODING.

Parameter	Hydrologic Condition	Plant Community Sloughs	Tree Island	Sawgrass
Total Nitrogen	Pre-drawdown	2.835(±.278)*	2.704(±.250)	2.819(±.283)
	Dry Marsh	3.111(±.426)	2.704(±.040)	2.618(±.135)
	Reflooded Marsh	3.613(±.145)	3.160(±.184)	2.963(±.164)
Total Phosphorus	Pre-drawdown	.014(±.003)	.036(±.006)	.034(±.006)
	Dry Marsh	.023(±.002)	.062(±.024)	.029(±.007)
	Reflooded Marsh	.027(±.002)	.047(±.031)	.027(±.004)
Avail. Phosphorus ($x10^{-1}$)	Pre-drawdown	.032(±.014)	.040(±.012)	.040(±.010)
	Dry Marsh	.026(±.002)	.058(±.011)	.062(±.014)
	Reflooded Marsh	.049(±.013)	.114(±.022)	.053(±.014)
Potassium (K)	Pre-drawdown	.067(±.014)	.051(±.001)	.076(±.014)
	Dry Marsh	.056(±.007)	.036(±.003)	.046(±.005)
	Reflooded Marsh	.091(±.006)	.073(±.002)	.084(±.003)
Calcium (Ca)	Pre-drawdown	1.705(±.083)	3.492(±.476)	2.050(±.223)
	Dry Marsh	2.087(±.574)	2.794(±.182)	1.680(±.155)
	Reflooded Marsh	2.443(±.450)	3.401(±.839)	1.867(±.115)
Magnesium (Mg)	Pre-drawdown	.199(±.028)	.381(±.132)	.340(±.055)
	Dry Marsh	.266(±.047)	.387(±.069)	.286(±.038)
	Reflooded Marsh	.271(±.033)	.359(±.098)	.349(±.028)

TABLE 10b. NUTRIENT AND METAL CONCENTRATIONS (% BY WEIGHT) IN CONSOLIDATED GYTTJA OVERLYING PEAT SOILS.

Number Replicates	TKN	TOT P	K	CA	MG
8	2.634(±.279)	.037(±.012)	.087(±.005)	10.181(±2.230)	.489(±.041)

* $\bar{x}$ (standard deviation)

TABLE 11. COMPARISON OF SOIL NUTRIENT CONCENTRATIONS WITH DEPTH. MEAN AND STANDARD DEVIATION BASED ON THE NUMBER OF REPLICATES AS INDICATED IN BRACKETS.

	Soil Core Depth			
Soil Nutrient %	0-20 cm (6)	21-40 cm (6)	41-60 cm (2)	61-80 cm (1)
Total N**	3.56 ± .38	2.60 ± .43	1.99 ± .21	2.50
Tot-P**	.035 ± .010	.019 ± .004	.011 ± .001	.010
Avail P-2**	.0045 ± .0017	.0011 ± .0007	.0003 ± .00007	.0008
K	.10 ±.03	.09 ± .02	.09 ± .06	.05
Ca	1.98 ± .20	1.86 ± .14	2.21 ± 1.37	2.00
Mg	.23 ± .03	.23 ± .05	.23 ± .10	.24

**Denotes significant differences between depths at P = .01

Water Quality and Nutrient Export

Table 12 summarizes water quality in WCA-2A marsh interior sites during 1980 prior to the drawdown, as water levels receded, and following marsh reflooding.

Samples collected from 29 December 1980 through 18 March 1981 show changes in marsh water quality as water depth declined. Nitrogen concentrations generally increased with dissolved organic nitrogen the most abundant form and ammonia the most abundant inorganic form. Major ion concentrations (Ca^{++}, Mg^{++}, and Cl^{-}) also increased resulting in higher conductivities, alkalinity, and hardness.

Water quality samples collected 21 May 1981 reflect nutrient and ion concentrations found in isolated pools within sloughs while the remainder of the marsh was dry. Nitrogen and several major ions reached their highest concentrations in these pools. Sulphide was particularly high compared with pre-drawdown concentrations. Samples collected one week later (28 May), following a heavy rainfall, showed reduced concentrations for most parameters monitored. Inorganic nutrient concentrations were similar to rainwater, but major ion concentrations remained high due to mineral salts re-dissolving. Potassium concentration increased, probably due to leaching of decaying plant material (Verry, 1975).

Further reductions in nitrogen and major ion concentrations occurred as additional rainfall in July reflooded the marsh. High water color values in samples collected 8 July suggest that an increase in organic matter decomposition occurred with reflooding of soils and plant litter (Kaufman, 1969). Phosphorus (total and inorganic) also reached highest concentrations during this period of initial marsh reflooding.

August and September water quality sample collections coincided with large S-10 inflows from WCA-1 that began on 20 August, following passage of

TABLE [illegible]. [illegible] SURFACE WATER NUTRIENT CONCENTRATIONS OF WCA-2A BEFORE, DURING DRAWDOWN AND AFTER MARSH REFLOODING; PERIOD JANUARY 1980 - DECEMBER 1981

Hydrologic Condition	Date	Preceding 30 Day Cumulative Rainfall (in.)*	Stage Level⁺ at time of Sample	N	NUTRIENTS NO_3 (mgN/L)	NH_4 (mgN/L)	Inorg. N (mgN/L)	D. Org. N (mgN/L)	Part. N (mgN/L)	Total N (mgN/L)	O-PO_4 (mgP/L)	TPO_4 (mgP/L)
Pre-Drawdown	2/27/80	1.34	14.20	21	.046	.04	.091	2.41	.15	2.60	.012	.021
	6/2/80	4.40	13.03	7	.004	.02	.024	-	-	2.18	.002	.088
	7/2/80	5.24	13.01	13	.005	.05	.055	-	-	2.94	.011	.096
	9/8/80	6.83	13.35	21	.148	.07	.259	3.15	.77	4.03	.011	.026
Drawdown	12/29/80	.40	11.98	18	.097	.91	.196	-	-	5.51	.016	.041
	2/5/81	.94	11.69	20	.061	1.02	1.090	4.66	0.49	6.31	.011	.045
	3/18/81	.94	11.45	15	.014	1.68	1.698	5.44	1.22	8.17	.025	.059
	5/21/81	2.97	10.73	4	1.696	5.82	8.939	9.78	1.10	19.79	.002	.071
	5/28/81	3.40	10.58	9	.161	67	.868	6.24	0.36	7.26	.002	.023
Reflooded Marsh	7/8/81	1.86**	11.39	15	.014	.02	.037	3.55	.39	3.95	.085	.111
	8/28/81	18.95	12.75	22	.249	.07	.328	2.05	0.16	2.50	.055	.062
	9/4/81	21.54	12.84	22	.042	.04	.092	2.24	0.35	2.68	.056	.061
	10/27/81	1.06	11.50	18	.010	.17	.185	3.64	.61	4.21	.055	.147
	12/3/81	3.85	11.81	22	.031	.11	.145	2.67	0.28	3.08	.037	.075

MAJOR IONS AND RELATED PARAMETERS

Hydrologic Condition	Date	K (mg/L)	Ca (mg/L)	Mg (mg/L)	Cl (mg/L)	SO_4 (mg/L)	ALK (MeQ/L)	Hardness (mg/L CaCo)	Conductivity (mhos/cm)	TOC (mg/L)	Color Units
Pre-Drawdown	2/27/80	5.28	72.23	21.58	158.5	42.3	4.58	269.2	991	33.8	91
	6/2/80	-	54.50	22.57	146.1	-	3.91	229.0	-	31.8	83
	7/2/80	-	63.24	23.54	160.7	-	4.54	254.8	-	43.9	121
	9/8/80	5.94	66.85	23.86	126.7	38.9	4.50	265.1	878	31.4	109
Drawdown	12/29/80	-	82.43	31.48	202.1	39.3	5.45	335.4	1091	41.5	102
	2/5/81	-	88.12	32.90	211.4	45.1	6.30	355.4	1135	44.4	82
	3/18/81	9.97	96.28	38.44	293.3	30.4	7.08	398.6	1508	54.1	107
	5/21/81	12.15	84.55	38.83	308.5	168.9	2.43	371.0	1486	112.2	107
	5/28/81	14.07	81.63	36.24	273.5	140.9	3.69	353.0	1607	80.0	80
Reflooded Marsh	7/8/81	8.95	79.67	30.30	240.0	163.3	3.71	336.7	1612	51.6	171
	8/28/81	5.19	51.04	16.54	59.8	-	3.04	195.5	477	25.0	160
	9/4/81	5.95	63.35	19.38	92.9	-	3.78	237.9	757	30.7	179
	10/27/81	9.49	76.94	29.25	224.1	-	5.06	312.5	1554	48.6	136
	12/3/81	8.72	75.53	27.66	145.9	-	4.46	300.4	1227	44.0	172

*Weighted rainfall data obtained from ACE monthly water budgets
**Actual amount probably in error, a number of rainfall recorders were not functional
⁺Stage as recorded at the 2-17 gauge
ΔA single particulate nitrogen value of 45.41 mgN/L was not included in the average
ΔΔA single particulate nitrogen value of 13.66 mgN/L was not included in the average

a tropical storm. These structures remained open until 15 September. Major nutrients and ions were generally lower during this period, reflecting the increased contribution of rain that occurred during preceding weeks. By December, surface water quality in WCA-2A was similiar to pre-drawdown conditions.

Nutrient loadings were calculated for both inflow and outflow structures during the drawdown period (November 1980 - June 1981) to estimate nutrient transport from WCA-2A. Table 13 shows the total inflow and outflow volumes recorded each month and total nutrient loads. Drawdown of WCA-2A resulted in a net transport of nutrients and chloride ions from the marsh due to the large volume of water discharged.

DISCUSSION

Plant Community Changes

The success of the drawdown in stimulating new species growth was dependent on several factors: (1) extent of soil drying, (2) duration of drying, (3) type of existing vegetation, (4) extent to which the community was adversely affected by prolonged flooding, and (5) presence of fire. The first two factors were most important to new species establishment in sloughs, while the remaining factors were more influential on tree islands. Tree islands are higher in elevation than the surrounding marsh, and consequently, soils were exposed early in the drawdown. Dominant ground cover on tree islands appeared to be more important in limiting new species colonization. Site disturbance, such as fire, was particularly beneficial in accelerating colonization on the drowned tree island.

Sedges and grasses were the principal colonizing species throughout the marsh. Rapid volunteer by these plants is typical of the pioneer succession

TABLE 13. NUTRIENT TRANSPORT FROM WCA-2A RESULTING FROM THE DRAWDOWN. LOSSES ARE FROM THE PERIOD 1 NOVEMBER 1980 to JULY 1981.

PARAMETER	Inflows* Total	Outflows** Total	Inflow-Outflow Loss
Surface water (acre-ft)	24992	125249	-100257
Total nitrogen (tonnes)	91.447	846.336	- 754.889
Total PO_4 (tonnes)	1.468	3.413	- 1.945
Chloride (tonnes)	3737.013	21682.539	- 17945.526

* Total inflows via structures S-10A, C, D, and S-7 only - rainfall not included.

**Totals from outflow structures S-38, S-143, S-11's, S-144, 145 and 146. Nutrient inflows from S-143 are estimates based on nutrient concentrations obtained from S-144; direct measure of nutrient concentrations at S-143 were not monitored.

that occurs in wetland environments when dewatered (Kadlec, 1962; Meeks, 1969; Holcomb and Wegener, 1974; Goodrick and Milleson, 1974). These species were most prevalent along the marsh perimeter and northern third of the area where marsh soils were drained quickly and dried more thoroughly. While most of these species were annuals and intolerant to flooding, their brief appearance provides a significant seed crop, especially for waterfowl.

Regrowth of emergent species occurred following reflooding of the marsh. Extensive new growth of Eleocharis cellulosa occurred in sloughs that dried early during the drawdown and where competition from residual vegetation was limited. Rhynchospora tracyi, another wet prairie indicator, was found only in the north end of WCA-2A where soils remained exposed for a longer period. Results indicate seeds of these species probably germinate over a narrow range of soil moisture content. Regrowth of R. tracyi was also extremely limited following the drawdown in 1973 (Dineen, 1974) due to similar problems of adequate drying. It is doubtful that a significant seed crop of this species has been produced since L-35B was completed in 1961.

Seed germination requirements for marsh plants are not well known. One factor that might have partially inhibited soil drying in the sloughs, and potential seed germination of wet prairie plant species, was the physical settling and compaction of gyttja. As this material dried, a calcareous crust was formed on the soil surface, effectively sealing underlying soil from further moisture loss. Removal of this material often revealed wet soils just beneath the surface. Inhibition of seed germination by similar aggregations of organic debris has been observed in other marsh environments (Harris and Marshall, 1963; Sykora, 1979). Other evidence suggests seeds of emergent species require exposure to light for germination (Kadlec and Wentz, 1974; Van de Valk and Davis, 1978). Formation of this calcareous-organic mat might have shielded underlying seeds from sufficient light exposure, in addition to prohibiting adequate drying.

Growing conditions for existing woody species were enhanced by the alteration in regulation schedule. Drowned willow stumps at tree island 1, however, showed no evidence of regrowth. This island has been inundated approximately 94% of time annually since 1961.* Continuous flooding of even water tolerant species results in accumulation of toxic compounds in the root zone (Patrick, 1974) causing root death (Harms et al., 1974). Prolonged flooding also affects food production by inhibiting photosynthesis. Once stored food reserves in the root stocks have been depleted, recovery from flood stress does not occur, even after water levels are reduced (Harms, et al., 1974).

Ground cover or understory vegetation on tree islands was not appreciably altered except at tree island 1. The dense and rapid growth of smartweeds on this island corresponded with a decline in relative abundance of cattail following burning (percent presence of cattail declined from 88.2 to 66.7%). Cattail on tree islands 2 and 3 declined as the marsh dried and no regrowth was evident after reflooding. Increased competition and the change in soil moisture content probably contributed to the reduction in cattail. Recent studies (Grace and Wetzel, 1981) also indicate that competition for light can directly influence cattail cover.

The increase in density of sawgrass after burning was similar to results described by Steward and Ornes (1975) but contrasted with Forthman (1973) who found burning produced no appreciable change in sawgrass density. During this study, sawgrass density increased an average 65% within eight months following the initial fire. Although the temporary presence of seedlings

*average conditions for the period of record 1961-1979 contributed to this increase, results indicate new culm production was continuous throughout marsh drawdown and reflooding.

Previous studies provide conflicting evidence concerning the rate of burned sawgrass regrowth. Forthman (1973) notes that higher rates of regrowth occurred in spring and summer, corresponding with increased solar radiation and temperature. Tiltman (1975) reported faster rates of regrowth following burning under flooded marsh conditions in December than during dry conditions in March.

Attempts to interpret rates of burned sawgrass regrowth corresponding to different hydrological conditions observed in this study are confounded by a number of variables. Variation in the rate of regrowth was extreme even among replicate stands experiencing similar hydroperiods. Differences in burning efficiency between sites were also evident, primarily due to the growth habit of culms. For example, at the OLDG site, culms emerge from large tussocks that extend 0.7 m or more above the soil surface. Burning in this stand occurred with only a few cm of water over the soil surface, resulting in greater exposure of the culms to fire. Greater fire exposure and more efficient burning would account for the lower average culm height attained at this site during the first four months of regrowth.

As a result of the potential variability in the efficiency of burning, the initial estimated rate of regrowth may not be comparable between sites. Forthman (1973) found that up to 20% of the pre-burn biomass was still present immediately following a fire and suggested that the quantity varied according to the intensity of the fire. Measures of the residual biomass immediately following the burn were not made during this study; consequently it is unknown how much of this residual pre-burn biomass was included in the initial measures of post-burn standing crop.

Subsequent estimated rates of regrowth during the dry and reflooded marsh conditions, however, accurately reflect new growth attained during the interval each represents. Based on a comparison of these results, the data suggest regrowth was similar among sites even though each experienced a different hydroperiod due to differences in elevation and efficiency of marsh drainage. This is further supported by the similarity in standing crop and culm height attained at sites MELH, RUBT, and OLDG after 12 months of regrowth.

Drawdown and Marsh Fertility

The observed changes in water quality during the marsh drawdown and initial reflooding are consistent with results reported from similar studies (Kadlec, 1962; Klopatek, 1978). A combination of factors contributed to increased nutrient availability: (1) increased leaching of nutrients from plant detritus, (2) increased or more complete organic decomposition, (3) change in nutrient solubility and mineralization, and (4) temporary concentration of nutrients by evaporation in isolated pools. Under flooded marsh conditions, decomposition of organic matter is limited by availability of dissolved oxygen (Kadlec, 1962). Nutrient mineralization is also inhibited under low oxygen or anaerobic conditions (DeLaune et al., 1976; Richardson et al., 1978). Drainage of the marsh may have increased decomposition resulting in a release of nutrients previously bound in the submerged plant litter.

Releases of nutrients also occur when submerged soils are exposed and reflooded. Submerged organic soils, such as peat, act as nutrient sinks under anaerobic conditions by adsorbing nutrients (Kadlec, 1962; Kamp-Nielsen and Anderson, 1977), particularly phosphorus (Patrick and Khalid, 1974). Drainage and drying of previously submerged soils increases nutrient mineralization. As these soils are reflooded, inorganic phosphorus is rapidly released to the overlying water (Patrick and Khalid, 1974). Leaching of phosphorus from soils probably contributed to the increased inorganic phosphorus observed in surface waters as the marsh reflooded in July. Results were similar to the "first flush" of phosphorus observed after marsh reflooding in Chandler Slough (Federico et al., 1978). An additional potential source of nutrients is the accumulated gyttja. Gleason (1974) found phosphorus concentrations in this material exceeded background levels of soil and plant litter. Gyttja also contained high levels of sulfur which could have contributed to the large increases in dissolved sulfides measured in isolated pools during the drawdown and during initial marsh reflooding.

SUMMARY

1. This study was implemented to restore specific plant communities and other ecological benefits (consolidation of plant detritus, exposure of marsh soils, and increased wildlife use) in WCA-2A by a reduction in regulation schedule. Under a revised schedule, stage level would be reduced to ground level during spring months, allowing the marsh to dry before reflooding by summer rainfall.

2. Changes within major plant communities (sloughs, tree islands, and sawgrass) together with marsh soil fertility and water quality were documented during the first year following the revised schedule. Controlled burning of sawgrass was implemented by Florida Game and Freshwater Fish Commission as water level receded to reduce fuel loads and potential wildfire hazards as the area dried.

3. Stage drawdown began 1 November 1980 and continued throughout the winter into spring 1981. Water level receded below ground surface at the 2-17 gauge (11.1 ft msl) around 29 March and remained below ground approximately 100 days. Lowest stage was 10.25 ft msl.

4. Drying of the marsh was only partially successful due to ponding of water within the marsh interior. Although reflooding began gradually, passage of a tropical storm caused the stage level to rise well above schedule. Stage level was permitted to remain above schedule to augment water supplies depleted by the previous years drought.

5. A number of new plant species became established following the drawdown. These were primarily colonizing annuals and grasses, and many were important wildlife forage foods. However, differences in the distribution and abundance of new species within the marsh were related to degree of soil drying and dominant plant cover. Following reflooding, less flood tolerant species were drowned.

6. Regrowth of burned sawgrass was continuous throughout the first year following burning. Increases in culm height and standing crop were, however, greatest during the first four months following burning. Culm density increased by 60% after one year of regrowth during the revised schedule.

7. Soil fertility increased after exposure and drying. Consolidation of gyttja and incorporation into the soil horizon contributed to nutrient and cation variability of slough soils. Some reduction in soil fertility of tree island and sawgrass communities coincided with increased plant growth. Soil nutrients and cations increased in concentration after the marsh reflooded.

8. Surface water nutrients and ion concentrations increased as soil and plant litter were exposed during stage drawdown. Increases were attributed to greater litter decomposition and soil mineralization. Nutrient and ion concentrations remained higher than pre-drawdown levels for a short period after marsh reflooding, but declined to ambient levels as rainfall and other inflows increased stage. The large quantity of water discharged during the drawdown resulted in a net transport of nutrients from the marsh.

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APPENDIX TABLE 1. DENSITY AND BIOMASS OF PLANT SPECIES FOUND AT THE SLOUGH MARGIN PRIOR TO MARSH DRAWDOWN, AFTER MARSH DRAWDOWN AND FOLLOWING REFLOODING.

Slough 2A1	Pre-Drawdown		Dry Marsh		Reflooded Marsh	
Species Composition	Den.*	Biom.*	Den.	Biom.	Den.	Biom.
Floating						
Nymphaea odorata	7.3	10.44	2.0	.20	10.7	4.77
Submergent						
Utricularia	ND	9.64	-	-	-	-
Chara						.07
Emergent						
Eleocharis elongata	151.3	5.28	59.3	.64	33.3	.31
Cladium(s)			14.7	.12	-	
Total	158.6	25.36	76.0	.96	44.0	5.15

Slough 2A2	Den.*	Biom.*	Den.	Biom.	Den.	Biom.
Floating						
Nymphaea odorata	2.7	2.48	3.3	.92	12.0	12.51
Submergent						
Utricularia sp.	ND	2.32	-	-	-	-
Chara sp.						.02
Emergent						
Eleocharis elongata	690.7	19.01	640.7	3.05	596.7	10.69
E. cellulosa	12.0	5.08	45.3	6.60	26.0	3.75
Paspalidum paludivagum	6.7	5.2	17.3	11.44	4.7	2.21
Cladium(s)			30.7	.16	-	-
Crinum americanum			1.3	5.34	.7	4.81
Sagittaria lancifolia					2.0	.55
Total	712.1	34.09	738.6	27.51	642.1	34.54

*Estimated from 10 quadrats 0.25 m^2
ND = No data obtained

APPENDIX TABLE 1. (Con't).

Slough 2A3	Pre-Drawdown		Dry Marsh		Reflooded Marsh	
Species Composition	Den.*	Biom.*	Den.	Biom.	Den.	Biom.
Floating						
Nymphaea odorata	14.0	43.36	10.7	1.44	8.6	6.87
Submergent						
Utricularia sp.	ND	8.68	-	-	ND	.35
Chara sp.						.21
Emergent						
Eleocharis elongata					9.3	.23
E. cellulosa			13.3	1.45	30.7	8.48
Paspalidium paludivagum					2.7	2.40
Cladium(s)			152.7	2.32	-	-
Total	14.0	52.04	176.7	5.21	51.3	18.54

*Estimated from 10 quadrats 0.25 m^2
ND = No data obtained

APPENDIX TABLE 2. PERCENT PRESENCE, DENSITY AND BIOMASS OF PLANT SPECIES OCCURRING IN WCA2A SLOUGHS DURING DRY MARSH CONDITIONS (MAY-JULY, 1981).

	2A1			2A2			2A3		
	% Pres.*	Den.** #/m2	Biom.** g/m2	% Pres.	Den. #/m2	Biom. g/m2	% Pres.	Den. #/m2	Biom. g/m2
Floating									
Nymphaea odorata	58.8	16.0	3.16	56.9	23.6	4.00	31.4(s)	4.8	.58
Submergent									
Utricularia sp.	-			-			-		
Chara sp.	-			-			-		
Emergent									
Eleocharis elongata	3.9	40.8	.22	17.6	35.2	.30	9.8	77.6	.54
E. cellulosa	17.6	NR		2.0	2.8	.99	5.9	NR	
Paspalidium paludivagum	2.0	NR		13.7	NR		31.4	13.6	7.95
Sagittaria lancifolia	3.9	NR		3.9	NR				
Pontederia lanceolata	2.0	NR							
Cladium jamaicensis									
Mature	5.9			2.0	NR				
Seedlings	86.3	29.2	2.71	84.3	34.4	2.70	90.2	4.0	.02
Rhynchospora tracyi	2.0	NR							
Panicum hemitomon	2.0	NR							
Crinum americanum							2.0		
Woody Species									
Cephalanthus occidentalis	2.0								
Total		86.0	6.09		96.0	7.99		100.0	9.09

*Percent presence in 51 quadrats 0.25 m^2
**Estimated from 10 quadrats 0.25 m^2
NR = Species not represented in sample
ND = No data obtained
(s) predominately from germinating seeds

APPENDIX TABLE 3. PERCENT PRESENCE, DENSITY AND BIOMASS OF PLANT SPECIES OCCURRING IN WCA2A SLOUGHS FOLLOWING MARSH REFLOODING (AUGUST-NOVEMBER, 1981).

	Slough Sites								
	2A1			2A2			2A3		
	% Pres.*	Den.** #/m^2	Biom.** g/m^2	% Pres.	Den. #/m^2	Biom. g/m^2	% Pres.	Den. #/m^2	Biom. g/m^2
Floating									
Nymphaea odorata	56.9	17.6	7.86	66.7	14.4	8.38	3.9	8.0	5.76
Submergents									
Utricularia sp.	3.9	ND	.02	3.9	NR		2.0	NR	.03
Chara sp.	35.3	ND	10.03	47.1	ND	1.06	92.2	ND	13.83
Emergent									
Eleocharis elongata	15.7	3.2	.01	19.6	NR		19.6	216.8	2.22
E. cellulosa	19.6	2.0	.61	5.9	3.6	.92	15.7	5.2	1.86
Paspalidium paludivagum	5.9	NR		9.8	.4	.06	39.2	20.8	20.38
Sagittaria lancifolia	2.0	NR		5.9	4.0	1.18			
Pontederia lanceolata	2.0	NR							
Cladium jamaicensis	9.8	NR		2.0	NR				
Panicum hemitomon	2.0	.8	.06						
Polygonum hydropeperoides	2.0	NR							
Woody									
Cephalanthus occidentalis	2.0								
Total		23.6	18.59		22.4	11.60		250.80	44.08

* Percent presence in 51 quadrats 0.25 m^2
**Estimated from 10 quadrats 0.25 m^2
NR=Species not represented in sample
ND=No data obtained

APPENDIX TABLE 4. SPECIES COMPOSITION AND PERCENT PRESENCE ON TREE ISLAND STUDY SITES DURING DRY (APRIL-JUNE) AND REFLOODED (JULY-NOVEMBER) MARSH CONDITIONS IN 1981.

	Tree Island							
	1		2A		2B		3	
Hydrologic Period	Dry	Flooded	Dry	Flooded	Dry	Flooded	Dry	Flooded
N =	51		26		26		50	
Aquatics								
Chara sp.			-*		-*			
Nymphaea odorata	3.9	15.7			-*			
Typha sp.	78.4	66.7	19.2	-	-*		PR	-
Utricularia sp.	-	3.9	-*		-*			
Paludal Herbs and Vines								
Crinum americanum	2.0	-						
Hymenocallis sp.	2.0	-						
Ipomoea sagittatta	2.0	3.9						
Milania scandens		2.0	15.4	23.1	42.3	53.8	26.0	18.0
Peltandra virginica	-	5.9	15.4	42.3	26.9	30.8	82.0	72.0
Pontederia lanceolata			-	3.8			10.0	2.0
Proserpinaca palustris				3.8	15.4	26.9	20.0	24.0
Sagittaria lancifolia	11.8	15.7	88.5	69.2	88.5	65.4		
Sarcostema clausa			19.2	30.8	19.2	46.2	68.0	22.0
Smilax lancifolia							PR	4.0
Sedges and Grasses								
Cladium jamaicensis	27.5	35.3	96.2	100.0	96.2	100.0	4.0	6.0
Cyperus odoratus	9.8	-				3.8	4.0	-
Dichromena colorata			11.5	3.8	34.6	7.7	24.0	22.0
Echinochloa sp.	25.5	-	3.8	-	15.4	-		
Echinochloa walteri	15.7	-						
Eleocharis baldwinni	2.0	-					16.0	10.0
Eleocharis elongata	5.9	9.8						
Leersia hexandra			15.4	7.7				
Panicum agrostoides							16.0	20.0
Panicum communalis								2.0
Panicum dichotomum			7.7	7.7	53.8	30.8	40.0	40.0
Panicum hemitomon	23.5	33.3			11.5	11.5	12.0	2.0
Paspalidium paludivagum	2.0	2.0						
Rhynchospora perplexa						3.8		
Seteria magna	3.9	-						
Unknown grass sp. No. 1				7.7		7.7	56.0	77.0
Unknown grass sp. No. 2							PR	

APPENDIX TABLE 4. (Con't).

	Tree Island 1		2A		2B		3	
Hydrologic Period	Dry/Flooded		Dry/Flooded		Dry/Flooded		Dry/Flooded	
N =	51		26		26		50	
<u>Mesophytic Forbs</u>								
Aster carolinianus			3.8	-		3.8	28.0	34.0
Aster sp.								2.0
Boehmeria cylindrica			26.9	3.8	23.1	23.1	76.0	32.0
Centella asiatica			11.5	15.4	76.9	61.5	28.0	30.0
Cirsium horridulum							PR	-
Diodia virginiana	2.0	-	23.1	3.8	15.4	15.4	24.0	-
Eupatorium coelestinum	2.0	-	11.5	7.7	19.2	15.4	24.0	10.0
Eupatorium sp. (dog fennel)	2.0	-		3.8	23.1	15.4	40.0	50.0
Galium sp.				7.7			16.0	34.0
Hydrocotyle umbellata			11.5	15.4	15.4	-	72.0	78.0
Lactuca sp.					3.8	-		
Ludwigia alata			3.8	-	7.7	-	14.0	6.0
Ludwigia repens			3.8	-	3.8	-	8.0	-
Melothria pendula							PR	PR
Pluchaea camphorata								6.0
Pluchaea foetida						3.8	24.0	6.0
Pluchaea purpurascens			3.8	-			22.0	-
Polygonum hydropiperoides	41.2	31.4	7.7	7.7		3.8	PR	8.0
Polygonum punctatum	64.7	62.7						
Vicia acutifolia			53.8	-			18.0	56.0
<u>Ferns</u>								
Acrosticum aureum	3.9	-	3.8	-			4.0	-
Blechnum serrulatum			34.6	34.6	80.8	80.0	86.0	48.0
Osmundum sp.	2.0	-					60.0	38.0
Thelypteris interrupta							28.0	16.0
Thelypteris palustris			15.4	11.5	42.3	30.8	80.0	72.0
<u>Shrubs and Trees</u>								
Baccharis sp.							PR	2.0
Cephalanthus occidentalis	31.4	27.5	46.2	26.3	11.5	-		
Ilex cassine							NC	NC
Myrica cerifera			3.8	11.5	53.8	42.3	NC	NC
Myrica seedlings	2.0	-	11.5	-	19.2	-	60.0	36.0
Persea borbonia							PR	12.0
Salix caroliniana	3.9	-						

NC = No Change
PR = Present but Rare
-* = Plant present prior to marsh drying but was not found during subsequent sampling periods.