CYPRESS WETLANDS FOR WATER MANAGEMENT,

RECYCLING AND CONSERVATION

Third Annual Report

to

National Science Foundation, Grant ENV 73-07823A02 (Formerly AEN 73-07823 A01), under the National Science Foundation's Program of Research Applied to National Needs (RANN)

and

The Rockefeller Foundation, Grant RF-76034

November 1, 1975
through December 15, 1976

A research project with participants from several divisions of the University of Florida, National Audubon Society, Inc., and other organizations coordinated through the Center for Wetlands with the assistance of a Steering Committee of User Agencies

Howard T. Odum, Principal Investigator
Katherine C. Ewel, Co-Principal Investigator
James W. Ordway, Site Manager
Margaret K. Johnston, Administrator of Center

Center for Wetlands
Phelps Lab
University of Florida
Gainesville, Florida 32611

December 17, 1976

PHASE 12: CORKSCREW SWAMP, A VIRGIN STRAND

M.J. Duever
National Audubon Society, Inc.

ECOSYSTEM ANALYSES AT CORKSCREW SWAMP

Michael J. Duever*
John E. Carlson*
Lawrence A. Riopelle*
Lance H. Gunderson**
Linda C. Duever*

*National Audubon Society, Inc.
**Dept. of Botany and Center for Wetlands

Field work on the Phase 12 program at Corkscrew Swamp Sanctuary is almost complete. Remaining are: 1) the last cattle exclosure sample in November; 2) monthly tree-coring until December; 3) final overstory productivity measurements in December and January; and 4) monthly water chemistry sampling through January (to complete the annual cycle in undisturbed cypress habitats). In conjunction with another research program, the main weather station will remain in operation, but water levels will be measured only monthly, instead of weekly.

Analysis of all remaining water chemistry samples, soil chemistry and structure parameters, and nutrient analyses of the 1976 vegetation, litter, and decomposition samples are scheduled for completion by February, 1977. In August, 1976, several additional peat cores were taken in the Central Marsh area, and nutrient, pollen, and age analyses of these are expected by February, 1977. Tree-ring counts should be complete in December.

The bulk of the remaining studies are in the data analysis stage, with emphasis on calculating total productivity and nutrient and water budgets for each of the major habitat types.

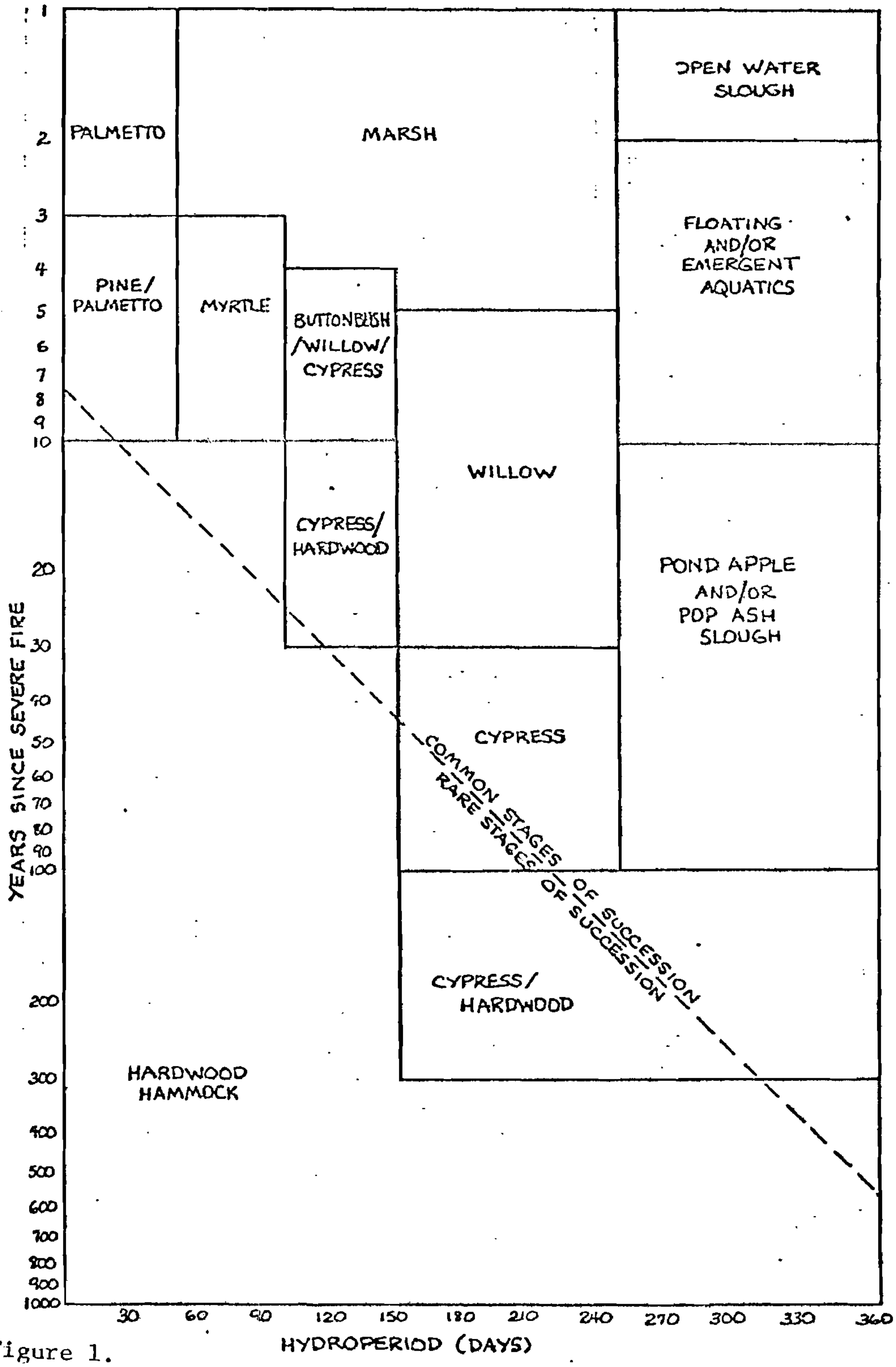
Hydroperiod Control of Vegetation Type

Our hypotheses on the relationship of major habitat types to fire frequency and hydroperiod (Duever et al., 1975) have been supported by data from this years's work on soil type and distribution, seral communities leading to cypress, and cypress aging. Figure 1 is a new diagram of the fire/hydroperiod/habitat relationship revised on the basis of recent data and communications with other south Florida researchers. Existing habitat types are above the dashed diagonal line in the diagram. Under wetter climatic conditions this line would shift downward, and during drier periods it would shift upward. The reasoning behind the hypothesis was presented last year and will be detailed in the final report.

Variation in Cypress Growth Across Strand

Within the habitat types generalized in Figure 1 we see considerable site-to-site variation in plant communities. An obvious example is the interior to exterior variation in forest structure responsible for the characteristicly rounded cross-sectional shape of cypress domes and strands. Possible causal factors include age, water levels, hydroperiod, nutrient availability, substrate type, and fire frequency.

In an attempt to evaluate these influences we measured DBH of four cypress trees at each 100 foot interval along the Central Marsh transect



OPEN WATER SLOUGH
PALMETTO
MARSH
FLOATING AND/OR EMERGENT AQUATICS
PINE/ PALMETTO
MYRTLE
BUTTONBUSH /WILLOW/ CYPRESS
WILLOW
CYPRESS/ HARDWOOD
POND APPLE AND/OR POP ASH SLOUGH
CYPRESS
COMMON STAGES OF SUCCESSION
RARE STAGES OF SUCCESSION
CYPRESS/ HARDWOOD
HARDWOOD HAMMOCK
YEARS SINCE SEVERE FIRE
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
30
60
90
120
150
180
210
240
270
300
330
360
HYDROPERIOD (DAYS)

Figure 1.

through the east side of the strand. We had found earlier (Duever et al., 1975) that DBH is closely related to height, so it was unnecessary to measure that parameter. We then cored each tree and counted rings to age the cores. In the course of other aspects of our research we had measured the depth of the peat at the same 100 foot intervals and monitored above and below ground water levels. Nutrient analyses of the vegetation, soils, and water have also been conducted, but are not yet compiled.

Figure 2 synthesizes the information presently available. Maximum and minimum water levels do not show much variability along the transect and are not directly correlated with age or DBH of the cypress. Both age and DBH increase gradually from the outside edge of the strand to about the 1200 foot point on the transect. From this point on are found much larger, older trees. At the very inside edge of the strand, smaller and younger trees again appear. The correspondence between age and DBH indicates that the differences in cypress tree size are primarily a function of age.

With the exception of the sharp decrease at 1800 feet. The age and DBH profiles correspond amazingly well with the depth of peat profile. Further, the point where the 1974 minimum water level intersected the peat profile is where the age and DBH of the trees increase abruptly. The 1974 dry season had unusually little rainfall and the lowest minimum water levels since 1962. The fact that the oldest and largest trees grow where the drought period water table intersects the base of the peat suggests that dry season water availability is a critical determinant of cypress survival. Where the peat is in contact with the water table for all of most years, moisture availability would be almost continuous near the ground surface because of the absorptive capacity of the peat; in contrast, where the water table receded into the underlying mineral soil, peat would rapidly dry out.

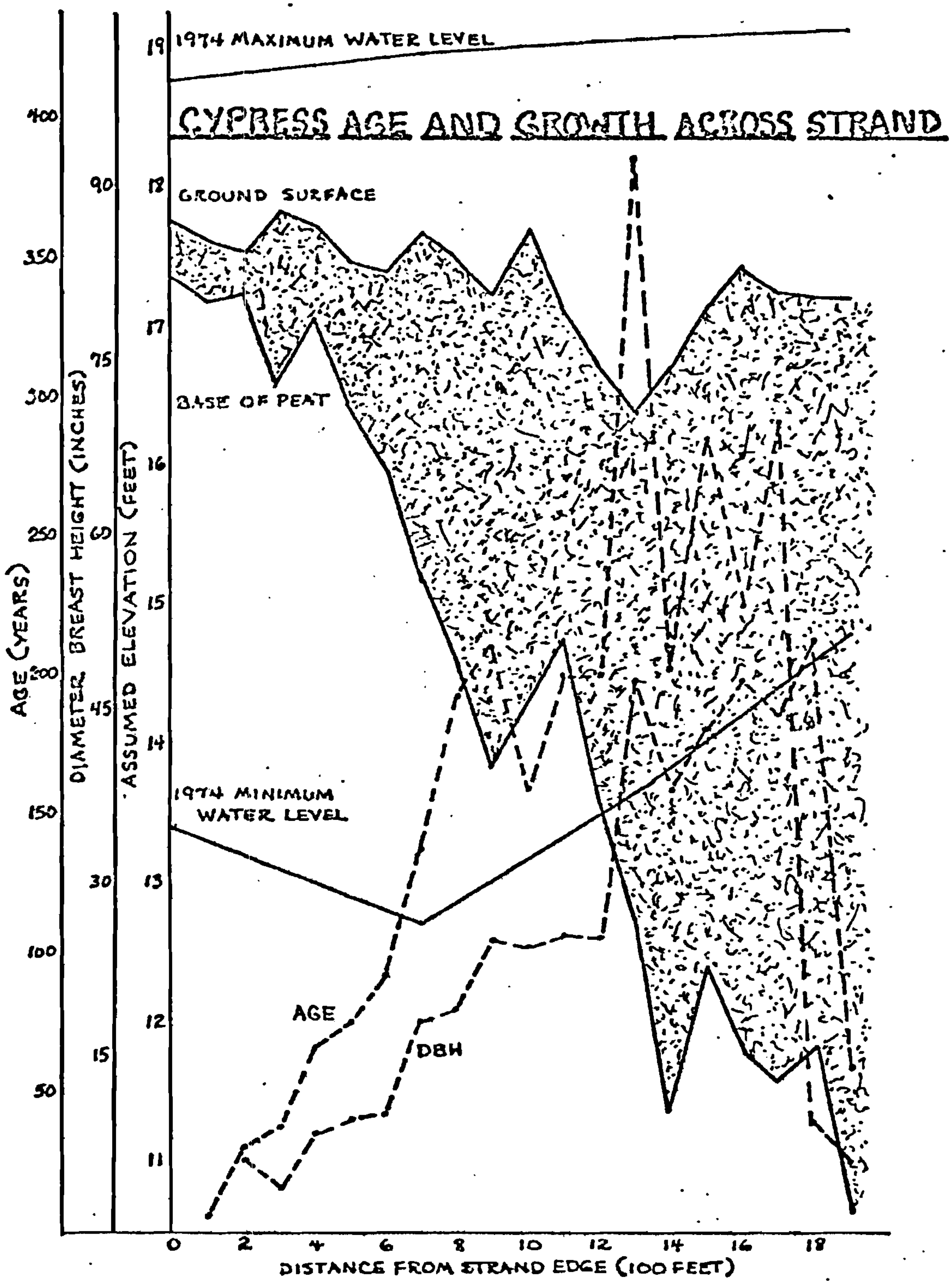

CYPRESS AGE AND GROWTH ACROSS STRAND
1974 MAXIMUM WATER LEVEL
GROUND SURFACE
BASE OF PEAT
1974 MINIMUM WATER LEVEL
AGE
DBH
AGE (YEARS)
DIAMETER BREAST HEIGHT (INCHES)
ASSUMED ELEVATION (FEET)
DISTANCE FROM STRAND EDGE (100 FEET)
400
350
300
250
200
150
100
50
90
75
60
45
30
15
19
18
17
16
15
14
13
12
11
0
2
4
6
8
10
12
14
16
18

Figure 2.

We are uncertain exactly how moisture availability affects cypress survival, but the abrupt change in size at the 1200 foot point suggests a threshold mechanism, while a gradient mechanism appears to control tree size and age toward the outside edge of the strand. We theorize that severe widespread fires entering from the adjacent uplands have not penetrated beyond the 1200 foot point during the past 200 years because of generally higher moisture levels in the vicinity of deep peat soils. The slow outward dispersal of new cypress trees from the old tree seed source, interacting with the effects of occasional fires pushing the cypress back, has resulted in the present size distribution of cypress outward from the 1200 foot point. Since fire frequency and severity would be expected to decrease with increasing moisture, and moisture in turn would increase with increasing peat depth, fires would maintain a young community at the strand edge and increasingly older community in the deeper parts of the strand.

Since the peat depth decreases almost to zero at approximately the same point that the cypress community ends, it appears that similar regimes of hydroperiod and fire may control the distribution of both peat and cypress.

The existence of higher or lower elevation deep peat areas that do not support cypress communities complicates the above interpretation. The deeper areas may be the result of peat fires, often started by lightning strikes, which burn out holes too deep to stay dry long enough for cypress seedlings to become established.

The major higher peat area is the Central Marsh, located within the horseshoe-shaped large cypress forest. We believe (due to presence of isolated large trees and buried stumps) that this area was once cypress forest in which litter accumulations built up a high enough peat surface to permit surface fires. These fires opened up the canopy and allowed flammable sawgrass to become established and maintained with the aid of man-caused fires. In areas where fire has been excluded, willow is succeeding the sawgrass and young cypress are coming up among the willows adjacent to the mature cypress seed source.

Seasonal Cypress Bole Production

While studying cypress tree rings to relate age to tree size and position in the strand, we became interested in trying to relate differences in annual ring width to environmental factors such as hydroperiod, climatic change, fire, and insect defoliation. As part of this investigation, in December, 1975, we initiated monthly coring of 20 cypress trees evenly scattered along the Central Marsh transect. We took two 1-inch cores at approximately breast height in two series, one vertical and another horizontal. To avoid girdling the tree, we selected only trees over 12 inches DBH. We normally cored trees early in the month and made simultaneous notes on the condition of the foliage. The cores were sanded and rings counted with a 50X dissecting microscope. At the beginning of the study we measured the twelve outside rings and counted the number of light and dark cells in the outermost (1975) ring. After growth began, we also counted new light and dark cells monthly to determine when bole growth occurred and to correlate the appearance of false rings with environmental factors.

Since the study will not be complete until December, 1976, it is premature to discuss the results in terms of growth rates in response to environmental factors. However, data are complete on initiation of spring growth and leaf-out in relation to water levels.

Table 1 shows the time when some or both of the paired cores exhibited first new growth. The first sign of new cell formation began in April, but was limited to only a few cores, no two of which came from the same tree. During May there was a slight increase in growth, but it was not until June that all of the trees were producing cells. Despite the general lack of bole growth, all the trees had some foliage and most were completely leafed out by early March. Although some production must have been going on during March and April, we noted little indication of net increases in bole diameter until May, when the wet season rains began. Cypress bole growth may be limited during the early growing season by low water availability, or perhaps production is funneled into leaf and branch biomass during this period. While a delay between time of leaf-out and subsequent increase in bole diameter is a known phenomenon, it would also be expected that water shortage would lead to reduced transpiration and productivity. Further analysis of the current year's growth and water level regime will give us more insight into how hydrological patterns have influenced cypress growth in those past years for which we have only tree-rings as records.

Cypress Biomass and DBH

Cypress biomass and diameter at breast height (DBH) have been measured at four sites in Florida and south Georgia: Corkscrew Swamp, the Fahkahatchee Strand in southwest Florida (Carter et al., 1973), a cypress dome near Gainesville, Florida (Mitsch et al., 1974), and the Okefenokee Swamp (Schlesinger, 1976). Wood biomass and DBH maintained a similar relationship with low variability at all sites (Figure 3). The greater variability (both within and between sites) for leaf biomass is

TABLE 1. TIMING OF BOLE CELL GROWTH INITIATION AND DEGREE OF LEAF-OUT

	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY
<u>CELL GROWTH</u>						
1 CORE			6	6	5	2
2 CORES			0	3	15	18
			6	9	20	20
<u>DEGREE OF LEAF-OUT</u> (Number of Trees)						
PARTIAL	3	5				
COMPLETE	1	15	20			

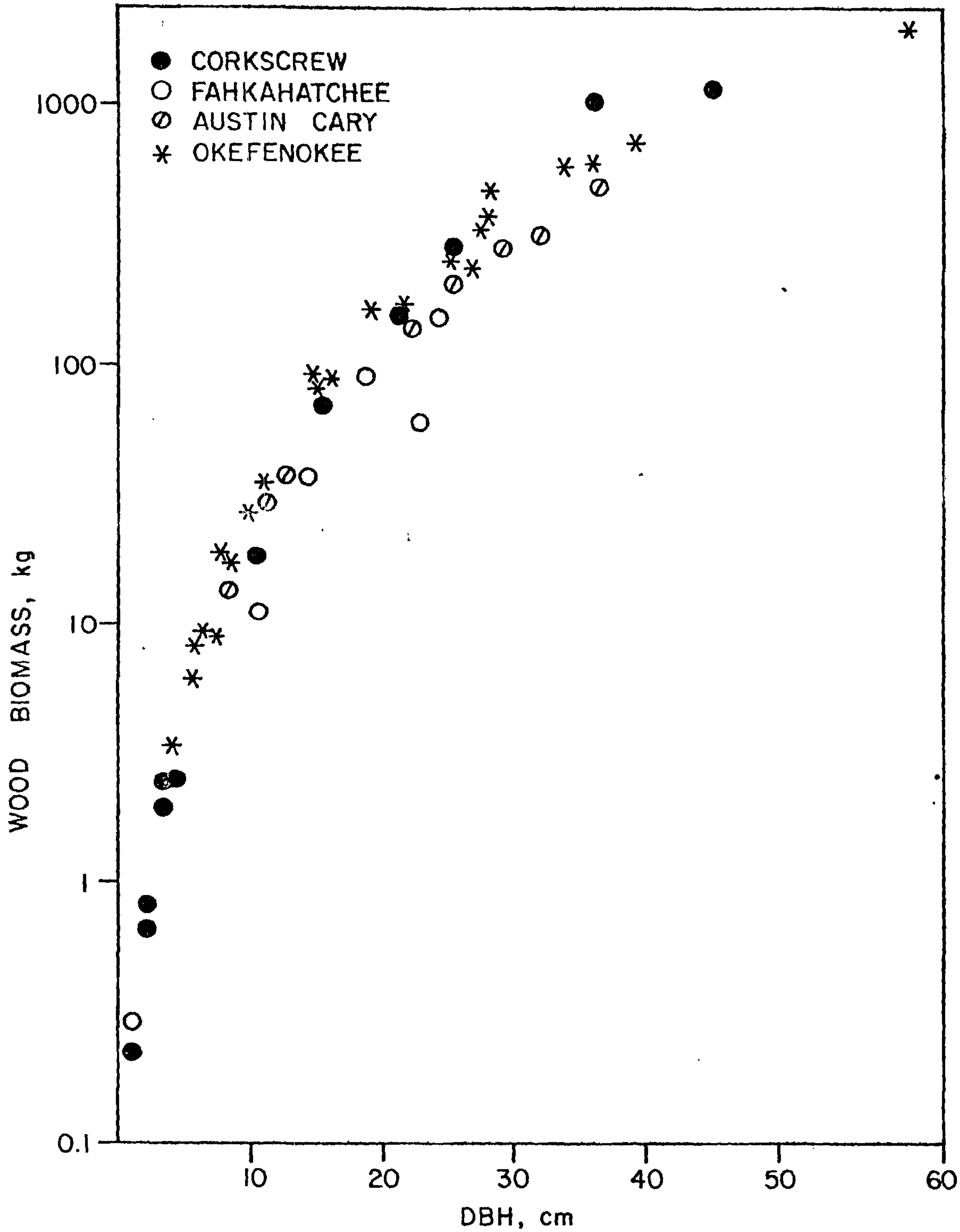


Figure 3. Comparison of cypress wood biomass/DBH at 4 sites.

probably related to light availability (Figure 4). Trees located within dense clusters appear to have much less foliage than trees of similar DBH at the strand edge or with access to a canopy opening.

Regressions of leaf and wood biomass/DBH will be calculated and used to complete estimates of tree and shrub biomass at harvest and productivity sites.

Marsh Productivity

The cattle exclosure study was designed to evaluate the effects of grazing on a variety of marsh habitats, but it also provided data on annual net productivity.

Methods used are described in the grazing studies section. The data in this analysis were all taken from inside the exclosures. Some cattle had been on all of the areas for a year or so prior to the study, and the "Bare Ground" and "Dutch's Pasture" sites had been severely overgrazed for many years. At least two sites in each major habitat type were sampled.

Litter quantity exhibited considerable community-to-community variability (Table 2). The overgrazed Bare Ground sites had the least litter standing crop (less than 40 g/m^2), and the two other overgrazed sites had relatively low quantities (from 30 to 60 g/m^2). *Spartina* habitats generally produced the most litter (400 to over 1000 g/m^2), and the remaining ungrazed marshes produced approximately 100 to 400 g/m^2. The few relatively high values in the pine-palm sites are probably due to additional inputs from overstory vegetation

Litter standing crop was usually maximum in late winter. The relatively short south Florida winters often permit many species to continue growth into December before being killed by frost. The only sites that frequently

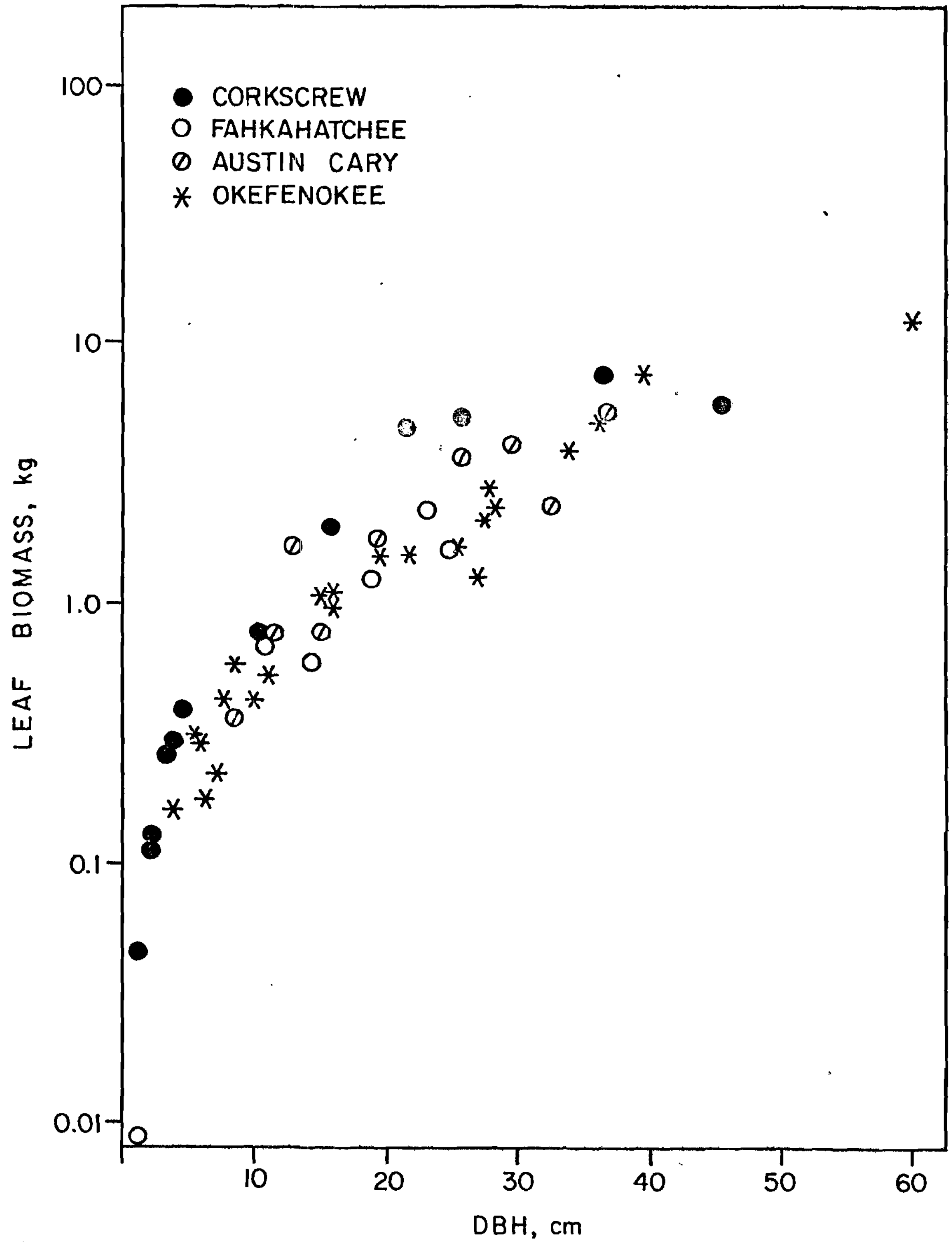


Figure 4. Comparison of cypress leaf biomass/DBH at 4 sites.

TABLE 2. 1975-1976 STANDING CROP OF MARSH LITTER IN GRAZING EXCLOSURES (gm/m²)

	AUGUST	NOVEMBER	MARCH	AUGUST	NOVEMBER
Small Bare Ground	10±0	20±9	32±3	15±5	
Large Bare Ground	2±0	5±4	37±4	13±5	
Dutch's Pasture-Transition	30±24	119±34	126±14	48±10	
Dutch's Pasture-Sagittaria	126±62	94±19	160±48	87±5	
Grapefruit Island-Spartina	610±170	466±168	452±62	706±92	
Northwest Fish Farm	388±214	159±12	365±169	266±28	
Northeast Fish Farm	2280±710	1231±211	659±174	586±178	
Little Corkscrew-Spartina	757±318	184±98	377±138	746±328	
Little Corkscrew-Maidencane	431±178	47±15	195±38	190±22	
Little Corkscrew Prairie West	323±63	286±196	520±345	135±30	
Little Corkscrew Prairie East	344±151	139±79	138±47	109±14	
Little Corkscrew Pine-Palm East	710±290	156±74	476±102	768±383	
Little Corkscrew Pine-Palm West	351±110	329±144	661±250	280±35	

exhibited maxima in August were dominated by Spartina with large clumps of standing dead litter. Litter standing crops were high at several other sites in August at the beginning of the study when cattle had just been removed. Only one of the pine-palm sites was high in August one year later, but samples from these sites included litter derived from overstory vegetation which often masked changes in understory litterfall patterns.

Biomass of marsh vegetation varied from approximately 10 to 70 g/m^2 in the overgrazed bare ground plots to 100 to over 500 g/m^2 in Spartina (Table 3). The pine-palm community supported only a very low understory biomass of 40 to 130 g/m^2, primarily because of shading in areas with a dense overstory. The other marsh sites had minimum biomass of approximately 100 g/m^2 and maximum biomass of from 250 to 450 g/m^2.

Seasonal biomass maxima were almost invariably found in August, and minima in March.

It is not surprising that bare ground plots with small biomass had the lowest net annual productivity or that the pine flatwoods understory, densely shaded in many spots, produced little (Table 4). The wet prairies, with only a slightly longer hydroperiod, but with much more open space than the pineland, had a net production of approximately 200 $g/m^2/yr$. Net production in Spartina was 350 to 800 $g/m^2/yr$, reflecting the large site-to-site variability in density of this species. The maidencane, arrowhead, and sedge communities had intermediate annual net productivity levels generally in the range of 150 to 300 g m^2/yr.

TABLE 3. 1975-1976 MARSH BIOMASS IN GRAZING EXCLOSURES (gm/m^2)

	AUGUST	NOVEMBER	MARCH	AUGUST	NOVEMBER
Small Bare Ground	46±3	70±20	11±4	23±2	
Large Bare Ground	29±17	32±14	20±12	73±22	
Dutch's Pasture-Transition	553±80	274±10	59±7	278±40	
Dutch's Pasture-Sagittaria	318±40	310±42	140±4	288±30	
Grapefruit Island-Spartina	553±80	498±144	378±54	202±27	
Northwest Fish Farm	239±27	154±17	97±20	254±6	
Northeast Fish Farm	1125±713	294±46	505±194	500±18	
Little Corkscrew-Spartina	750±229	252±46	257±86	380±88	
Little Corkscrew-Maidencane	442±82	253±30	151±9	468±22	
Little Corkscrew Prairie West	236±16	122±39	74±32	283±32	
Little Corkscrew Prairie East	366±95	144±34	149±30	304±7	
Little Corkscrew Pine-Palm East	71±3	62±14	105±54	96±26	
Little Corkscrew Pine-Palm West	133±28	106±24	43±11	57±21	

TABLE 4. NET ANNUAL MARSH PRODUCTIVITY

	NUMBER OF SITES	NET ANNUAL PRODUCTIVITY ($g/m^2/yr$)
BARE GROUND-OVERGRAZED	2	53-59
SEDGE - OVERGRAZED	1	494
UNGRAZED	1	157
ARROWHEAD-MAIDENCANE OVERGRAZED	1	178
UNGRAZED	1	317
SPARTINA	3	351-831
PRAIRIE	2	209-222
PINE FLATWOOD UNDERSTORY*	2	43-90

*Vegetation under 1 meter tall.

Grazing Studies

Cattle grazing has been the most significant recent human activity in the Corkscrew marshes and upland habitats. During 1975-1976, grazing impact on these environments was evaluated at 13 sites using fenced exclosures of either 10 or 25 square meters. The larger plots were for evaluation of effects on overstory communities, while the smaller were for evaluation of impacts on marsh vegetation. Three paired samples (three inside, three outside) were taken at the beginning of the study in August, 1975, and again in December, 1975, and in March and August, 1976. A final sample is scheduled for November, 1976. Stem diameter measurements of the overstory were taken in August, 1975, and again in August, 1976. Changes in biomass, litter standing crop, and presence or absence of species were used to quantify grazing effects while ground and aerial photos and ground observation provided qualitative evaluation of impacts.

Table 5 shows which sites had significant differences (t-test) in inside and outside understory biomass and litter standing crop and/or qualitative differences. No sites exhibited significant differences in biomass and litter standing crop between interior and exterior of exclosures at the beginning of the study in August, 1975, and only one site had a significant difference in biomass by December, 1975. The number of sites where significant differences existed increased through August, 1976, and the trend is expected to continue through the final planned sample in November, 1976.

Measurability of differences was influenced by a variety of factors, including within site variability, intensity of grazing, and timing of vegetative production and its conversion to litter. The construction of

TABLE 5. GRAZING EXCLOSURES

LOCATION	BIOMASS - SIGNIFICANT DIFFERENCE INSIDE V.S. OUTSIDE (* - .05 ** - .01 *** - .001)						VISUAL DIFFERENCES ⊙ - detectable ⊙⊙ - distinct		
	MARCH 1976		AUGUST 1976		NOVEMBER 1976		photo		on-site
	live	litter	live	litter	live	litter	aerial	ground	observer
Dutch's Pasture - Sagittaria									
Dutch's Pasture - Transition	*		*	*					
Large Bare Ground									
Small Bare Ground									
Grapefruit Island - Spartina		*							
Northwest Fish Farm				**			⊙⊙	⊙	⊙
Northeast Fish Farm			***				⊙⊙	⊙⊙	⊙⊙
Little Corkscrew Prairie East			**				⊙	⊙⊙	⊙⊙
Little Corkscrew Prairie West			*				⊙	⊙⊙	⊙⊙
Little Corkscrew - Maidencane	**		**	**			⊙⊙	⊙⊙	⊙⊙
Little Corkscrew - Spartina			*				⊙⊙	⊙⊙	⊙⊙
Little Corkscrew Pine-Palm East								⊙⊙	⊙⊙
Little Corkscrew Pine-Palm West	*							⊙⊙	⊙⊙

exclosures in July, 1975, was late enough in the growing season that few differences in understory biomass were detectable until August, 1976, when production of the 1976 growing season was measured. At that time there were few differences in litter standing crop, but differences can be expected to increase as the 1976 production dies. At most of the sites with a long history of intensive grazing (the "Bare Ground" and "Dutch's Pasture" sites), light grazing pressure in 1976 had little effect either quantitatively or qualitatively. Quantitative differences were insignicant at the Little Corkscrew Pine-Palm sites, but there were distinct visual differences in the understory vegetation in open portions of the site. Areas shaded by a dense overstory supported little understory vegetation and random sampling of sites with scattered clumps of trees and shrubs increased the variability enough to mask the obvious effects of grazing. Absence of effects at Grapefruit Island is probably due to distance from areas frequented by cattle and relatively poor forage quality.

The high degree of impact measured near Northeast Fish Farm and on Little Corkscrew Island is understandable. Little Corkscrew is the highest ground in the generally marshy area leased for grazing and several supplemental feeders are located there, so the island is the focal point of cattle activity.

In general, visual observations closely paralleled the quantitative analyses.

No differences in taxonomic composition inside and outside the exclosures were detected during the 1-year study period. The changes in species composition between August, 1975, and August, 1976, took place both inside and outside the exclosures.

The Corkscrew Watershed

The Corkscrew Swamp watershed boundaries shown in Figure 5 were defined from 5-foot contours on United States Geological Survey topographic maps (scale 1:24000). The drainage area within and above the sanctuary is 295 km^2, of which about 90 km^2 is normally inundated for more than 6 months each year. The sanctuary occupies 46 km^2, about half of the area with a 6 month hydroperiod.

The major flows enter the sanctuary along its eastern boundary and leave along the southern edge. At high water level, significant outflows also occur along the western boundary and through a slough directly south of Lake Trafford. An old high water connection with the Okaloacoochee Slough east of Lake Trafford no longer functions due to development.

At present, no major canals drain the watershed above the sanctuary. At the northwest corner of the watershed there is a small canal lying along the Lee-Hendry County line and ending north of State Route 82, but it affects only a minor portion of the watershed.

Changes in timing of runoff into the sanctuary seem to be the only significant hydrological modification to the watershed. The agricultural areas surrounding the sanctuary have short canals for wet season drainage leading into Corkscrew Marsh, but the level terrain minimizes their effectiveness. During the dry season the farmers supplement shallow groundwater supplies from deep wells, which apparently more than compensates for the small amount of water drained off prematurely.

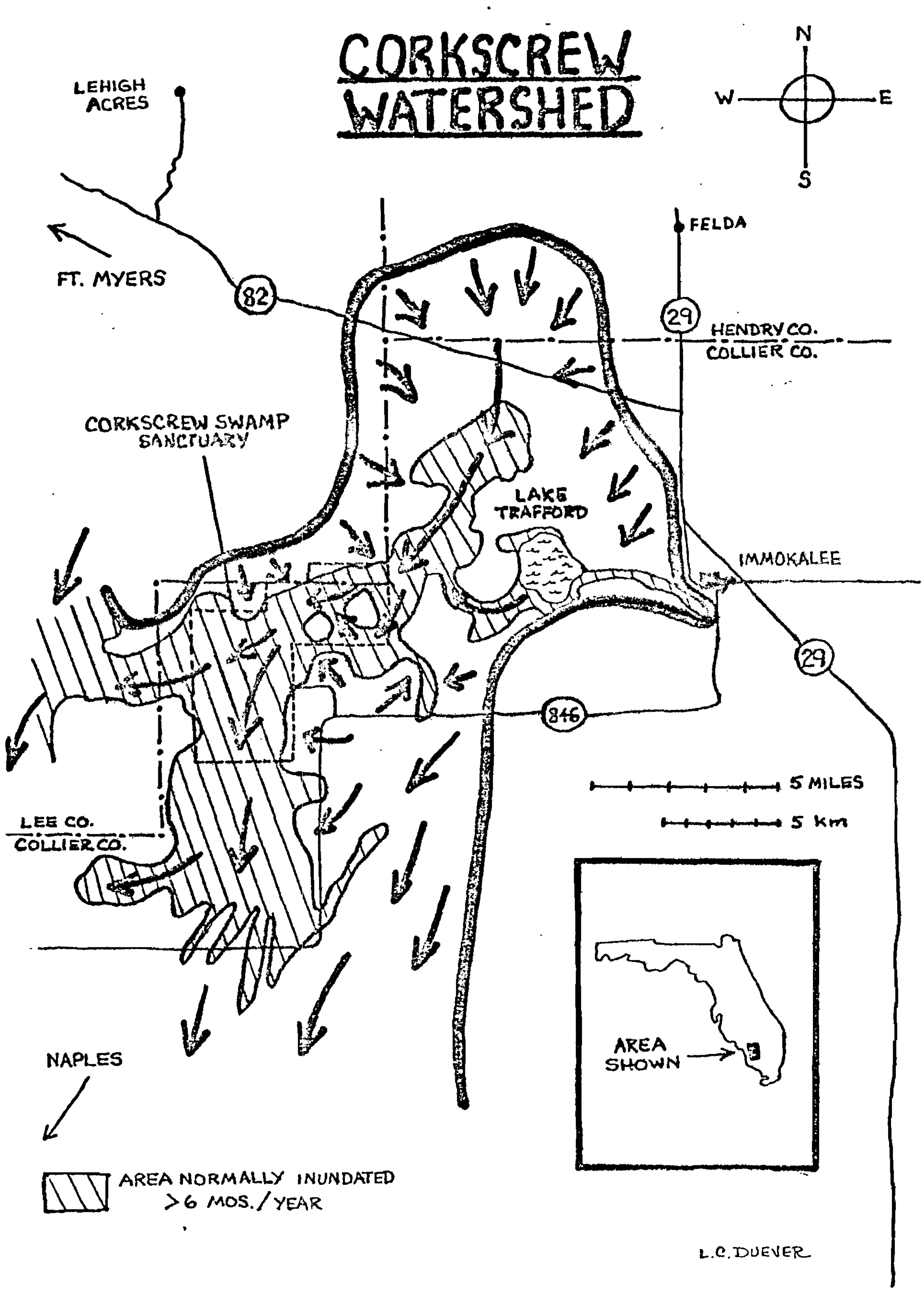

CORKSCREW WATERSHED
N
W
E
S
LEHIGH ACRES
FT. MYERS
82
FELDA
29
HENDRY CO.
COLLIER CO.
CORKSCREW SWAMP SANCTUARY
LAKE TRAFFORD
IMMOKALEE
29
846
5 MILES
5 km
LEE CO.
COLLIER CO.
AREA SHOWN
NAPLES
AREA NORMALLY INUNDATED >6 MOS./YEAR
L.C. DUEVER

Figure 5.

Soils

Corkscrew soils are predominantly sands with peat accumulations in depressions, and much scattered limerock and numerous shell beds beneath the surface. Where rock outcrops are higher than the surrounding area they have been colonized by hardwoods and covered by a loamy organic soil. In some areas rocks are found buried under peat deposits in depressions. Nowhere at Corkscrew is rock or shell found naturally exposed at the ground surface.

The sand deposits are not only the major soil type, but the patterns in which they were deposited and subsequently eroded determine the area's major topographic features. The only significant exceptions are the small and scattered rock outcrops that support hardwood hammocks and the rock underlying certain depressions which has limited the depth of erosion (the Central Marsh area).

The sands generally vary from tan to brown in color and are characteristically fine and thus relatively impermeable. In drier areas with relatively deep sands, such as pine-palmetto habitats, upper strata are often a strongly leached white sand with a dark speckling of intermixed undecomposed organic matter towards the surface. At depths of 3 to 4 feet the material leached from the surface strata forms a dark brown to black hardpan which grades into the deeper brown sands.

In wetter areas, such as low pine flatwoods and shallow marshes, the brown sands extend from the surface down to depths of 3 to 6 feet, then grade into the gray or blue-gray sands characteristic of permanent inundation. At intermediate depths an orange or brown mottling indicative of periodic inundation can occur. This appears to be associated with plant root channels.

Dark brown "sticky" sands are a common feature below peat deposits more than a foot or so deep and are apparently a result of the mixture of decomposed peat or muck with underlying sand.

Peat deposits are found in mineral substrate depressions with a relatively long hydroperiod. Such depressions at Corkscrew are invariably low spots in the sand surface. The upper 2 or 3 feet of the peat profile are dominated by fibrous material which grades downward into mucky peats, some of which have almost a "slurry" consistency. At sites where there are several feet of peat over a sand strata, dark "sticky" sands normally extend to a depth approximately twice the thickness of the peat layer. Crayfish are probably responsible for this apparent mixing of sand and muck and also for small amounts of sand that occasionally appear in the upper strata of otherwise homogeneous deep peat deposits. Crayfish are abundant at Corkscrew, and during the dry season we have found them over 4 feet beneath the soil surface.

Rock appears in the soil profile in several forms: small pebbles, large individual rocks, and strata. The small pebbles, normally soft and well weathered, occur extensively on the sanctuary, varying in size and abundance. They are a common feature in shell beds, mixtures of sand and clay and near the surface of rock strata, but are also often a component of sand deposits, concentrated in distinct layers. The soft rock strata are usually those higher elevation outcrops supporting hammocks and are thus the sites with greatest exposure to atmospheric weathering. The hardened strata are normally inundated most of the year, and may be solid limestone, cemented shell deposits, or a mixture of the two. Determining the depth and distribution of rock strata is extremely difficult because of their irregular surface and the problem of distinguishing continuous strata from isolated large rocks and boulders or dense concentrations of pebbles.

Shell deposits vary in size from small quantities mixed with the other materials to almost pure accumulations more than 3 feet thick. Water level data from areas with and without shell deposits indicate that these strata can be extremely permeable conduits. Dry season water table depression is greatest in areas where shell is extensive and continuous, but at some sites with thick shell strata there is little water table depression, perhaps because the shell beds are small or isolated by impermeable surrounding strata. Shell beds were always separated from the ground surface or peat deposits by at least several feet of sand.

Clay (marl?) occurs widely as a minor component in sand strata and is predominant in a few scattered areas. What appears to be an almost pure marl under many of the thicker peat deposits on the Central Marsh and South Dike transects and occurs sporadically under some of the deeper peats in other areas. A marl with some sand intermixed underlies parts of the Grapefruit Island transect.

Corkscrew soils exhibit the same erratic strata patterns noted by earlier researchers in southwest Florida. In an attempt to clarify the relationship between vegetation and substrates, we have done over 100 soil cores on the sanctuary, primarily along the five transects, but also at a number of scattered sites. Soil profiles of five transects are depicted in Figures 6-9. Profiles were not constructed for the South Dike because of the small number of cores taken and their similarity to those on the Central Marsh transect.

No clear relationship between major habitats and substrate types was found (Figures 6-9). Elevation, which affects water levels and hydroperiod,

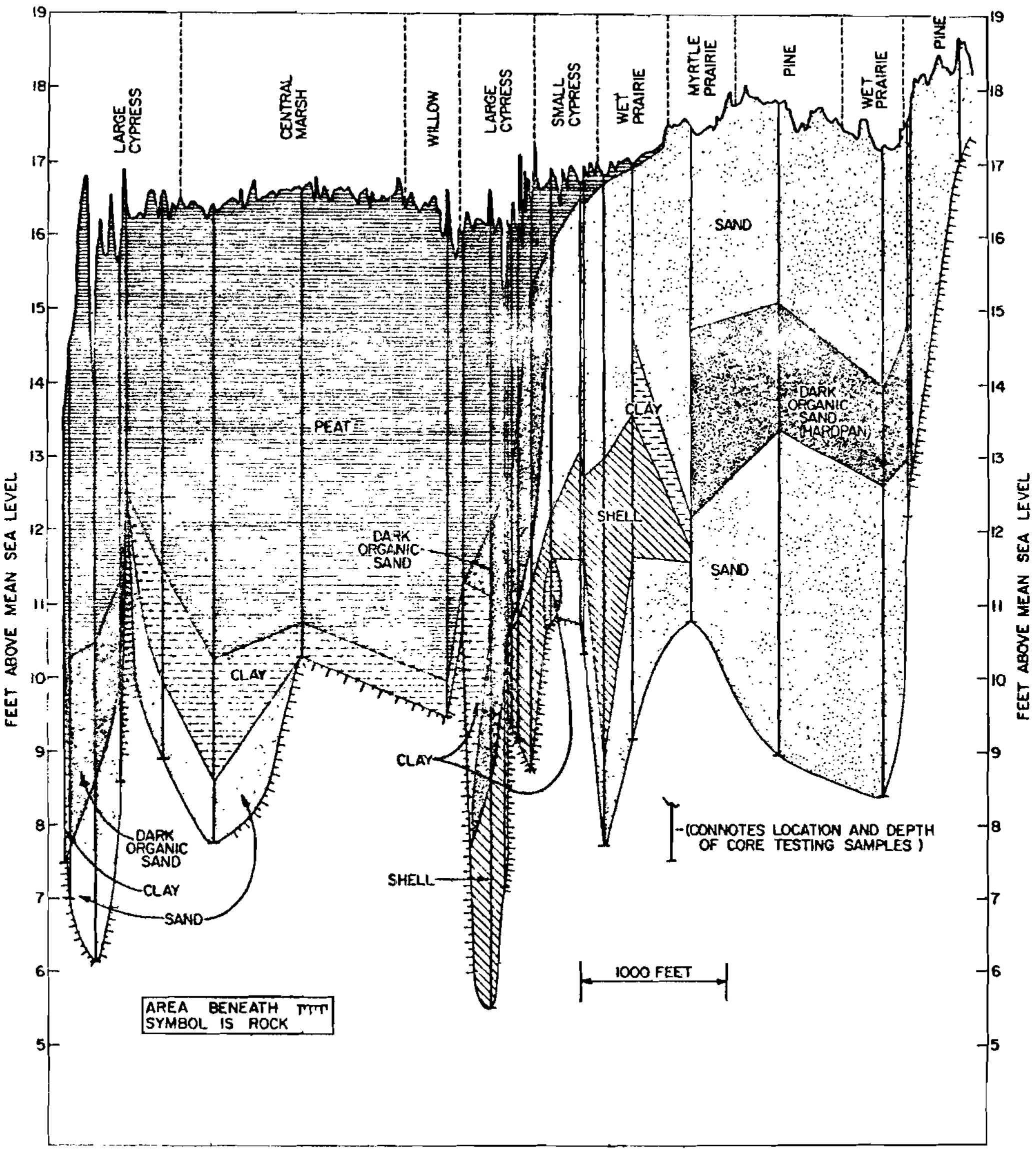


Figure 6. Central Marsh transect soil profile.

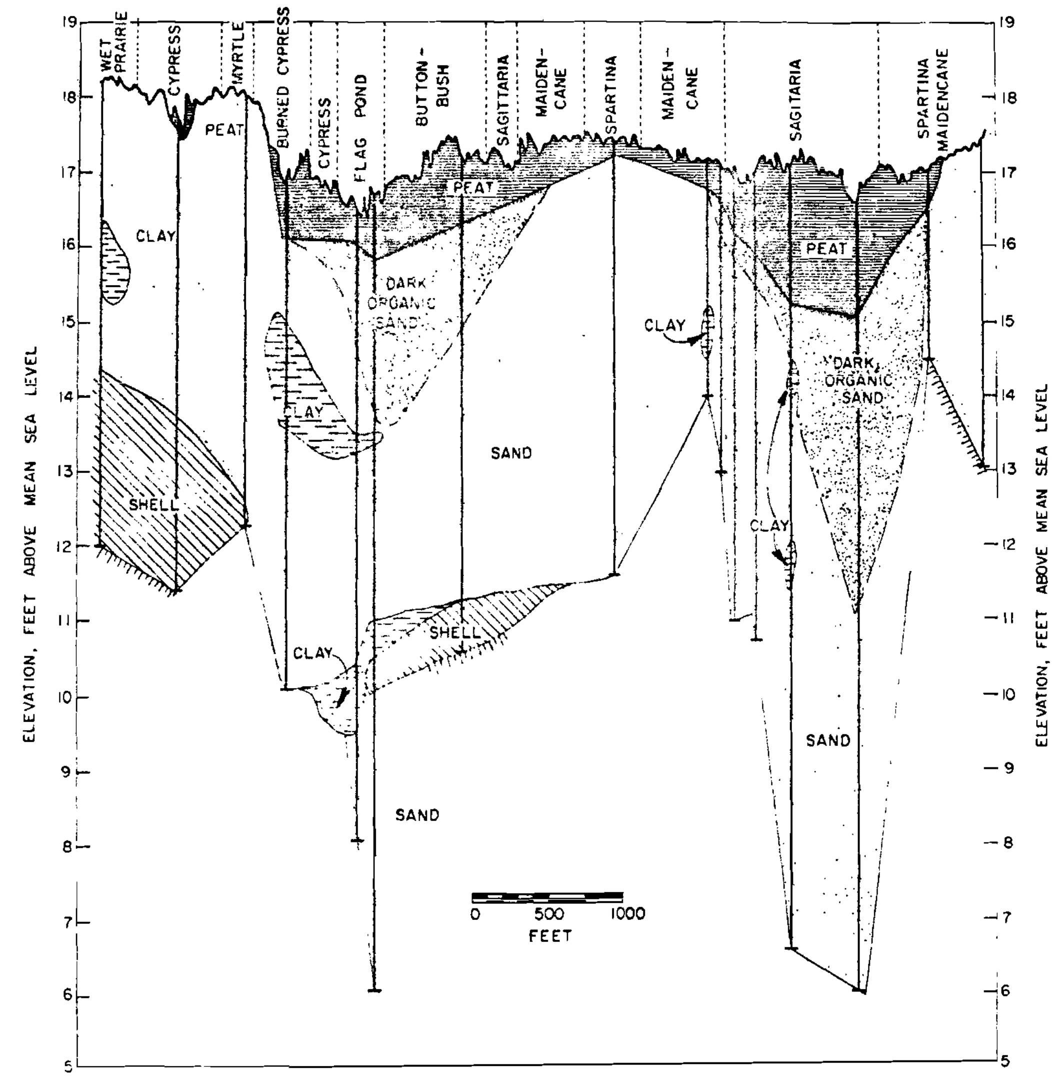


Figure 7. North Marsh transect soil profile.

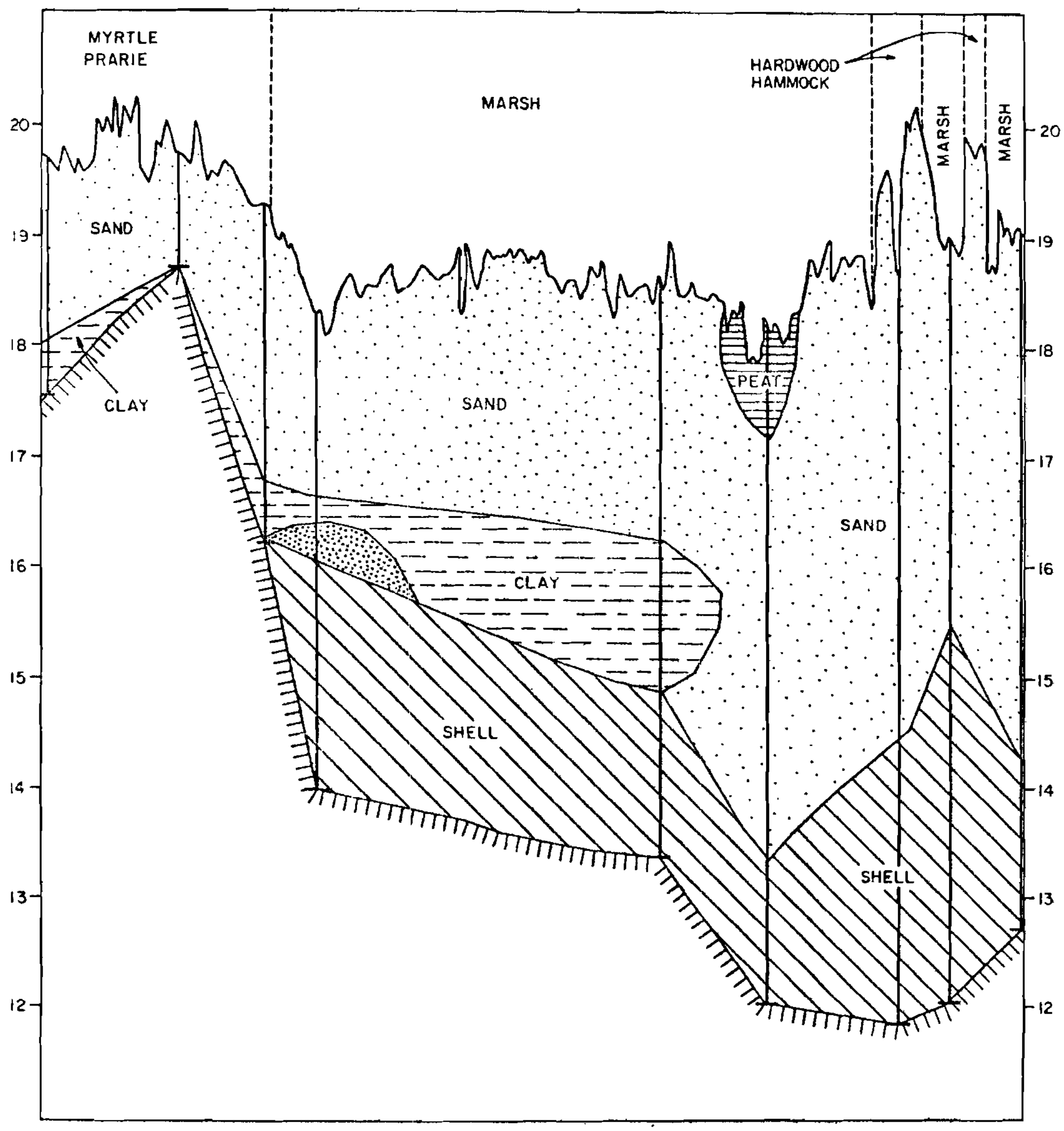


Figure 8. Grapefruit Island transect soil profile.

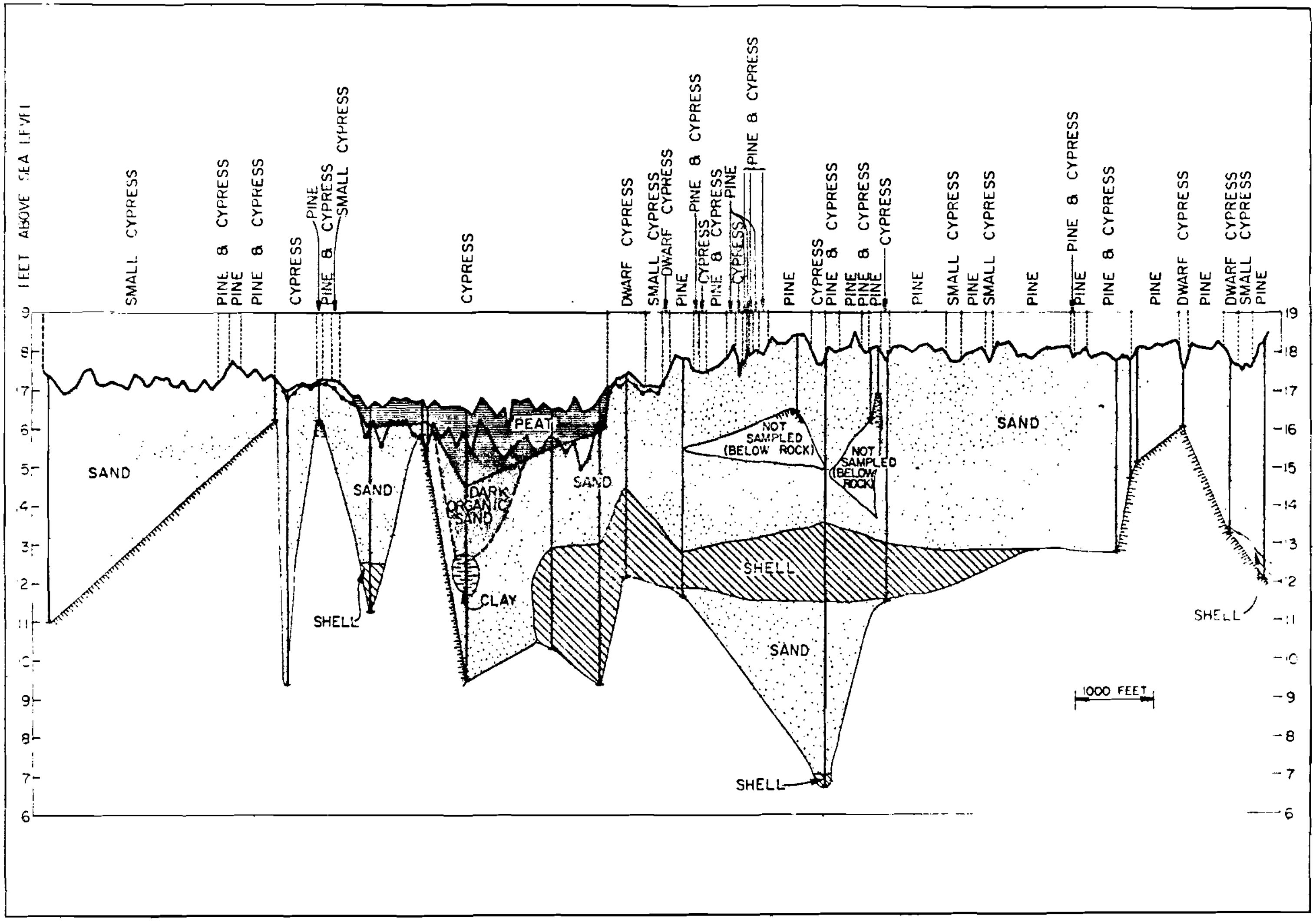


Figure 9. Gordon Swamp transect soil profile.

appeared to be much more significant. The pinelands and hammocks occur on higher elevations, whether these be sand or rock substrates. Lower sand, rock, or peat areas support marshes or cypress, and the lowest sites are open water, again regardless of substrate type. Of course, peat formed only where depressions were deep enough to remain wet for much of the year.

Substrate permeability is obviously a significant factor affecting groundwater flows. Thus distribution patterns of relatively impermeable rock, clay (marl?), and peat strata and extremely permeable shell deposits are important determinants of groundwater flow routes, and must be understood before flow quantities can be estimated.

To evaluate the relationship between substrate type and groundwater flows, we compared the soil profiles for each transect with the seasonal water table profiles (Duever et al., 1975). The water table profile was relatively level on the North Marsh transect, indicating that substrate type had little differential effect on groundwater flows (Fig. 7).

On the Grapefruit Island transect, the dry season water table profile slopes from Ruess Island to Little Corkscrew Island. This corresponds to the direction of slope of both the relatively impermeable rock and clay strata and the permeable shell beds (Fig. 8). Depression of the dry season water table profile and areas of shell deposits also correspond on the Central Marsh transect where there are higher dry season water levels in areas with peat, rock, and clay (marl) strata (Fig. 6).

Soil types also influence water quality and nutrient availability. Physical and chemical analyses of the soil samples are now complete and analysis of this data is in progress.

A 3/4-inch diameter rod was pushed by hand into the soil at 100 foot intervals along each transect to determine more accurately the mineral soil surface profile and the depth of associated peat deposits. Where both soil cores and rod penetrability measurements were taken, good agreement between methods was found. Penetrability measurements produced much more detailed profiles because the ease and speed of the method allowed many more sites to be sampled even when they were inundated. Inundation limited soil coring because sand strata often collapsed when waterlogged.

LITERATURE CITED

Carter, M.R., L.A. Burns, J.R. Cavinder, K.R. Dugger, P.L. Fore, D.B. Hicks, H.L. Revells, and J.W. Schmidt. 1973. Ecosystems analysis of the Big Cypress Swamp and estuaries. National Technical Information Service, U.S. Dept. of Commerce, Springfield, Va.

Duever, M.J., J.E. Carlson, and L.A. Riopelle. 1975. Ecosystems analyses at Corkscrew Swamp. Pages 627-725 In H.T. Odum, K.C. Ewel, J.W. Ordway, and M.K. Johnston (eds.). Cypress wetlands for water management, recycling and conservation. Center for Wetlands, Univ. of Florida, Gainesville.

Mitsch, W.J., P.A. Straub, D.M. Post, and S.W. Cowles III. 1974. Biomass determinations of individual pond cypress (*Taxodium distichum* var. *nutans*) trees and of an entire cypress dome. Pages 445-458 In H.T. Odum, K.C. Ewel, J.W. Ordway, M.K. Johnston, and W.J. Mitsch (eds.) Cypress wetlands for water management, recycling and conservation. Center for Wetlands, Univ. of Florida, Gainesville.

Schlesinger, W.H. 1976. Biogeochemical limits on two levels of plant community organization in the cypress forest of Okefenokee Swamp. Ph.D. Dissertation. Cornell Univ., Ithaca, New York. 142 pp.