REGENERATION OF CYPRESS, *TAXODIUM DISTICHUM* AND *TAXODIUM ASCENDENS*, IN LOGGED AND BURNED CYPRESS STRANDS AT CORKSCREW SWAMP SANCTUARY, FLORIDA

By

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Chairman: John Ewel
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Regeneration of two species of cypress, *Taxodium distichum* (L.) Richard (baldcypress) and *Taxodium ascendens* Brogn. (pondcypress), was investigated in successional seres resulting from logging (1954) and burning (1963) of cypress strands at Corkscrew Swamp Sanctuary, near Naples, Florida.

The effects of a dike constructed in 1969 to impound water to the north were also examined. Sites were established in areas that were: 1) logged and north of the dike, 2) logged and south of the dike, 3) logged-and-burned and north of the dike, 4) logged-and-burned and south of the dike, and 5) burned and north of the dike.

Seedlings of *T. ascendens* were transplanted in January, 1976 among existing vegetation and into cleared areas at each study site, and seedling heights were measured through October, 1976. Seeds of *T. distichum* and *T. ascendens* were sown at each study site. Germination of seed was monitored in the field and under greenhouse and laboratory conditions. Water levels were monitored at each site from October, 1975 through October, 1976. Vegetation maps were drawn from sequential sets of aerial photographs to determine rates of change of the vegetation after

disturbances of logging and burning.

There was no significant difference in the growth rates of cypress seedlings among the five sites. No detectable difference was measured between seedlings growing among existing vegetation and seedlings growing in cleared areas. Maximum mean height increase of seedlings measured was 80%. Survival of transplanted seedlings was 66%.

Maximum germination of sown cypress seeds was 4.8%. Average germination in the field was 2.1%; less than 5% of those which germinated survived through the wet season.

At the logged sites hardwoods such as *Ilex cassine*, *Acer rubrum*, *Persea palustris*, *Myrica cerifera*, and *Myrsine guianensis* are present in the overstory and are actively regenerating. Some cypress regeneration by coppicing and seed is occurring at these sites also. The logged-and-burned and burned sites are dominated by *Salix caroliniana*. There is no cypress regeneration at the logged-and-burned sites, but some regeneration is occurring by coppice and seed at the burned site.

Measurements of water levels indicate longer periods of inundation at the logged and logged-and-burned sites than at the burned site. The dike creates lower water levels to the south, but does not change the period of inundation.

Vegetation maps indicate that hardwoods persist following logging. Colonization by *S. caroliniana* follows destruction of the hardwoods by fire.

Lack of seed sources, immobility of cypress seed, low viability, and crucial water requirements for germination seem to be retarding cypress regeneration. Once established, cypress is able to compete with existing vegetation.

John Ewel

Chairman

INTRODUCTION

South Florida cypress forests, dominated by baldcypress *Taxodium distichum* (L.) Richard and pondcypress *Taxodium ascendens* Brogn., have been described by Small (1920), Harper (1927), Davis (1943), and Craighead (1971). Davis (1943) described three types of cypress forests: domes, strands and heads. Cypress domes are found in shallow, circularly concave depressions in the limestone substrate (Craighead, 1971). Cypress strands are found in deeper, elongated depressions, and cypress heads are cypress domes contiguous with strands near the strand headwaters.

The period of inundation in a cypress ecosystem is a function of topography, substrate and rainfall. The topography of most of south Florida is very flat (gradients of 8 to 16 cm/km) and surface water flow is slow (0.8 km/day) (Carter et al., 1973). Elevations in cypress sloughs may be 1.5 m lower than surrounding pineland. Peat substrates predominate in cypress strands and the increased water holding capability of peat over the well-drained soils of the surrounding pinelands and wet prairies prolongs the hydroperiod in the strands. Mean annual rainfall for the Big Cypress area is from 1400 to 1500 mm with 60 to 65% falling from June to August (Carter et al., 1973). Duever et al.,(1975) monitored cypress strand ecosystems at Corkscrew Swamp Sanctuary and found that inundation usually commences in early June and lasts from 200 to 250 days.

Cypress strands are considered by some to be subclimax communities to mesic, mixed hardwood forests (Davis, 1943; Craighead, 1971) dominated by tropical species in southern south Florida and temperate species in the northern parts of south Florida (Alexander and Crook, 1973). The transition to climax status is accomplished by the slow process of peat accumulation which alters edaphic conditions permitting hardwoods to become established and thrive in the more mesic conditions around the bases of the cypress trees (Penfound, 1952). Due to the long life span of cypress trees and periodic peat removal (by fire and water flow), however, cypress forests usually remain as cypress forests for long periods of time.

The strand ecosystems are subject to change by a myriad of factors, both natural and anthropogenic. Natural forces which bring about change include fire, lightning, hurricanes, frosts and alligators (Davis, 1943; Craighead, 1971). Man-induced changes that initiate secondary succession include lumbering, and canal and levee building (Davis, 1943; Alexander and Crook, 1973). The value of baldcypress as lumber led to extensive logging which removed almost all of the large (greater than 0.5 m diameter) trees from south Florida.

Logging

Logging of baldcypress in the Big Cypress Swamp area of Florida was initiated in the 1920's. Harvesting of the cypress peaked in the mid-1940's and tapered off in the 1950's, when most of the large trees had been removed (Betts, 1960). Hardwood species, which were subcanopy trees in the unlogged forest, dominate following lumbering (Alexander and Crook, 1973). No cypress reforestation programs were established in Florida.

In the 1940's the use of railroads to carry cypress logs to sawmills became widespread in south Florida. The operation began with construction of earthen dikes parallel to the long axis of the swamp. Perpendicular spurs were built into adjacent cypress areas at intervals of 0.5 km. While the rails were being laid on these dikes, a crew of workers would girdle the cypress trees. The girdled trees would be left standing for several months prior to felling, so that the logs would dry out and float when cut. Severe degradation of the lumber was caused by ambrosia beetle attacks during this period (Craighead, 1971). The trees were felled during high water and cut into 10 m lengths which were skidded to the railway cars using an overhead cable. Large skid trails were left from removal by this method (Prestridge, 1947), and many of the tram roads and spurs are still apparent today.

Reforestation of cut-over cypress wetlands (transplanting nursery grown cypress seedlings) began in Louisiana in 1948 (Bull, 1949) and continued through 1951 (Rathborne, 1951). Rathborne (1951) estimated a 70-year regrowth period following this operation. Stubbs (1972) stated that most logged cypress-tupelo forests have naturally regenerated, but tupelo (*Nyssa* spp.) may dominate instead of cypress. Stump sprouts are important in the regeneration cypress-tupelo swamps (Johnson, 1972). Supplying seed may be necessary, as uncut seed trees and coppice may produce inadequate amounts of seed (Stubbs, 1972). Sternitzke (1971) suggested that the standing stock of cypress in the southeastern U. S. increased 2% per year through 1968, most of which is regrowth from cut-over forests. The supply of marketable timber in Florida is largely pondcypress (*T. ascendens*): not regrowth of baldcypress (*T. distichum*) (Sternitzke, 1972).

Succession following Logging

Succession following lumbering may be determined by the severity of the physical effects of the logging operation. DeBell et al. (1968)

found that 60% of all saplings and 8% of all small diameter trees of overstory species were killed by felling and skidding during a selective lumbering of bottomlands in Louisiana. Remaining seed trees and stump sprouting may result in rapid regrowth following cutting (Oosting, 1956). Vegetation reproduction such as stump sprouts, adventitious shoots, and epicormic branches may result in rapid regrowth, but the regrowth is susceptable to fungal infection and the growth form of the trees which are left is usually not good (Smith, 1962). If culls are the only remaining trees, the proportion of undesirable genetic stock in the community may be larger than in the prelogging community. Regeneration of wetland forests may be slow if few seed sources are left and if seed germination requires very specific conditions (Stubbs, 1972). Exposure of organic soils, and subsequent subsidence of the soil level, was one result of logging in south Florida cypress strands (Alexander and Crook, 1973). These changes in the soil due to logging may alter the successional patterns.

Mueller-Dombois and Ellenberg's (1975) explanation of succession after logging (using Egler's (1954) terms of "relay floristics" and "initial floristic composition") may be applicable to patterns observed in south Florida swamps. The relay pattern of species replacement is a result of modifications of a site by a group of species in such a way that their own survival is limited, and the survival of a succeeding group of specie is enhanced with arrival of the succeeding species' propogules. The other theory, "initial floristic composition", attributes the pattern of species replacement to differences in growth rates and life spans of the groups of species, with a majority of propogules being present at the beginning of the sere. Most or all of the cypress seed sources may be exhausted following a lumbering operation. Following the disturbance, secondary succession proceeds rapidly through a stage dominated by those fast-growing hardwood species which remain after the logging operation. Succession may stagnate until proper conditions and arrival of cypress seed (relay floristics mechanisms) result in the reestablishment of cypress dominated communities.

Fire

Fire in natural forested wetlands may occur if the substrate becomes dry. Peat, even with its high water retention capacity, becomes dry during years of low rainfall, leaving the system vulnerable to fire (Craighead, 1971). Fire could be partly responsible for maintaining the cypress forests in a subclimax stage of succession (Alexander and Crook, 1973) by the removal of hardwoods.

The high water retention properties of peat usually create an effective barrier to fire during the wet season and early into the dry season (Craighead, 1971), yet surface burns may occur early into the dry season (Robertson, 1953). If the moisture content of the peat goes below 30 percent, the peat may ignite, initiating a slow-burning peat fire (Craighead, 1974). The heat from the fire may dry out underlying layers of peat which may in turn be consumed (Alexander and Crook, 1973). The peat fire may continue to smolder until it is extinguished by rains or meets a non-combustible barrier such as the water table (Robertson, 1953) or sand layer (Cypert, 1961).

Succession following Burning

Succession after a fire in south Florida may be related to the time of the year and severity of the burn. Fast moving surface fires may consume understory and shrubby species (Cypert, 1961), as well as seedlings and saplings of overstory species (Penfound, 1952). Hardwood species and upland conifers may also be weeded out by surface fires. Ewel and Mitsch (1975), for example, found that cypress survived a surface burn in a north central Florida cypress dome better than slash pine, *Pinus elliottii*, and tupelo, *Nyssa* spp. growing in the same dome.

The species composition of a swamp is drastically altered after a deep peat burn. A deep burn consumes the roots of large cypress and bay trees (Cypert, 1961) and eliminates recovery by sprouting (Alexander and Crook, 1973). In open water areas, which may be a result of peat removal by the fire, both rooted and floating aquatic plants then become part of the successional vegetation (Penfound, 1952). The charred stumps are foci for colonization by non-aquatic herbaceous invaders (Beaven, 1939). Fast growing shrubs such as titi, *Cyrilla racemiflora*, and buttonbush, *Cephalanthus occidentalis*, are conspicuous in northern Florida swamps until regeneration of the overstory cypress and bay trees occurs (Cypert, 1973). Frequent fires in south Florida allow stands of willow, *Salix caroliniana*, to prevail (Robertson, 1953; Loveless, 1959; Craighead, 1971).

Fire in a logged cypress swamp is often more devastating than fire in an unlogged swamp (Cypert, 1961; Alexander and Crook, 1973) because the remaining slash and dense undergrowth that follows a lumbering operation burns more hotly than does the sparse undergrowth of uncut swamps (Cypert, 1961). The shallow root systems of the second-growth forests are more likely to be damaged by the hotter fires. The severe burns may destroy seed sources and vegetative regrowth, deterring succession until propogules arrive and proper conditions are reestablished for the development of predisturbance dominant species.

Cypress Autecology

Taxodium is a genus in the Taxodiaceae, a family in the Coniferales.

Taxodium distichum is commonly known as baldcypress, cypress, southern cypress, gulfcypress, tidewater red cypress and yellowcypress (Fowells, 1965). The name baldcypress is used because the tree is annually deciduous (Mattoon, 1915). T. distichum ranges on the southeastern coastal plain from Delaware to Texas, and in the Mississippi River valley to Indiana and Illinois (Mattoon, 1915). T. ascendens has a narrower range, from Virginia to Louisiana on the coastal plain. A third species, T. mucronatum, is found in northern Mexico (Small, 1931).

Known as the "wood eternal", cypress has been used for outside construction such as siding, sashes, doors, blinds, steps, railings, porches, buckets, tanks, moulding and shingles (Mattoon, 1915). In Florida, cypress has been used to make crates to carry soft drinks and oranges. One common use for pondcypress is fence posts, although the portion of the post which is alternately wet and dry decays faster than the portions which remain wet or are constantly dry. Today in southern Florida, small sawmills cut pondcypress into stakes, used to support tomato plants grown in the winter.

Taxodium is monoecious. The female cones appear in March and April, and mature in October through December (Bonner, 1974). The male cones are present from December to March and form tassle-like clusters 8 to 12 cm long. The female cones are 1.3 to 3.1 cm in diameter and contain 18 to 30 seeds (Mattoon, 1915). Two ovules are associated with each scale on the cone (Bonner, 1974). The cones usually disintegrate on the tree, but may fall entire to the ground. Due to their size, the seeds are not dispersed by wind but by flowing water (Fowells, 1965). The seed must soak from one to three months (Mattoon, 1916), not to break a physiological dormancy, but so that water can permeate the thick seed coat (Murphy and

Stanley, 1975). The seed will remain viable underwater up to one year (Applequist, 1959), yet will not germinate while underwater (Demaree, 1932). Germination will occur on dry ground, but not on well-drained soils (Mattoon, 1915). Percent germination varies: Applequist (1959) reported 35%, Mattoon (1915) gave values ranging from 55 to 88%, Bonner (1974) measured from 67 to 93% (full seed only), and Murphy and Stanley (1975) reported values from 13 to 90% (full seed).

The germinated seedling has from four to eight cotyledons, averaging six (Welch, 1932). Water requirements for the seedling seem to determine the distribution of the species. Irreversible wilting occurs three to four hours following loss of soil moisture (Dickson and Broyer, 1972). Growth on anaerobic, flooded soil is less than growth on aerobic, flooded soil (Dickson and Broyer, 1972). The seedling will not grow if completely inundated, yet will produce new sprouts following a six week inundation (Welch, 1932). Sufficient growth during the first dry season must occur for the seedling to escape inundation (Demaree, 1932), as prolonged inundation will result in mortality (Demaree, 1932; Bull, 1949; Betts, 1960).

Bonner (1974) reported that no animals are believed to eat the seed or resinous cone material, but squirrels at Corkscrew Swamp Sanctuary have been observed eating the seed. Cypress seed was a component of the diet of the now extinct Carolina paroquet (Sprunt, 1954). Rabbits and nutria may eat the new shoots, branches, bark and roots of seedlings (Fowells, 1965).

Felled trees, 25 to 40 cm in diameter, will produce healthy sprouts from the stump. Trees up to 200 years old may sprout when cut down, but the more advanced the age of the tree, the less vigorous the regrowth (Detwiler, 1916). Trees that are girdled and felled usually do not sprout (Mattoon, 1915).

The taxonomic distinction between T. distichum and T. ascendens is questionable. Some taxonomists (Small, 1933; Long and Lakela, 1971) consider them to be two species. Other authors (West and Arnold, 1956; Kurz and Godfrey, 1962; Fowells, 1965) consider pondcypress to be a variety (T. distichum var. nutans (Ait.) Sweet) of baldcypress. Differences between the two types include leaf shape, leaf arrangement and orientation of young branches. T. distichum has linear leaves, flattened along the branches, and young branches which spread away from the main axis of the trunk (Long and Lakela, 1971). T. ascendens has subulate leaves, appressed to the stem, and young branches which ascend or become parallel to the main axis of the trunk (Long and Lakela, 1971). In areas where both types of cypress occur, the characteristics of leaf shape, leaf arrangement and branch orientation may intergrade, which leads to difficulty in distinguishing between them.

Objectives

Successional communities resulting from lumbering, burning and burning-following-lumbering of Taxodium- dominated strands are present within Corkscrew Swamp Sanctuary. Three questions were proposed: 1). Is there evidence that restoration of the predisturbance community is occurring? 2). Given that the community will again resemble the predisturbance system, can the process of secondary succession be accelerated? 3). Is the successional vegetation long-lived, constituting a disclimax, or is the vegetation actively changing?

To answer the first question, an inventory of the vegetation of each community was done. Actively regenerating species would be present as seedlings and/or saplings and seed sources present may give an indication of which species may potentially dominate the community.

Seedlings and seeds of *Taxodium* were planted into the successional communities to determine if parts of the successional process may be by-passed. Survival of the seedlings would indicate that proper site conditions exist for growth, and that other factors such as seed supply, seed viability, or germination requirements may be limiting regeneration of *Taxodium*.

Vegetation maps were constructed from chronological sequences of aerial photographs. From the maps, vegetation changes were determined to measure rates of change following logging, burning, and logging-and-burning.

STUDY SITE

Corkscrew Swamp Sanctuary, located in northern Collier County, Florida (Fig. 1), is the largest remnant of the cypress strand ecosystems which at one time collectively made up parts of the Big Cypress Swamp as described by Davis (1943). The Sanctuary presently consists of approximately 4200 ha owned and maintained by the National Audubon Society, primarily for the preservation of the cypress forests and the associated woodstork, *Mycteria americana*, rookery.

Before permanent dwellings were built in 1954, the site was used as a camp, first by hunters and later by game wardens protecting water birds from plume hunters. Logging was initiated to the south of the Sanctuary by the Lee Tidewater Cypress Company in the late 1940's. Logging continued until 1954 when the Corkscrew Cypress Rookery Association was formed to protect remaining habitats used as rookeries. The Association purchased 907 ha for $170,000, and the Lee Tidewater Cypress Company donated 259 ha to form the sanctuary. The National Audubon Society assumed supervision and maintenance of the Sanctuary and acquired 1295 more hectares from the Collier Enterprise over a twelve year period. An additional 1748 hectares were purchased in 1968 as buffer areas.

A fire entered the sanctuary from the southeast on June 8, 1962. The eastern strand of logged baldcypress was burned along with portions of the unlogged pondcypress. Rains extinguished the fire on June 10, 1962.

In the late 1960's, officials of the Sanctuary feared that drainage from an extensive canal system associated with the Golden Gate

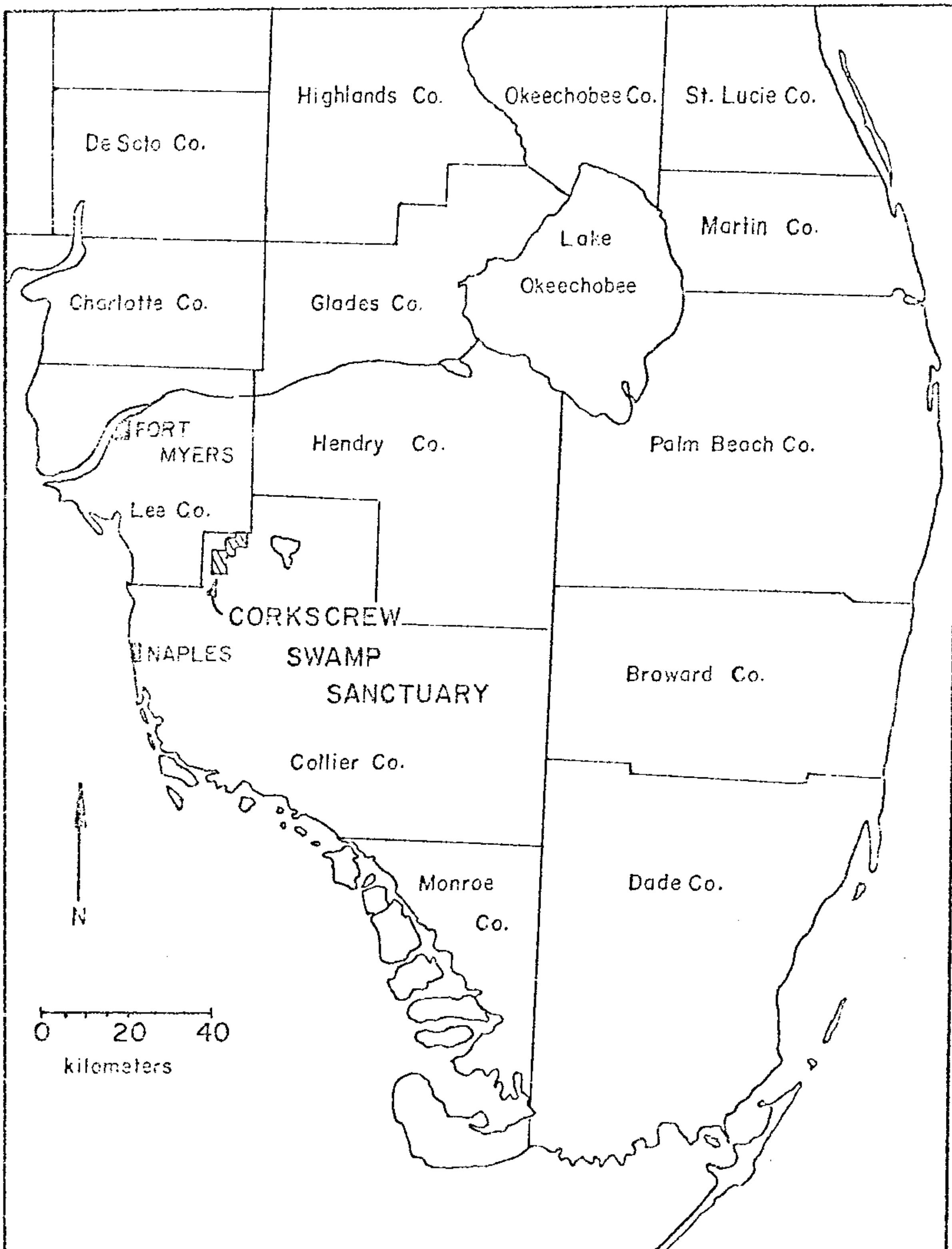
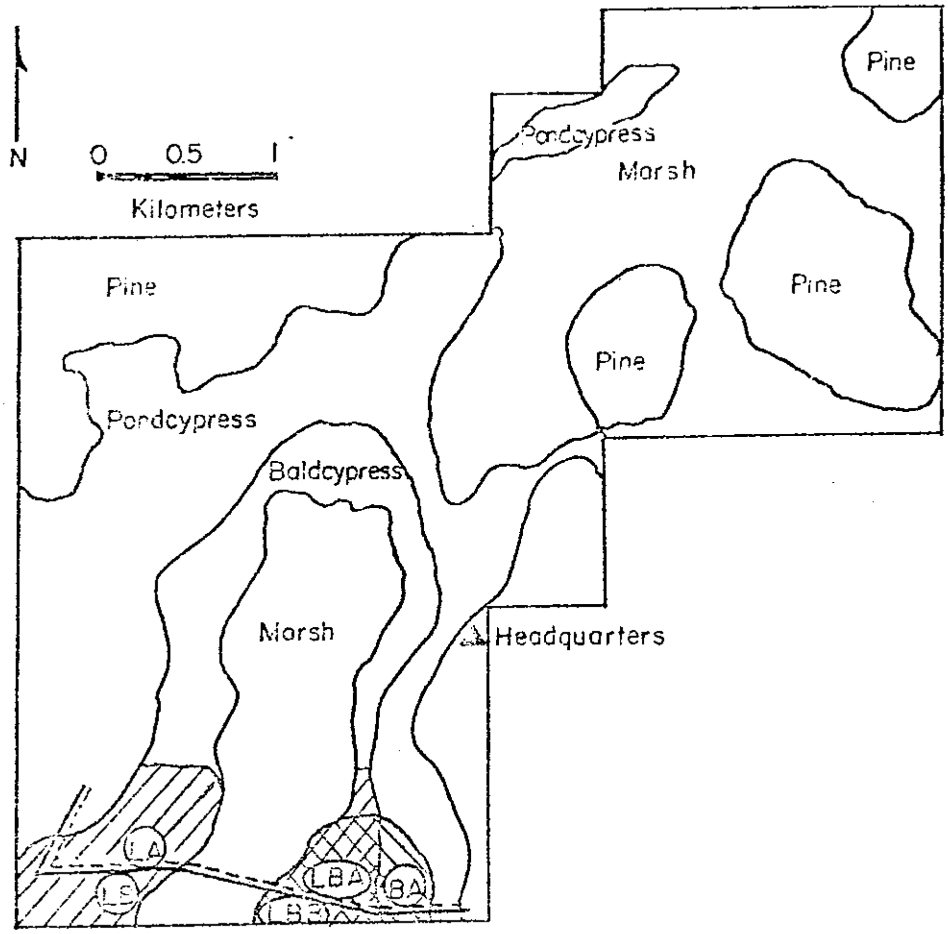


Figure 1. Location of Corkscrew Swamp Sanctuary in southern Florida.

development, located 5 km to the south, could lower water levels within the sanctuary. In 1969 construction was completed on a dike designed to impound water in the Sanctuary. Two existing railroad tramways were joined across a central marsh to complete the earthen dike. The dike is approximately 2 m high and 5 m wide at the top.

Major habitats and recent histories of the study sites within the Sanctuary are shown in Figure 2. Experimental sites were established in the logged area of the western strand, one above (north of) the dike and one below (south of) the dike. Two sites were set up in the logged-and-burned area of the eastern strand, one established above (north of) the dike and one below (south of) the dike. One site was established in the burned pondcypress area above the dike. Figure 3 includes a photograph of the vegetation of each of the five study sites. As an inventory was done as part of the research, the vegetation of each of the study sites is described in detail in the Results section.

Taxodium distichum dominates the baldcypress zone of the virgin strand and *T. ascendens* dominates the pondcypress zone. Marsh habitats are dominated by *Sagittaria graminea*, *Pontedaria cordata*, *Cladium jamaicensis*, *Panicum hemitomum*, and *Spartina bakerii*. *Pinus elliottii* var. *densa* and *Seronoa repens* prevail in the pine habitat. *Salix caroliniana* covers the burned area. *Acer rubrum*, *Ilex cassine*, *Persea palustris*, *Myrsine guianensis*, *Myrica cerifera* and *Salix caroliniana* are present in the logged cypress area.



Logged during early 1950's

Burned in 1962

South dike, construction completed in 1969

STUDY SITES:

LA - Logged, not burned, above the dike

LB - Logged, not burned, below the dike

LBA - Logged and burned, above the dike

LBB - Logged and burned, below the dike

BA - Not logged, but burned, above the dike

Figure 2. Habitat types and recent history of study sites within Corkscrew Swamp Sanctuary. Site BA was formerly dominated by pondcypress; the others were formerly dominated by baldcypress.

Figure 3. Photographs of study sites at Corkscrew Swamp Sanctuary taken in December, 1976.

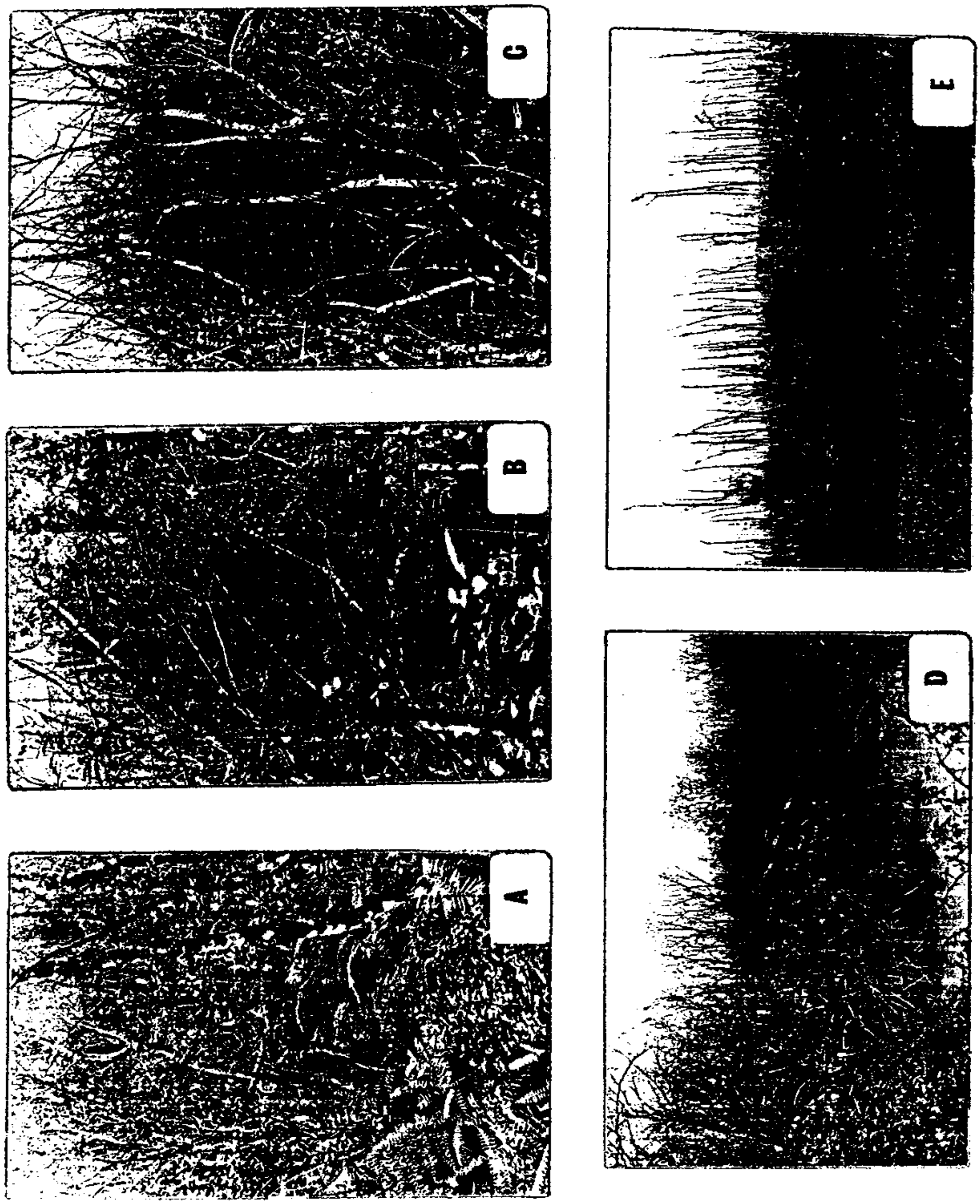
(A) Logged, above-the-dike study site. Notice felled cypress tree, not removed because hollow.

(B) Logged, below-the-dike study site. Mixed hardwoods.

(C) Logged-and-burned, below-the-dike study site. Dense thicket of *Salix caroliniana*.

(D) Logged-and-burned, above-the-dike study site. Clumps of *Salix caroliniana* growing on burned-out stumps interspersed among deeper water areas.

(E) Burned, but not logged, above-the-dike study site. Borrow pit and aquatic vegetation are in the foreground. The dark vegetation is a berm covered with *Myrica cerifera*. The gray background is a stand of *Salix caroliniana* and emergent snags are a mixture of live and dead *Taxodium*.


A
B
C
D
E

METHODS

This study included a description of the vegetation present at the five experimental sites, planting of cypress seed and seedlings, monitoring of water levels at each study site, and an examination of sequential sets of aerial photographs.

Vegetation Description

To determine if restoration of a predisturbance system is occurring, a quantitative vegetation description of each of the five experimental sites was done. Three components were considered: trees, shrubs, and understory plants. Trees were considered to be all plants with diameters at breast height (DBH = 1.37 m above ground) greater than 3.8 cm. Shrubs were designated as all woody plants less than 3.8 cm DBH and greater than 1 m tall. All vascular plants less than 1 m tall and all non-woody plants greater than 1 m tall were considered to be part of the understory.

Trees were measured in a 25 m x 25 m plot, and shrubs were measured in a 10 m x 10 m plot nested within the tree plot (Fig. 4). A 1 m wide path was cleared around the 25 m x 25 m plot, and each plot was delineated by string stretched from corner stakes.

For each species in each of the three categories, a measure of dominance, density, and frequency was made. These measures were converted into relative values (%) and summed to yield an importance value (Curtis, 1959) for each species. Maximum value for a single species is 300.

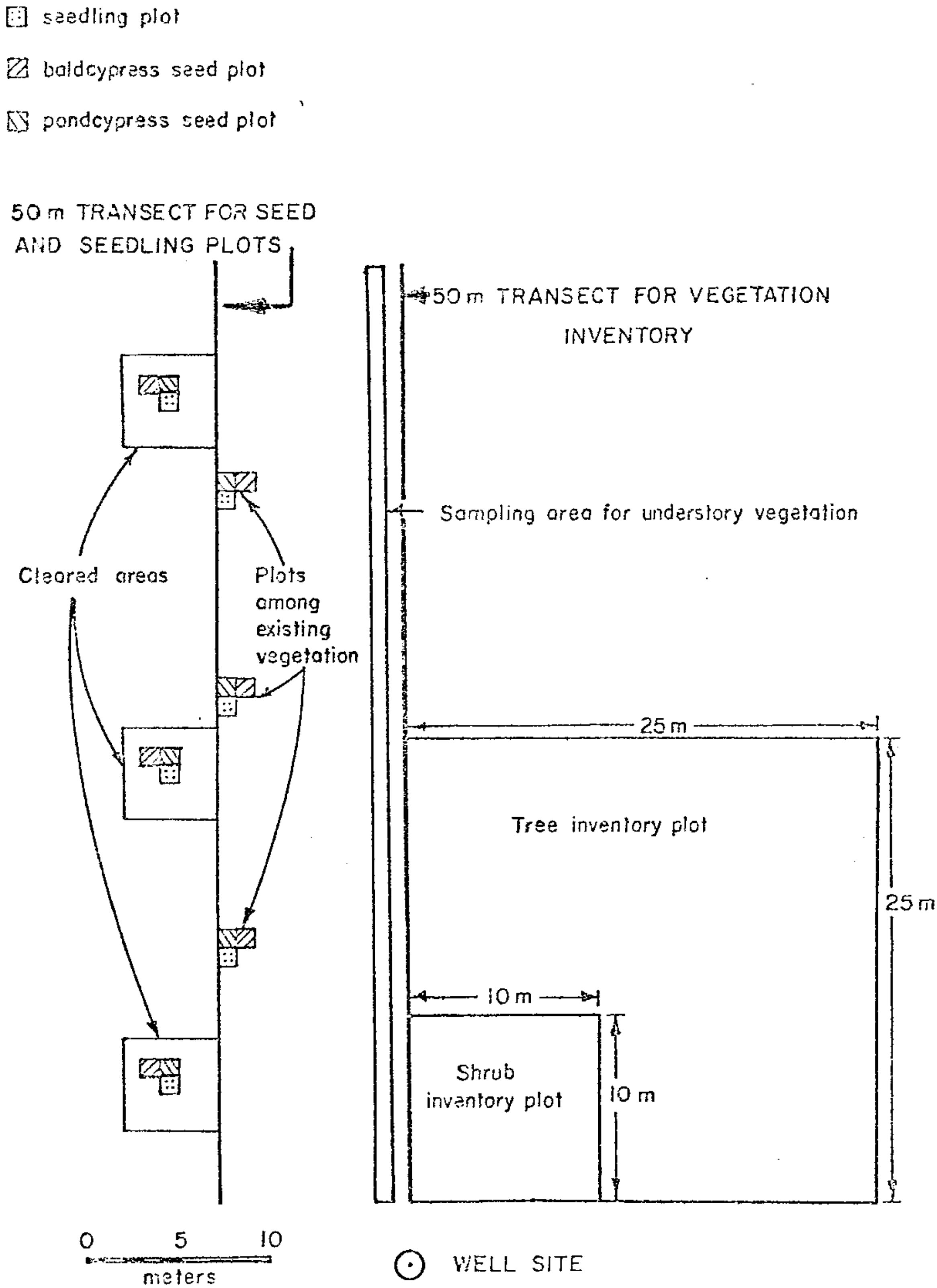


Figure 4. Schematic map of sampling procedure at each study site. Arrangement of tree, shrub, and understory inventory plots, baldcypress and pondcypress seed plots, seedling transplant plots and well site is shown.

Dominance was expressed for the tree and shrub categories by measuring diameters and calculating basal areas. Tree diameters (DBH) were measured with a steel diameter tape to the nearest 0.1 cm. Shrub diameters were measured to the nearest 0.013 cm at a height of 30 cm using vernier calipers. Relative dominance was calculated for each species as:

$$\frac{\text{basal area of a species}}{\text{total basal area in plot}} \times 100$$

Density of each species was obtained by counting the number of individuals of each species within the plot. Relative density was calculated as:

$$\frac{\text{number of individuals of a species}}{\text{total number of individuals in plot}} \times 100$$

Frequency of tree species was measured as the number of times the species occurred in twenty-five, 2 m x 2 m plots. The plots were selected by randomly selecting coordinates on a grid system established in the tree plot. Frequency of shrub species was tallied as occurrence in twenty-five 1 m x 1 m plots nested within the 2 m x 2 m tree plots. Relative frequency was calculated as:

$$\frac{\text{number of occurrences of a species in 25 plots}}{\text{total occurrence of all species in 25 plots}} \times 100$$

Importance values were calculated differently for understory species. The composition of the understory varies seasonally, so six harvests were made, at two-month intervals, starting in November, 1975 and ending in September, 1976. At each harvest, three 1 m x 1 m plots were selected at random along the 50 m north-south transect at each study site (Fig. 4). The plots were clipped of all above ground understory biomass. The clippings were dried at 70 C for 48 hours and dry weight was recorded, by species, to the nearest 0.1 gram. Relative dominance was expressed as:

$$\frac{\text{dry weight of a species}}{\text{total dry weight}} \times 100$$

Stems were counted as a measure of density and relative density calculated:

$$\frac{\text{number of stems of a species}}{\text{total stems}} \times 100$$

Frequency was calculated as presence or absence in the three harvest quadrats, and converted to relative frequency as follows:

$$\frac{\text{frequency of occurrence in three plots}}{\text{total frequency per harvest date}} \times 100$$

Relative dominance, relative density and relative frequency were summed to yield an importance value for each species on each harvest date.

Seedlings

To test the hypothesis that secondary succession can be accelerated by introducing the dominant predisturbance species into postdisturbance seres, cypress seedlings were transplanted into the five experimental sites.

The cypress seedlings were transplanted during January, 1976. The seedlings were collected from the periphery of the undisturbed cypress strand, where the trees exhibit pondcypress characteristics. The criteria for selection was any cypress tree between 0.5 m and 1 m tall, having a basal diameter less than 12 mm. The seedlings were all found within 0.5 km of each other. Removal was accomplished by breaking the ground around the seedling with a shovel, grasping firmly at the base of the stem and gently extracting. The roots were washed of remaining soil and placed in plastic bags with water and bladderwort (*Utricularia* sp.). Planting was done within one hour of removal by inserting a flat 15 cm x 40 cm shovel into the ground, and rocking it back and forth to create a V-shaped hole. The bare root seedling was inserted and the hole filled by packing with surrounding soil.

A total of 120 seedlings were transplanted into the five sites. Six 1 m x 1 m plots were set up at each site, with four seedlings per plot, one seedling planted near each corner of the plot. Each seedling was marked by a number-letter-number code written on an aluminum tag attached to the stake nearest the seedling. Three plots were established among the existing vegetation, and three were centered in 5 m x 5 m cleared areas (Fig. 4). All plots were at randomly selected distances along a 50 m transect parallel to the transect established in the vegetation survey (Fig. 4). As a transplant-shock control, three plots were established in the area from which the seedlings were removed.

The height of each seedling was measured to the nearest 12 mm when transplanted and again on February 29, March 22, April 17, May 14, June 11, July 17, and October 23, 1976. The seedlings were observed for presence or absence of leaves on each date. The leaf shape and arrangement and branch arrangement were observed following transplanting and on the final measurement date to determine the effects of site on leaf morphology.

Seeds

To distinguish which stage of the life cycle of cypress may be limiting survival, seeds were also planted at each experimental site. Murphy and Stanley (1975) stated that cypress seeds germinate following a 50 to 60 day soaking period during which the thick seed coat becomes permeable. Demaree (1932) listed requirements for cypress survival to include germination on dry ground and sufficient growth to escape inundation. Seed plots were established adjacent to the seedling plots to determine whether these conditions exist in the study sites.

October through November the female cones are abundant on trees (Mattoon, 1916). Late in November cones were retrieved by shaking the branches until the cones fell or by harvesting with a screen net-like bag attached to a 3 m pole. Because of the question as to exact differences between the two types of cypress (pond and bald), seeds were collected from trees which exhibited pondcypress attributes and from trees with baldcypress characteristics. The cones were air-dried in three 1.5 m x 0.6 m screen-bottomed flats for five weeks. On January 4, 1976 both baldcypress and pondcypress seeds plus cone debris were divided into five equal portions. Each portion was put into a fiberglass screen bag and sown shut. One bag of pondcypress seed and one bag of baldcypress seed were nailed to a post so that animals could not remove them and put in deep-water areas for soaking at each experimental site. As the water went below ground at each site, the seed plus cone debris were weighed out in 250 g and 125 g samples to yield approximately 250 pondcypress seeds and 100 baldcypress seeds respectively. The seeds were planted in 1 cm deep furrows. Dates of planting were Feb. 13 (burned, above-the-dike), February 27 (logged-and-burned, below-the-dike), March 16 (logged, below-the-dike) and March 23 (logged-and-burned, above-the-dike and logged, above-the-dike).

On the day of planting, 200 pondcypress seeds and 200 baldcypress seeds were separated from cone debris. Four 50-seed replicates were planted in organic soil in wooden flats and placed under greenhouse conditions. Daily germination was tallied as appearance of cotyledons above the ground. The resulting seedlings were monitored for differences in leaf morphology.

Another group of cones was collected on December 29, 1976 to determine potential germination under laboratory conditions. The cones were air-dried and the seed separated from debris. Four 100-seed lots of each type (pondcypress and baldcypress), were soaked for four hours in 95% sulfuric acid (specific gravity 1.84), as recommended by Murphy and Stanley (1975), then rinsed overnight in tap water. Twenty seeds were placed on moist filter paper in each of five plastic petri dishes for each 100 seed sample. The dishes were placed in an incubator set on a cycle of exposure to light for 8 hours at 30 C and darkness for 16 hours at 20 C. Germination as evidenced by the appearance of cotyledons was monitored daily.

Water Levels

Water levels were measured weekly at one well in each of the five experimental sites. The distances from the top of a 5.1 cm diameter steel pipe to the water level inside and outside the pipe were measured to the nearest 6.25 mm. Inside measurements were made by dropping a float, attached to a fishing reel, into the well. The slack was removed from the line and the distance was measured from a mark on the float to the well top. The tops of the wells were surveyed by M.J. Duever and L.A. Riopelle and calibrated to mean sea level heights. The water level measurements at different sites were made within one hour of each other to minimize differences due to daily oscillations caused by evapotranspiration.

Aerial Photographs

Vegetation maps were made from three sets of aerial photographs. The first set (1:20,000) was taken in January, 1953, before the study area was logged or burned. This set (Flight Code DSM-4L, #'s 21,22,23,55,56,57) was purchased from the USDA Soil Conservation Service, Cartographic Division, Hyattsville, Maryland. The second group (1:20,000) was taken in November and December, 1963, nine years following logging and eight months following the burn. These photographs (Flight Code DSM-3DD, #'s 178, 179, 180 and DSM-4DD, #'s 30,31,32) were borrowed from the Soil Conservation Service Office in Gainesville, Florida. The most recent photographs (1:75,000) were taken in December, 1972 by Mark Hurd Aerial Surveys, Inc. (Flight Code IRC-CUJ, #'s 1594, 1595, 1102). All photos were 22.8 cm x 22.8 cm (9" x 9") black and white contact prints.

RESULTS

Vegetation Inventory

The southern coastal willow, Salix caroliniana, had the highest importance value in both the tree and shrub plots at the burned, above-the-dike site (Table 1). The high density of stems and high frequency of occurrence of Salix resulted in high importance values in tree plot # 1, while the relatively larger diameters of Taxodium and Sabal account for the lower importance value of Salix in tree plot # 2. Myrtle, Myrica cerifera, was second in importance value in tree plot # 1 and third in tree plot # 2. This is due to higher relative frequency, and a higher density than Taxodium, Sabal or Persea. Taxodium in the tree plots were either survivors from the fire or naturally regenerated from seed. Persea, Cephalanthus and Sabal were encountered in the tree plot as scattered individuals. Saplings (tree species taller than 1 m and less than 3.8 cm DBH) of Myrica, Taxodium, Annona, and Cephalanthus in the shrub plots indicate that regeneration of these species is occurring.

Composition and importance values were similar at the plots above and below the dike in the logged-and-burned area (Table 2). Only two species were encountered in the tree plots above and below the dike, where Salix forms almost a pure strand. Myrica was slightly more important in the plot below the dike than in the plot above the dike, probably because there is more dry ground below the dike. No Taxodium was encountered in the tree plots above and below the dike in the area that was logged-and-

Table 1. Importance values for overstory species at the burned, above-the-dike study site.

	Relative Density	+ Relative Dominance	+ Relative Frequency	= Importance value
Tree Plot # 1				
Salix caroliniana	91	87	81	259
Myrica cerifera	6	8	14	28
Persea palustris	1	1	1	3
Taxodium ascendens	2	3	4	9
Shrub Plot # 1				
Salix caroliniana	83	88	71	242
Myrica cerifera	13	9	12	36
Cephalanthus occidentalis	3	2	4	9
Baccharis halmifolia	1	1	4	4
Annona glabra	1	1	1	1
Tree Plot # 2				
Salix caroliniana	72	38	82	192
Myrica cerifera	15	14	12	41
Taxodium ascendens	11	26	6	43
Cephalanthus occidentalis	1	1	1	1
Sabal palmetto	1	21	1	22
Shrub Plot # 2				
Salix caroliniana	93	96	79	268
Myrica cerifera	3	2	8	13
Taxodium ascendens	1	1	8	10
Baccharis halmifolia	1	1	4	5
Ludwigia peruviana	1	1	1	1
Cephalanthus occidentalis	1	1	1	1

Table 2. Importance values for overstory species at the logged-and-burned, above-the-dike and below-the-dike study sites.

	Relative Density +	Relative Dominance +	Relative Frequency =	Importance value
Tree Plot Above-the-Dike				
Salix caroliniana	97	99	99	295
Myrica cerifera	3	1	1	5
Shrub Plot Above-the-Dike				
Salix caroliniana	50	75	71	196
Cephalanthus occidentalis	33	17	13	63
Baccharis halmifolia	9	7	2	18
Myrica cerifera	4	4	7	15
Ludwigia peruviana	3	1	1	5
Annona glabra	1	1	1	3
Tree Plot Below-the-Dike				
Salix caroliniana	96	96	94	286
Myrica cerifera	4	4	6	14
Shrub Plot Below-the-Dike				
Salix caroliniana	62	84	61	207
Baccharis halmifolia	20	5	17	42
Cephalanthus occidentalis	14	9	9	32
Myrica cerifera	3	2	9	14
Ludwigia peruviana	1	1	4	6

burned. *Salix*, *Cephalanthus* and *Myrica* were in both shrub plots above and below the dike in the logged-and-burned area.

Hardwoods such as dahoon holly, *Ilex cassine*, red maple, *Acer rubrum*, myrtle, *Myrica cerifera*, swamp bay, *Persea palustris*, pop ash, *Fraxinus caroliniana*, and pond apple, *Annona glabra* were conspicuous in the tree plot at the logged-not-burned study site, above-the-dike (Table 3). *Taxodium* in the tree plot are remnants from logging and sprouts from stumps. *Cephalanthus* was the dominant species found in the shrub plot. Saplings were present of the following hardwoods: Myrsine, *Myrsine guianensis*, *Myrica*, *Ilex*, *Persea* and *Acer*. No individuals of *Taxodium* were encountered in the shrub plot, but a sapling was noticed in the tree plot.

Hardwood species also dominate the tree plot at the logged-not-burned, below-the-dike study site (Table 4). Importance values of *Acer* and *Ilex* were the highest in the tree plot, where ten species were encountered. No trees of *Taxodium* were observed in the tree plot. Importance values of *Acer*, *Annona*, *Fraxinus* and *Myrica* were higher at the below-the-dike plot than the above-the-dike plot, while *Salix* and *Cephalanthus* were more important in the above-the-dike plot than in the below-the-dike tree plot. *Cephalanthus* was the dominant species in the shrub plot, as was the case in the above-the-dike site. Saplings of *Myrsine*, *Persea*, *Acer* and *Ilex* were found in the shrub plot at the below-the-dike site.

Importance values are given for each understory species on each harvest date for each study site in Tables 5-9. The values for each species were summed over the six harvest dates and ranked in each table with the largest cumulative value at the top, decreasing toward the bottom. Swamp fern, *Blechnum serrulatum*, was the dominant understory

Table 3. Importance values for overstory species at the logged, above-the-dike study site.

	Relative Density	+	Relative Dominance	+	Relative Frequency	=	Importance value
Tree Plot							
Ilex cassine	31		19		27		77
Acer rubrum	12		25		11		48
Salix caroliniana	17		13		11		41
Myrica cerifera	15		9		11		35
Taxodium distichum	3		24		4		31
Cephalanthus occidentalis	12		4		11		27
Persea palustris	4		3		15		22
Fraxinus caroliniana	2		1		4		6
Ficus aurea	1		1		3		5
Annona glabra	2		1		1		4
Shrub Plot							
Cephalanthus occidentalis	20		29		45		94
Myrsine guianensis	36		20		11		67
Myrica cerifera	22		20		14		56
Ilex cassine	5		8		14		27
Itea virginica	5		10		4		19
Persea palustris	4		1		11		16
Acer rubrum	3		4		4		11
Salix caroliniana	2		5		1		8
Baccharis halmifolia	3		1		1		5

Table 4. Importance values for overstory species at the logged, below-the-dike study site.

	Relative Density	+	Relative Dominance	+	Relative Frequency	=	Importance value
Tree Plot							
Acer rubrum	28		38		15		81
Ilex cassine	19		22		33		74
Myrica cerifera	14		6		22		42
Persea palustris	12		7		7		26
Annona glabra	3		16		4		23
Fraxinus caroliniana	10		4		7		21
Cephalanthus occidentalis	7		2		4		13
Salix caroliniana	3		2		4		9
Ficus aurea	1		2		4		7
Myrsine guianensis	3		1		1		5
Shrub Plot							
Cephalanthus occidentalis	53		80		15		148
Baccharis halmifolia	18		4		4		26
Myrsine guianensis	7		3		15		25
Itea virginica	9		2		11		22
Persea palustris	4		3		4		11
Acer rubrum	6		3		1		10
Myrica cerifera	1		1		7		9
Ilex cassine	1		2		4		7

species at all sites.

Seedlings of _Salix_, _Myrica_ and _Cephalanthus_ were the only tree species in the clipped plots at the burned, above-the-dike study site (Table 5). No _Taxodium_ was harvested from any of the sample quadrats at this site.

Seedlings of _Myrica_ were found in the November and March harvests at the logged-and-burned, above-the-dike site (Table 6). Seedlings of _Salix_ and _Myrica_ were harvested in January and May, respectively, at the logged-and-burned, below-the-dike site (Table 7). Twenty-two species were harvested below the dike, and thirteen were harvested above. No cypress was found in plots either above or below the dike at the logged-and-burned sites.

Seedlings of _Acer_ were abundant in the harvests from the logged, below-the-dike site from November, 1975 through July, 1976 (Table 8). _Myrsine_ seedlings were found in the November harvest. _Ilex_ seedlings were found in the January harvest below the dike, and _Acer_ seedlings were components of the March, May and July harvests at the logged, above-the-dike site (Table 9). Seedlings of _Annona_ were encountered during the March and May harvests above the dike. _Myrsine_ was sampled in May and _Cephalanthus_ seedlings were sampled in the March harvests above the dike. No seedlings of _Taxodium_ were clipped at either of the logged sites.

High biomass values occurred between late spring and late fall at all the study sites (Table 10). Maximum biomass was measured during the July harvest at the logged sites and the burned site (Table 10). Maximum biomass occurred above the dike at the logged-and-burned site in March. The logged-and-burned, below-the-dike site yielded high biomass harvests in November, July and September, 1976.

Table 5. Importance values of species in each harvest of understory plants at the burned, above-the-dike study site.

Species	Date (month-day-year)						Mean
	11-16-75	1-22-76	3-4-76	5-13-76	7-14-76	9-24-76	
Blechnum serrulatum	0	122	35	86	152	74	78.2
Panicum hemitomon	61	0	0	65	20	67	35.5
Pontedaria cordata	86	31	56	28	0	0	33.5
Diodia virginiana	21	28	46	0	15	33	23.8
Proserpinaca palustris	21	19	45	8	0	50	23.8
Sarcostemma clausa	0	0	34	51	32	9	21.0
Woodwardia virginica	13	15	0	31	50	0	18.2
Polygonum punctatum	20	11	45	10	0	15	16.8
Andropogon sp.	34	0	0	0	0	10	7.3
Mikania batafolia	0	16	16	0	0	8	6.7
Sagittaria graminea	0	30	8	0	0	0	6.3
Ludwigia repens	0	20	0	0	0	0	3.3
Baccharis halmifolia	6	0	0	0	7	0	2.2
Typha latifolia	13	0	0	0	0	0	2.2
Sagittaria lancifolia	13	0	0	0	0	0	2.2
Bacopa maritima	0	0	12	0	0	0	2.0
Aster carolinianus	0	0	0	10	0	0	1.7
Osmunda regalia	0	0	0	0	9	0	1.5
Cyperus sp.	0	9	0	0	0	0	1.5
Cephalanthus occidentalis	0	0	0	0	0	8	1.3
Eupatorium compositifolium	0	0	0	7	0	0	1.2
Juncus polycephalus	6	0	0	0	0	0	1.0
Myrica cerifera	6	0	0	0	0	0	1.0
Salix caroliniana	0	0	0	0	6	0	1.0
Boehmeria cylindrica	0	0	0	0	5	0	0.8

Table 6. Importance values of species in each harvest of understory plants at the logged-and-burned, above-the-dike study site.

Species	Date (month-day-year)						Mean
	11-16-75	1-22-76	3-4-76	5-13-76	7-14-76	9-24-76	
Blechnum serrulatum	145	80	179	0	0	13	69.5
Polygonum punctatum	0	127	20	28	93	9	55.9
Mikania batafolia	17	48	23	120	131	10	53.2
Boehmeria cylindrica	34	0	10	27	34	37	23.7
Peltandra virginica	16	0	0	0	0	73	14.8
Aster carolinianus	0	24	12	22	0	9	11.2
Cyperus sp.	0	20	0	28	0	18	11.0
Sarcostemma clausa	0	0	10	45	0	0	9.2
Myrica cerifera	40	0	15	0	0	0	9.2
Woodwardia virginica	51	0	0	0	0	0	8.5
Osmunda regalia	0	0	0	0	42	8	8.3
Typha latifolia	0	0	11	30	0	9	8.3
Azolla caroliniana	0	0	15	0	0	0	2.5

Table 7. Importance values of species in each harvest of understory plants at the logged-and-burned, below-the-dike study site.

Species	Date (month-day-year)						Mean
	11-16-75	1-22-76	3-4-76	5-13-76	7-14-76	9-24-76	
Blechnum serrulatum	103	28	98	71	83	114	82.8
Baccharis halmifolia	23	73	36	15	57	11	35.8
Sagittaria lancifolia	21	76	17	25	34	12	30.8
Pontedaria cordata	0	53	0	68	29	0	25.0
Nephrolepis exalta	48	0	51	9	7	0	19.2
Spirodela polyrhizae	0	0	0	0	0	107	17.8
Polygonum punctatum	7	20	9	7	22	14	13.2
Cyperus sp.	0	0	0	5	23	43	11.8
Boehmeria cylindrica	7	7	17	21	15	0	11.2
Ludwigia repens	0	18	10	12	25	0	10.8
Mikania batafolia	7	8	9	7	8	11	8.3
Thelyptris normalis	18	0	0	9	0	18	7.5
Aster carolinianus	7	0	18	15	0	0	6.7
Osmunda regalia	23	0	0	6	0	0	4.8
Andropogon sp.	14	0	10	0	0	0	4.0
Peltandra virginica	15	8	0	0	0	0	3.8
Hydrocotle umbellata	0	7	0	14	0	0	3.5
Woodwardia virginica	7	0	13	0	0	0	2.2
Typha latifolia	0	0	12	0	0	0	2.0
Myrica cerifera	0	0	0	10	0	0	1.7
Salix caroliniana	0	7	0	0	0	0	1.2
Parthenocissus quinquefolia	0	0	0	7	0	0	1.2

Table 8. Importance values of species in each harvest of understory plants at the logged, below-the-dike study site.

Species	Date (month-day-year)						Mean
	11-16-75	1-22-76	3-4-76	5-13-76	7-14-76	9-24-76	
Blechnum serrulatum	59	72	0	75	30	61	49.5
Osmunda regalia	44	8	10	77	8	96	40.5
Nephrolepis regalia	0	31	79	23	102	0	39.2
Acer rubrum	52	26	71	29	27	0	34.2
Sagittaria lancifolia	0	0	53	12	45	52	27.0
Woodwardia virginica	36	16	31	15	23	0	20.2
Boehmeria cylindrica	24	38	24	11	9	12	19.7
Myrsine guianensis	0	0	14	43	0	25	13.7
Polygonum punctatum	0	29	0	8	0	16	8.8
Peltandra virginica	22	0	0	0	22	0	7.3
Thelyptris normalis	23	8	0	0	0	13	7.3
Itea virginica	0	21	0	0	0	9	5.0
Myrica cerifera	0	0	9	17	0	0	4.3
Diodia virginiana	0	10	0	0	10	0	3.3
Melothria pendula	0	0	0	0	18	0	3.0
Pontedaria cordata	0	17	0	0	0	0	2.8
Baccharis halmifolia	0	15	0	0	0	0	2.5
Aster carolinianus	0	0	0	0	0	15	2.5
Mikania batafolia	14	0	0	0	0	0	2.3
Persea palustris	13	0	0	0	0	0	2.2
Smilax laurifolia	12	0	0	0	0	0	2.0
Panicum sp.	0	0	9	0	0	0	1.5
Ilex cassine	0	6	0	0	0	0	1.0

Table 9. Importance values of species in each harvest of understory plants at the logged, above-the-dike study site.

Species	Date (month-day-year)						Mean
	11-16-75	1-22-76	3-4-76	5-13-76	7-14-76	9-24-76	
Blechnum serrulatum	111	186	53	57	52	78	89.5
Spirodela polyrhizae	0	0	0	0	0	170	28.3
Woodwardia virginica	46	0	35	54	13	0	24.7
Boehmeria cylindrica	40	22	50	14	18	0	24.0
Thelyptris normalis	0	0	0	0	75	21	16.0
Sagittaria lancifolia	0	21	50	0	24	0	15.8
Nephrolepis exalta	17	10	0	0	55	0	13.7
Crinum americanum	0	0	0	65	0	0	10.8
Osmunda regalia	29	0	15	14	0	0	9.7
Mikania batafolia	0	10	21	19	7	0	9.5
Panicum sp.	32	12	0	0	8	0	8.7
Aster carolinianus	8	13	20	9	0	0	8.3
Acer rubrum	0	0	14	15	15	0	7.3
Annona glabra	0	0	17	17	0	0	5.7
Melothria pendula	8	0	0	0	24	0	5.3
Pistia stratioides	0	0	0	0	0	30	5.0
Myrsine guianensis	0	0	0	26	0	0	4.3
Cephalanthus occidentalis	0	0	26	0	0	0	4.3
Polygonum punctatum	0	10	0	0	7	0	2.8
Campyloneuron costatum	0	0	0	10	0	0	1.7
Habenaria sp.	8	0	0	0	0	0	1.3

Table 10. Above ground understory biomass during the study period. Each value is a mean of three 1 m^2 samples (± one std. deviation). Values are oven dry g/m^2.

Study Site	Date (month-day-year) 11-16-75	1-22-76	3-4-76	5-13-76	7-14-76	9-24-76
Burned, above-the-dike	57 ± 36.0	35 ± 16.7	24 ± 8.1	104 ± 30.7	320 ± 96.0	91 ± 32.1
Logged-and-burned, above-the-dike	61 ± 59.7	24 ± 14.3	329 ± 470.4	80 ± 109.4	6 ± 3.9	104 ± 127.0
Logged-and-burned, below-the-dike	111 ± 65.3	39 ± 13.0	35 ± 38.2	51 ± 77.4	97 ± 34.2	103 ± 21.0
Logged, below-the-dike	24 ± 28.5	27 ± 4.1	38 ± 27.3	80 ± 75.7	132 ± 98.1	89 ± 36.8
Logged, above-the-dike	51 ± 46.5	61 ± 25.9	46 ± 22.9	44 ± 33.9	126 ± 64.2	41 ± 24.8

Water Levels

The ground at the burned, above-the-dike well (Fig. 5) was the highest in elevation of all study sites, at 5.10 m above mean sea level (MSL). The surface of the well was dry for 180 days, from February 16 to August 14. The water levels inside the pipe ranged from a low of 4.03 m above MSL (-1.07 m below the soil surface) on May 12 to a high of 5.43 m above MSL (+0.33 m above the soil surface) on October 2, 1976. The elevation of the seed and seedling plots ranged from 5.10 m to 5.13 m above MSL.

The ground surface at the logged-and-burned, above-the-dike well was dry for 107 days, from March 11 to June 27 (Fig. 6). Lowest water was measured on May 12 at 4.14 m above MSL (-0.78 m below the soil surface). Water levels reached 5.35 m (+0.43 m above the soil surface) on November 2, 1975 and October 2, 1976. The elevations of the seedling plots ranged from 4.61 to 5.17 m above MSL.

The water levels inside the pipe at the logged-and-burned, below-the-dike site were consistently higher than the level outside the pipe (Fig. 7), indicating that the dike was lowering surface water to the south. However, the site below the dike was dry for 108 days, approximately equal to the dry period above the dike. Thus, the dike results in higher water on its upstream side, but does not seem to alter the duration of the time period when the soil is flooded. The lowest water level was measured on May 18 at 4.38 m above MSL (-0.54 m below the soil surface) Maximum water level was 5.19 m above MSL (+0.27 m above the soil surface) before water retaining boards in the culverts through the dike were removed in June, 1976. Levels reached 5.38 m above MSL (+0.46 m above the soil surface) following removal of the water retaining boards. The elevations of the seedling plots below the dike did not vary as much as those of the

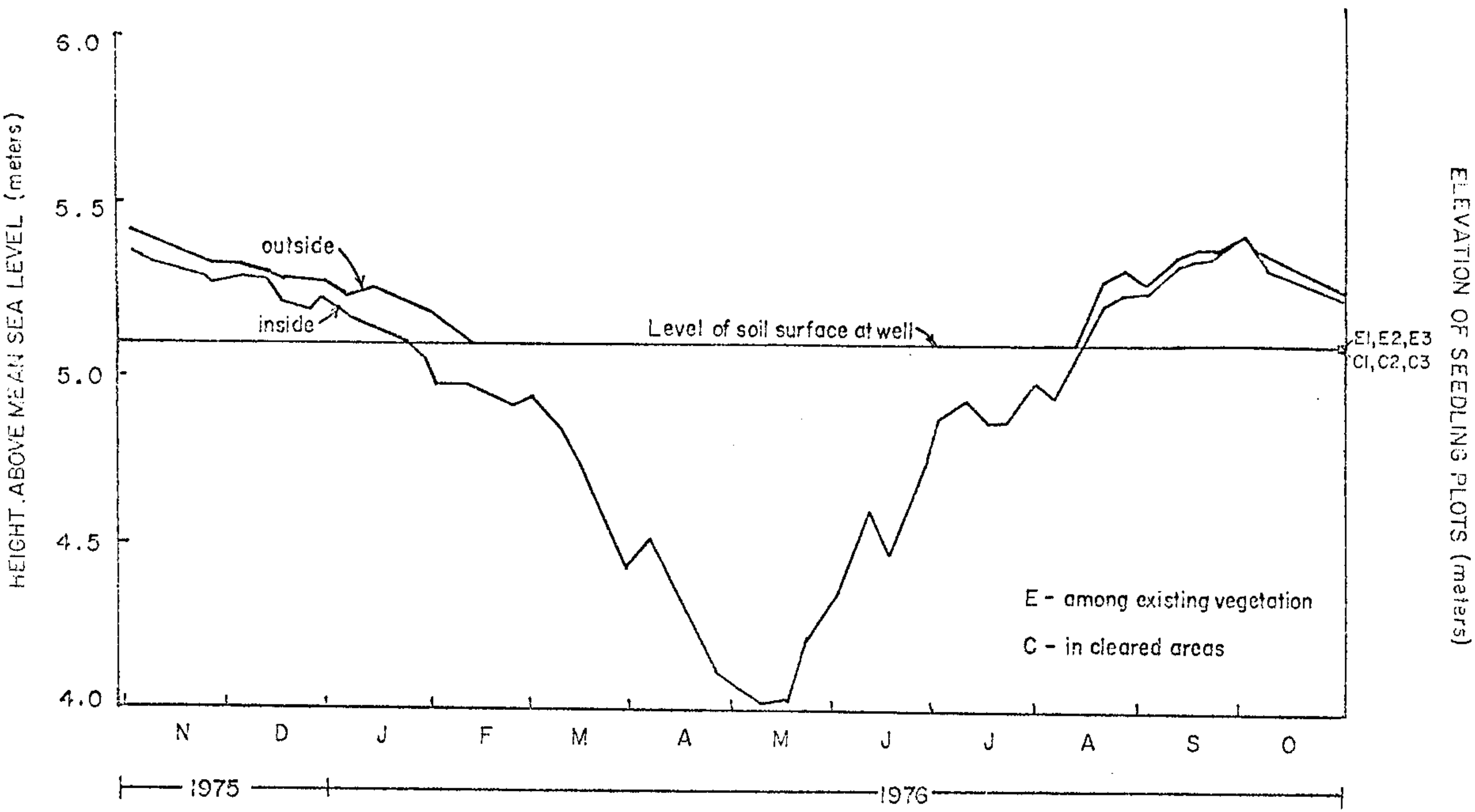


Figure 5. Water levels at the burned, but-not-logged, above-the-dike study site.

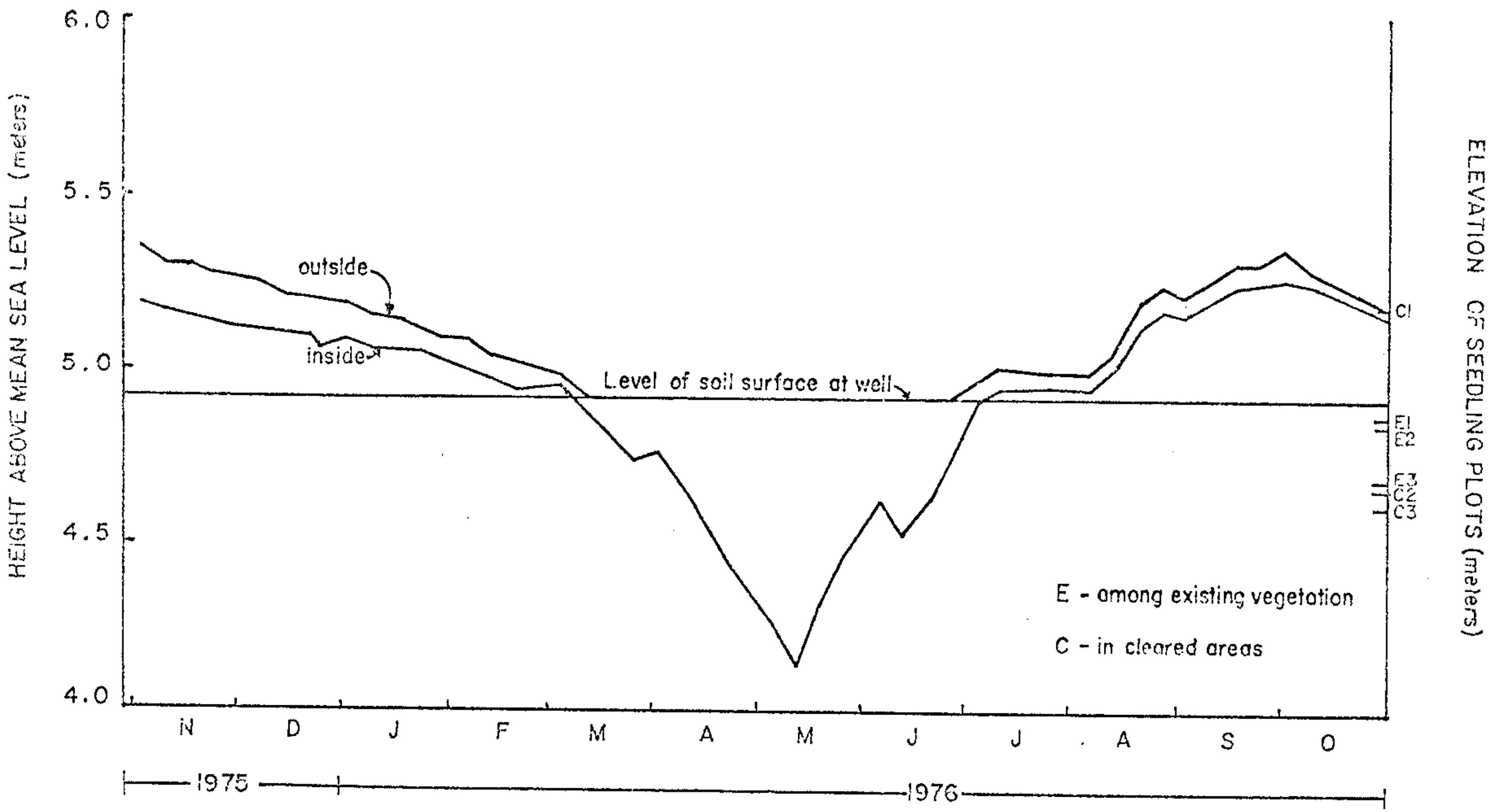


Figure 6. Water levels at the logged-and-burned, above-the-dike study site.

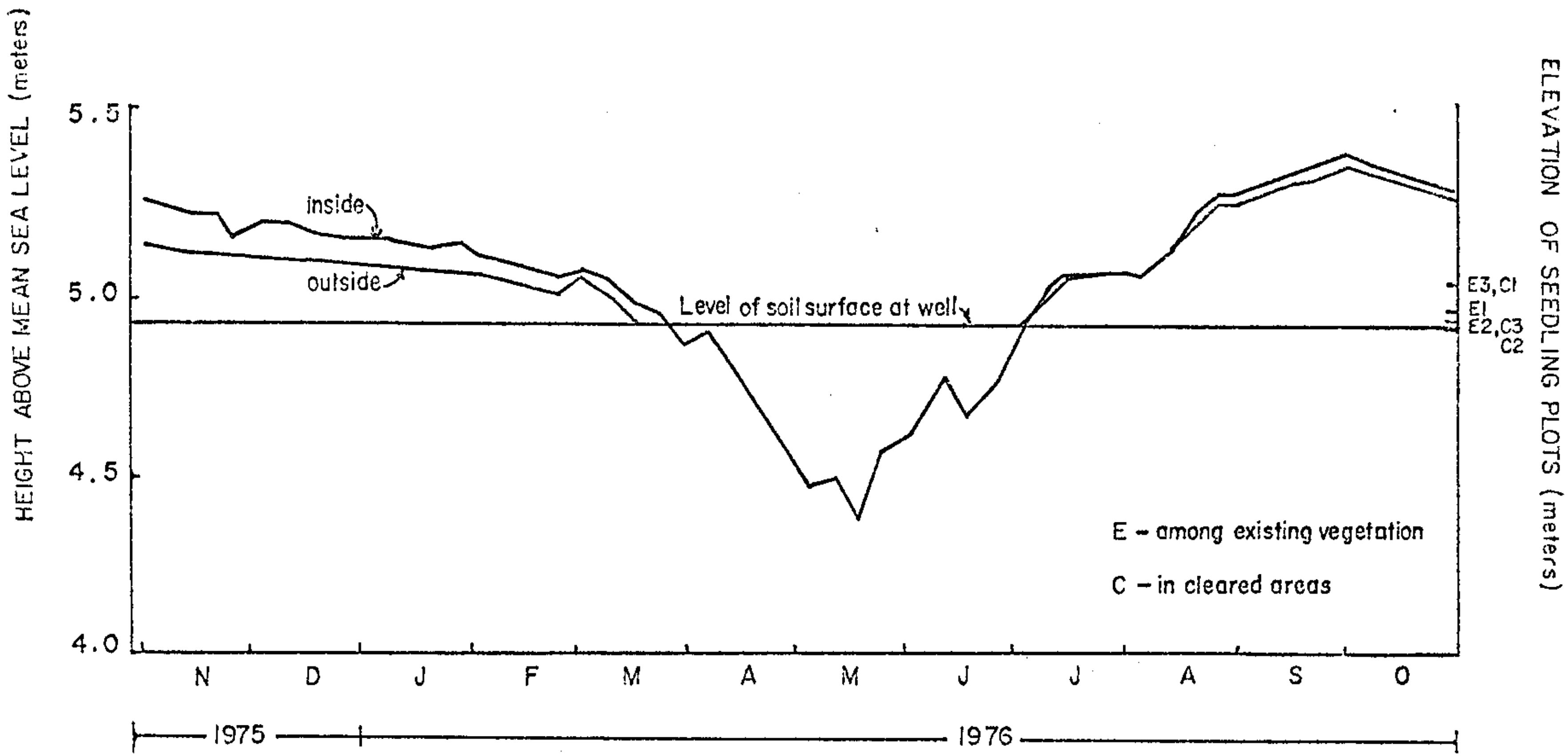


Figure 7. Water levels at the logged-and-burned, below-the-dike study site.

plots above the dike, ranging from 4.92 m to 5.04 m above MSL.

At the logged, but not-burned, above-the-dike study site (Fig. 8) the lowest water level was measured on May 15 at 4.66 m above MSL (-0.33 m below the soil surface). Water levels peaked on October 2 at 5.53 m above MSL (+0.54m above the soil surface). Elevations of the seedling plots ranged from 4.80 to 5.01 m above MSL, resulting in dry periods ranging from 38 to 103 days.

Water levels below-the-dike at the logged study site were lower than levels above the dike, even after removal of the water retaining boards. Inside-the-well measurements were higher than outside-the-well measurements below the dike in the logged area (Fig. 9). No water was visible on the ground outside the well for 114 days, from April 1 to July 17. Low water was measured at 4.47 m (MSL) (-0.40 m below the soil surface) on May 18. High water was measured at the well on October 2 at 5.25 m above MSL (+0.38 m above the soil surface). Elevations of the seedling plots differed by 0.18 m (4.83 to 5.01 m above MSL) and were dry for periods of from 100 to 155 days.

Seedlings

Compensation was made for the variation in initial size of the transplanted seedlings by expressing height increases as percents. Percent increases were summed for each plot, then divided by the number of surviving seedlings to yield a mean percent height increase per plot.

Assumptions of an analysis of variance include homogeneity of variances and that the data follow a normal distribution. A chi-square goodness of fit test (Snedacor and Cochran, 1967) was used to determine that the percent height increases followed a normal distribution. Bartlett's test for homogeneity of variances (Sokal and Rohlf, 1969)

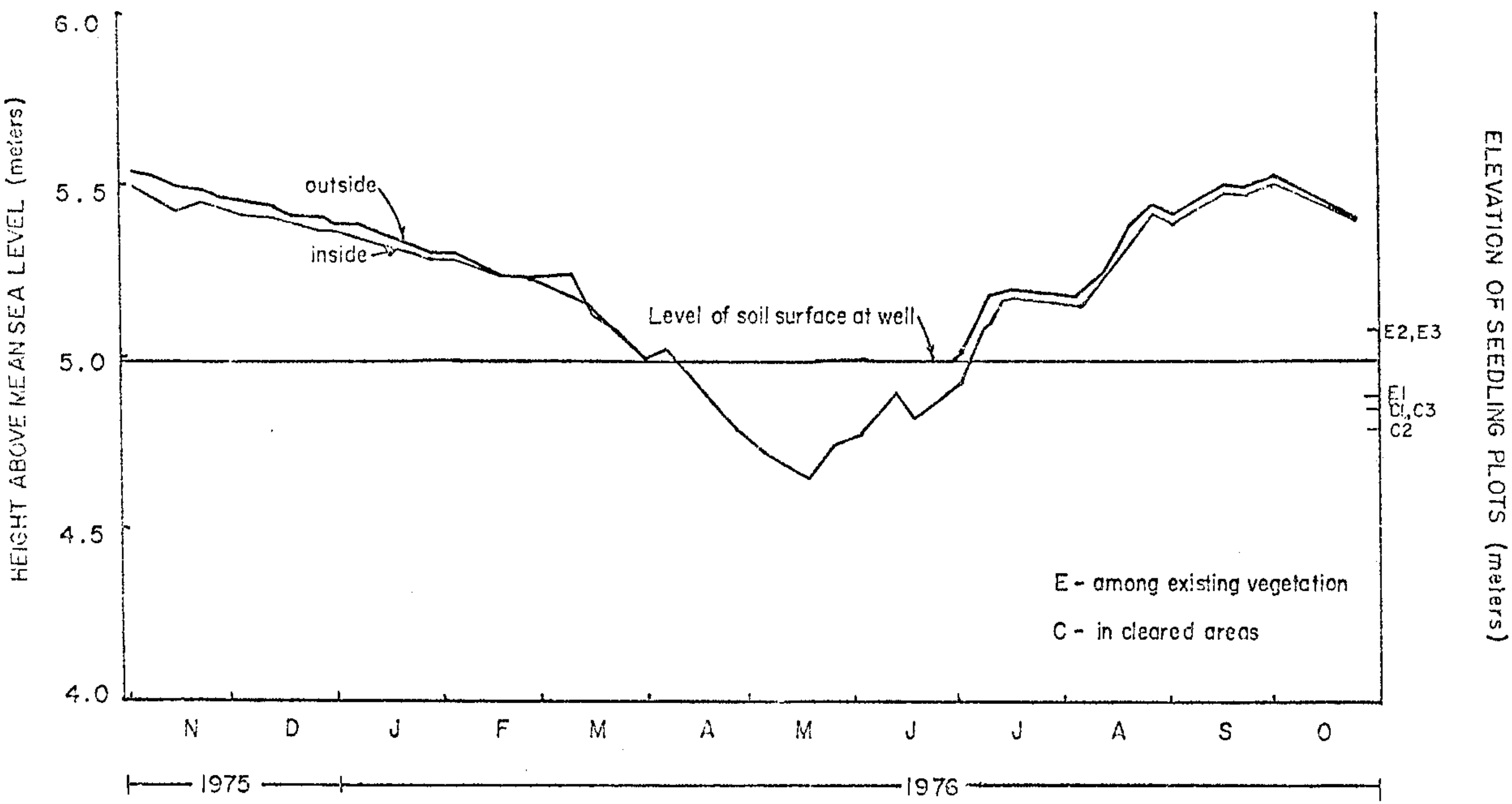


Figure 8. Water levels at the logged, but-not-burned, above-the-dike study site.

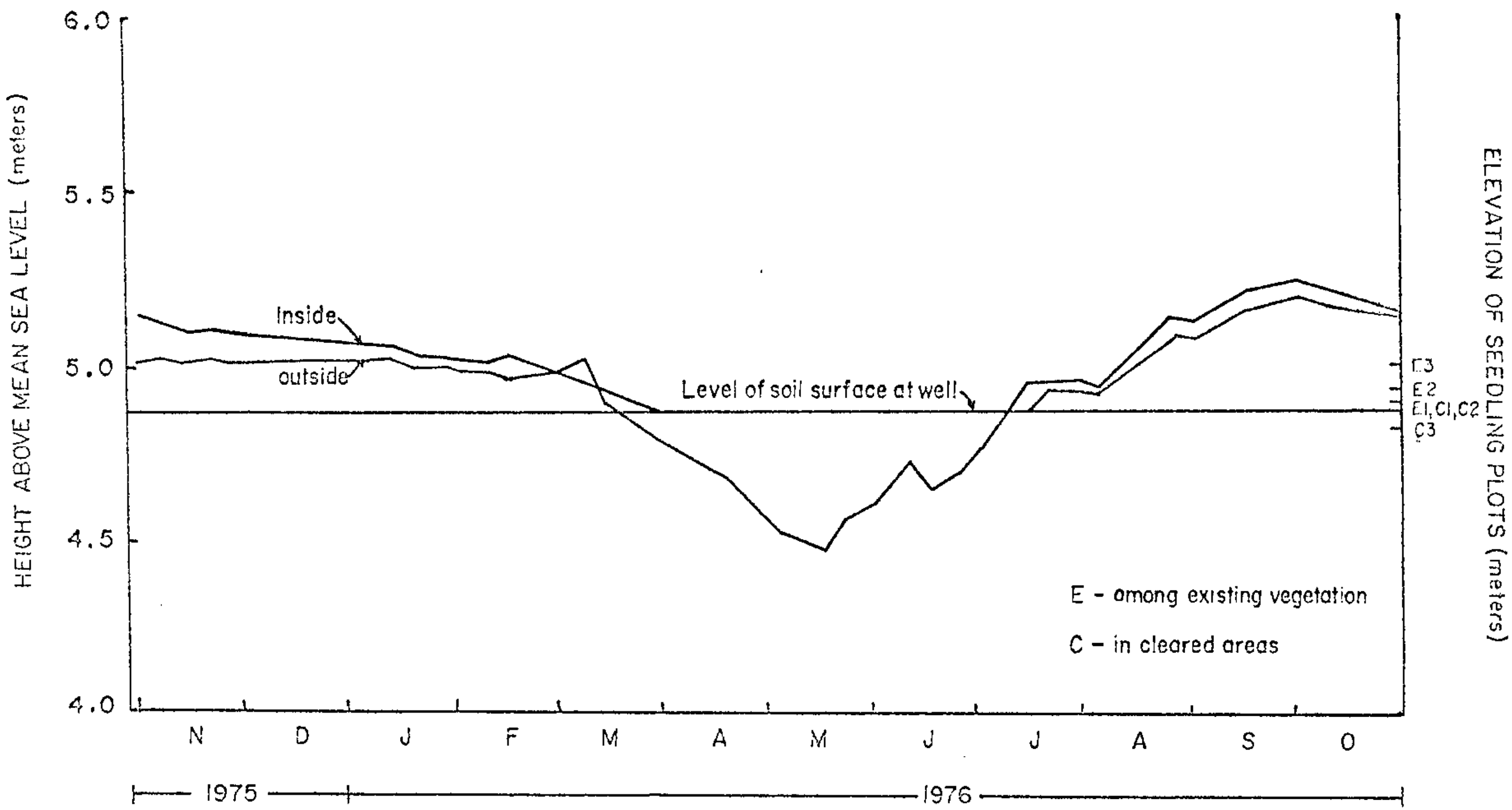


Figure 9. Water levels at the logged, but-not-burned, below-the-dike study site.

indicated that the variances were homogeneous. A two-way analysis of variance (Sokal and Rohlf, 1969) detected no significant difference in growth among study sites, or between growth of seedlings in cleared areas and among existing vegetation.

The seedlings growing in cleared areas exhibited a greater average growth at all sites than seedlings growing in uncleared areas (Fig. 10). A one-way analysis of variance (Snedacor and Cochran, 1967) was used to compare treatments at each site. A statistical difference (p=0.05) was revealed between treatments at the logged-and-burned site below the dike, but no differences were detected at the other sites due to large variances.

By the end of the study, there was greater average mortality of seedlings growing among existing vegetation at all sites except the logged-and-burned, above-the-dike site (Fig. 11). Because of variability, however, a two-way analysis of variance yielded no significant difference in mortality either between cleared and uncleared areas, nor among sites.

The number of seedlings with leaves increased at all of the sites by March as the seedlings leafed out (Fig. 12). The seedlings transplanted into the cleared areas sprouted leaves earlier than the seedlings growing among existing vegetation. The number of live seedlings remained roughly constant from April through July, when water levels rose. Between July and October seedlings died following inundation at the above-the-dike sites in the logged and logged-and-burned areas. Overall seedling survival was 66% at the experimental sites, yet only 58% survival was tallied at the control transplant site established in the area from which the seedlings were removed. The seedlings died at the transplant-shock control site because of loss of root contact with soil moisture, not inundation, as lower water levels and longer dry season were observed at this

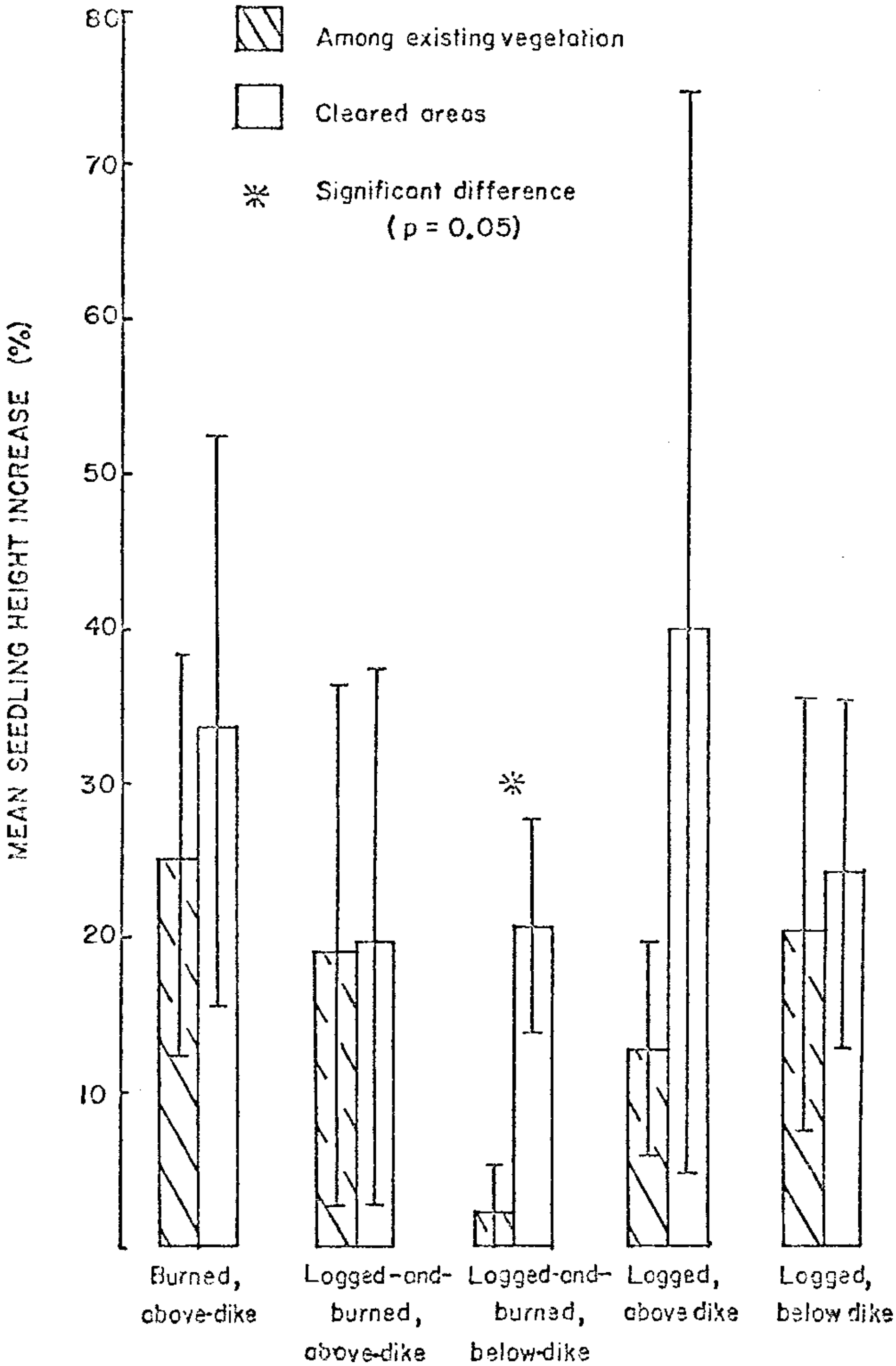


Figure 10. Height increases of transplanted seedlings at the study sites. Values are means; bars represent ± one standard deviation.

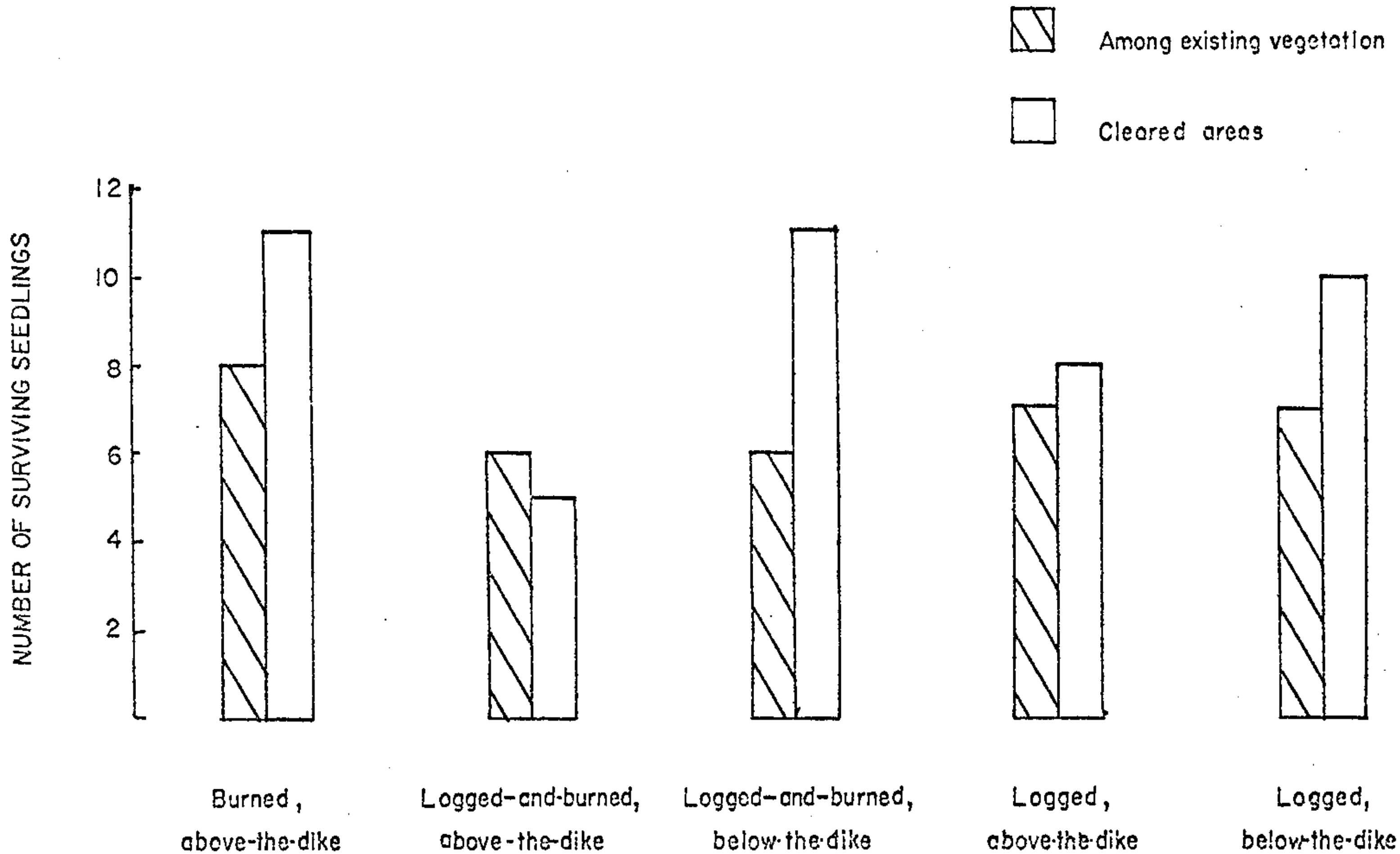


Figure 11. Number of transplanted seedlings surviving to the end of the study period at the study sites. Each bar represents an initial planting of 12 seedlings.

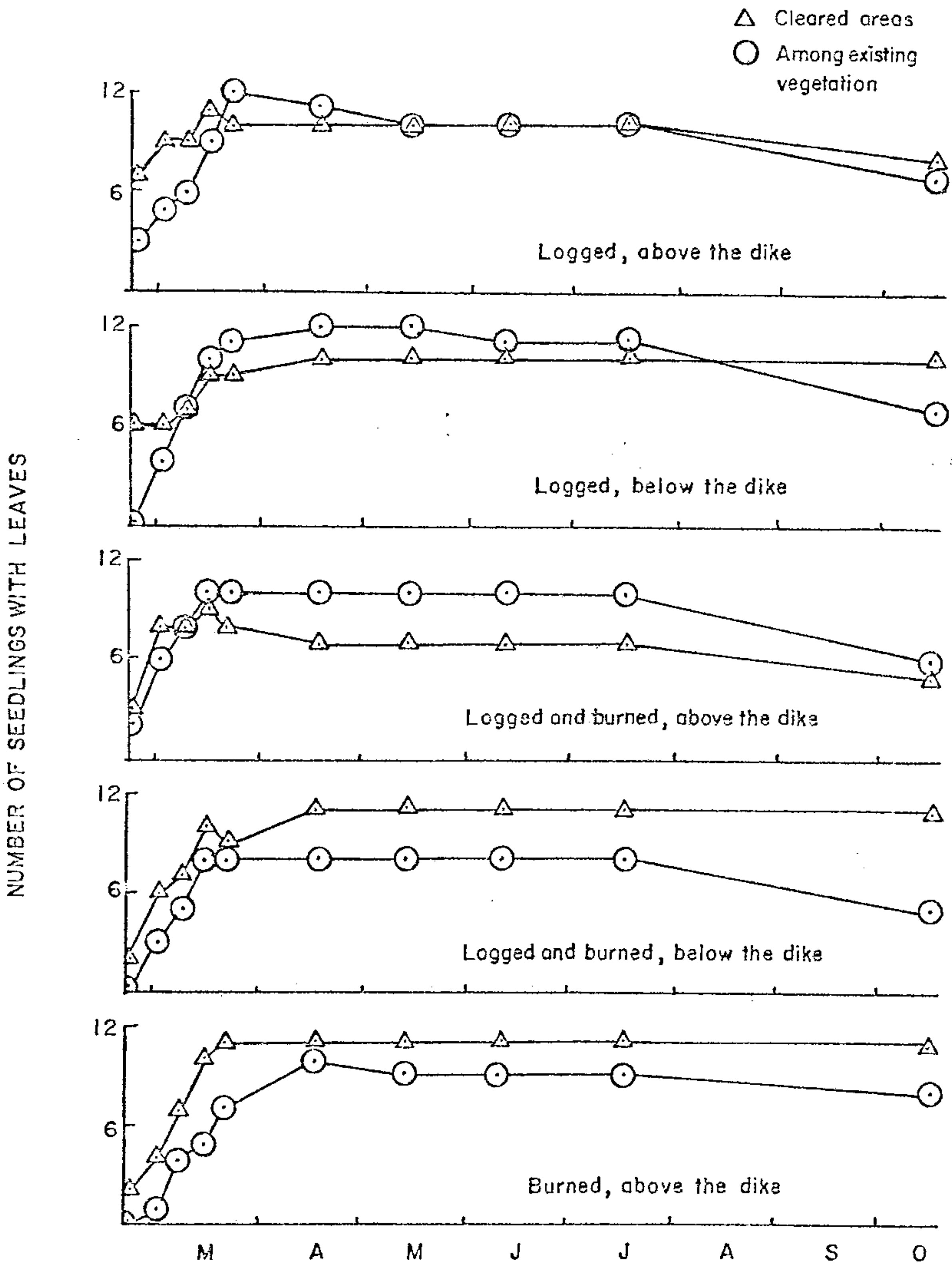


Figure 12. Number of transplanted seedlings with leaves from 24 February to 23 October 1976 at each study site.

site.

Leaf shape, leaf arrangement, and branch orientation were determined on the seedlings at the time of transplanting (January) and at the end of the study (October). The leaf shape did not change following transplanting, however the other characters did change. At the end of the study, the leaves were flattened and away from the stem on the seedlings transplanted among existing vegetation. The ends of the stems were flat, not ascending. The seedlings transplanted into the cleared areas exhibited pondcypress characteristics of appressed leaves leaves along the stem and ascending branches.

Seeds

Seed Germination in the Field

At all sites seed germination was low, averaging 2.1% of all seed planted. Maximum germination was 4.8% for pondcypress seed sown in the cleared area at the logged, above-the-dike site. No difference in percent germination was detected between pondcypress and baldcypress seed.

At the burned, above-the-dike study site, seeds had begun germinating in the cleared areas by the eleventh day following sowing (Table 11) and among existing vegetation after 17 days. The number of germinated seedlings was greatest in the cleared plots on March 2, and in the plots among existing vegetation on March 16. By May 14 the number of germinated seedlings in all plots began to decrease, probably due to receding water levels. One seedling survived through both dry and wet seasons and was still alive in October. Mean germination for baldcypress seed sown at the burned, above-the-dike site was 2.8%, while 1.6% of the pondcypress seed germinated. Mean germination of all seed sown at the site was 2.2%.

Table 11. Number of living seedlings at the burned, above-the-dike study site.

Treatment	Seed Source	Plot	Feb. 14	Feb. 25	March 2	March 9	March 16	March 22	April 17	May 14	June 11	July 17	October 23
Existing vegetation	pondcypress	1	250*	0	1	3	4	5	3	2	1	1	1
		2	250*	0	0	0	0	0	0	0	0	0	0
		3	250*	0	0	0	3	1	1	1	1	1	0
	baldcypress	1	100*	0	0	1	3	1	1	1	1	1	0
		2	100*	0	0	3	5	1	1	1	0	0	0
		3	100*	0	2	3	3	2	2	1	1	1	0
Cleared of existing vegetation	pondcypress	1	250*	1	5	5	5	5	4	0	0	0	0
		2	250*	0	3	7	5	5	1	1	0	0	0
		3	250*	1	4	4	2	1	0	0	0	0	0
	baldcypress	1	100*	0	1	1	2	3	0	0	0	0	0
		2	100*	0	1	2	2	1	0	0	0	0	0
		3	100*	0	1	1	2	0	0	0	0	0	0

*number of seeds planted

_inundated

The seed placed at the logged, above-the-dike site for soaking was lost, so the seed soaking at the logged-and-burned, above-the-dike site was divided and sown at both sites. This is why the number of seed sown at these two sites (Tables 12 and 14) is one-half the amount sown at other sites.

Germination was highest at the logged-and-burned, above-the-dike site (Table 12) on May 14, but by June 11, all but two of the 14 germinated seedlings had died following loss of soil moisture. The remaining seedlings were inundated by July 17 and dead by October 23. Average germination at the site was 1.5% for pondcypress seed and 1.7% for baldcypress seed. Mean germination at the site was 1.6%.

Peak germination was observed in the cleared areas at the logged-and-burned, below-the-dike site (Table 13) one month before maximum germination in the plots located among existing vegetation. Mortality in the cleared plots was highest in April and May, when water levels were lowest. Mean germination at the site was 1.9%. The pondcypress germination averaged 2.1%; that of baldcypress averaged 1.7%.

Mean germination at the logged, above-the-dike study site (Table 14) was 2.2%, with pondcypress seed averaging 2.8%, and baldcypress seed averaging 1.7%. Germination was much lower below the dike, averaging less than 1.0%. Pondcypress seed germination averaged 1.1% below the dike; that of baldcypress averaged 0.8%. Germination was higher in the cleared areas, both above and below the dike, roughly one month before peak germination in the uncleared areas. Mortality occurred both above and below the dike before inundation in June.

Mean percent germination was higher in the cleared plots at the logged sites for both pondcypress and baldcypress seed, although the

Table 12. Number of living seedlings at the logged-and-burned, above-the-dike study site.

Treatment	Seed Source	Plot	March 22	April 17	May 14	June 11	July 17	October 23
Existing vegetation	pondcypress	1	125*	2	1	1	0	0
		2	125*	0	1	0	0	0
		3	125*	0	3	0	0	0
	baldcypress	1	50*	0	1	1	1	0
		2	50*	0	0	0	0	0
		3	50*	0	3	0	0	0
Cleared of existing vegetation	pondcypress	1	125*	1	0	0	0	0
		2	125*	0	1	0	0	0
		3	125*	0	3	0	0	0
	baldcypress	1	50*	0	0	0	0	0
		2	50*	0	0	0	0	0
		3	50*	0	1	0	0	0

*number of seeds planted
_ inundated

Table 13. Number of living seedlings at the logged-and-burned, below-the-dike study site.

Treatment	Seed Source	Plot	March 2	March 9	March 16	March 22	April 17	May 14	June 11	July 17	October 23
Existing vegetation	pondcypress	1	250*	0	0	0	0	0	0	0	0
		2	250*	0	3	4	9	7	7	7	5
		3	250*	0	2	1	0	0	0	0	0
	baldcypress	1	100*	0	0	0	0	0	0	0	0
		2	100*	0	1	3	2	2	2	2	1
		3	100*	0	2	0	0	0	0	0	0
Cleared of existing vegetation	pondcypress	1	250*	0	4	11	5	0	0	0	0
		2	250*	2	8	5	0	0	0	0	0
		3	250*	0	0	0	0	2	0	0	0
	baldcypress	1	100*	0	3	1	1	0	0	0	0
		2	100*	0	1	0	0	0	0	0	0
		3	100*	0	0	2	0	0	0	0	0

*number of seeds planted
_inundated

Table 14. Number of living seedlings at the logged, above-the-dike study site.

Treatment	Seed Source	Plot	March 22	April 17	May 14	June 11	July 17	October 23
Existing vegetation	pondcypress	1	125*	0	2	0	0	0
		2	125*	0	0	0	0	0
		3	125*	1	0	0	0	0
	baldcypress	1	50*	0	1	0	0	0
		2	50*	0	0	0	0	0
		3	50*	0	0	0	0	0
Cleared of existing vegetation	pondcypress	1	125*	9	0	0	0	0
		2	125*	0	0	0	0	0
		3	125*	9	0	0	0	0
	baldcypress	1	50*	2	1	1	0	0
		2	50*	0	0	0	0	0
		3	50*	2	0	0	0	0

*number of seeds planted
_inundated

Table 15. Number of living seedlings at the logged, below-the-dike study site.

Treatment	Seed Source	Plot	March 16	March 22	April 17	May 14	June 11	July 17	October 23
Existing vegetation	pondcypress	1	250*	0	0	0	0	_0_	_0_
		2	250*	0	1	2	0	_0_	_0_
		3	250*	0	0	0	0	_0_	_0_
	baldcypress	1	100*	0	0	0	0	_0_	_0_
		2	100*	0	1	1	0	_0_	_0_
		3	100*	0	0	0	0	_0_	_0_
Cleared of existing vegetation	pondcypress	1	250*	0	3	3	0	_0_	_0_
		2	250*	0	10	1	0	_0_	_0_
		3	250*	0	1	0	0	_0_	_0_
	baldcypress	1	100*	0	4	0	0	_0_	_0_
		2	100*	0	0	0	0	_0_	_0_
		3	100*	0	0	0	0	_0_	_0_

*number of seeds planted
_inundated

observed differences are not statistically significant (Fig. 13). At other sites, no differences in germination of pondcypress seed and baldcypress seed were observed. No significant difference in seed germination was observed either among sites or between treatments.

Seed Germination in the Greenhouse

Germination of cypress seed was much higher in the greenhouse than in the field. Mean germination of pondcypress and baldcypress seed soaked at the study sites, then sown in greenhouse flats, is shown in Figure 14. The seed soaked for 41 days at the burned, above-the-dike site, for 58 days at the logged-and-burned, below-the-dike site, for 72 days at the logged, below-the dike site, and for 78 days at the logged-and-burned, above-the-dike site. The seed at the logged, above-the-dike site was lost. No statistical difference was detected between pondcypress and baldcypress seed germination in the flats using a two-way analysis of variance, nor was any difference detected which could be attributed to soaking treatment.

Seed Germination in the Laboratory

Germination of acid scarified seed in the laboratory was higher than germination of seed sown in the field or greenhouse. Mean germination percentages were calculated from four 100-seed replicates (Fig. 15). Germination commenced on the fifth day following treatment. An average of 5.5% of the pondcypress seed and 11.3% of the baldcypress seed had germinated by the tenth day. After thirty days, an average of 10.5% of the pondcypress seed and 14.8% of the baldcypress seed had germinated. The germination of pondcypress seed ranged from 6 to 16%, while germination of the baldcypress seed ranged from 11 to 18%. No significant difference in thirty-day germination percentages was detected between

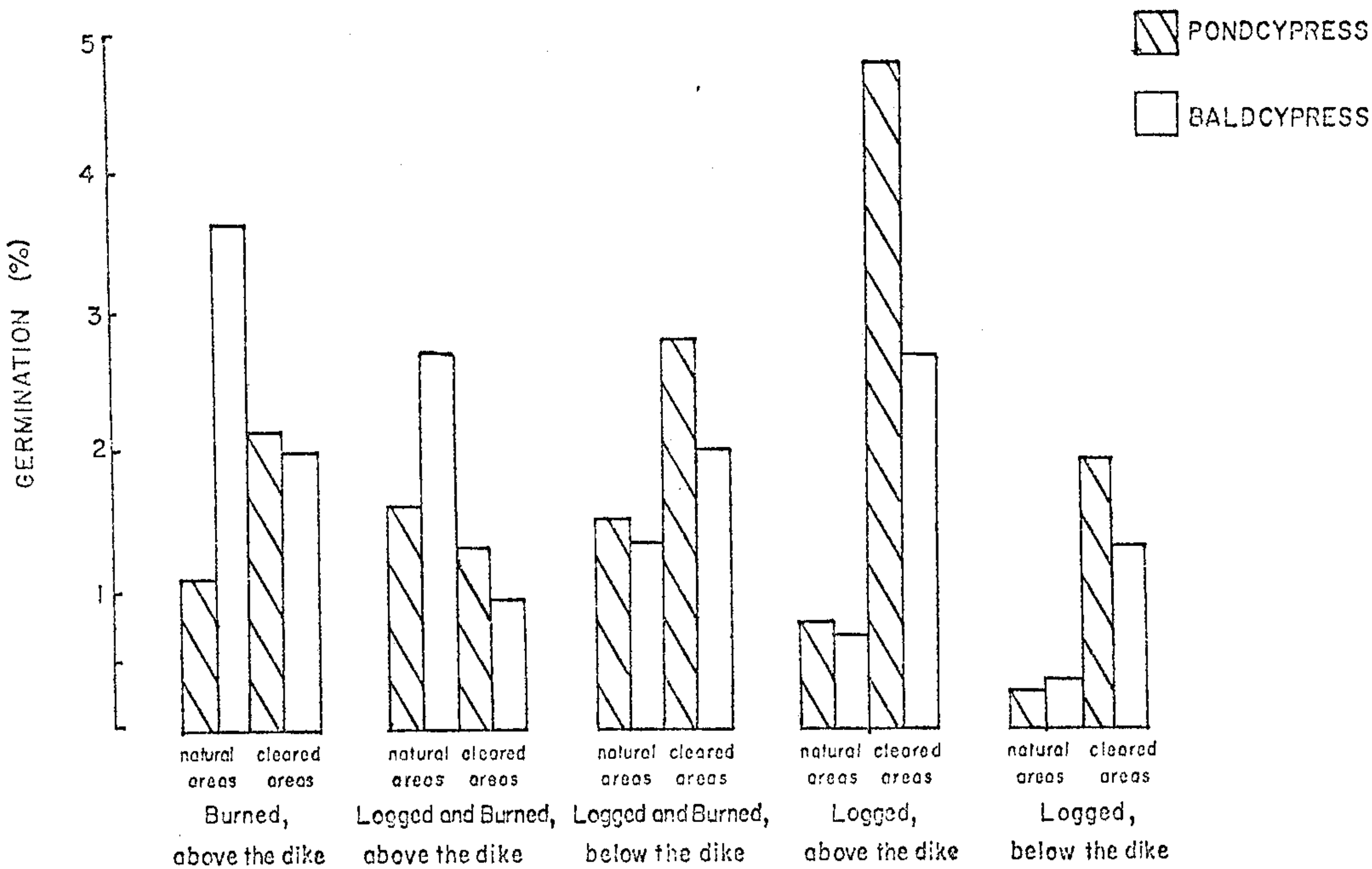


Figure 13. Mean germination of pondcypress and baldcypress seeds sown at each study site.

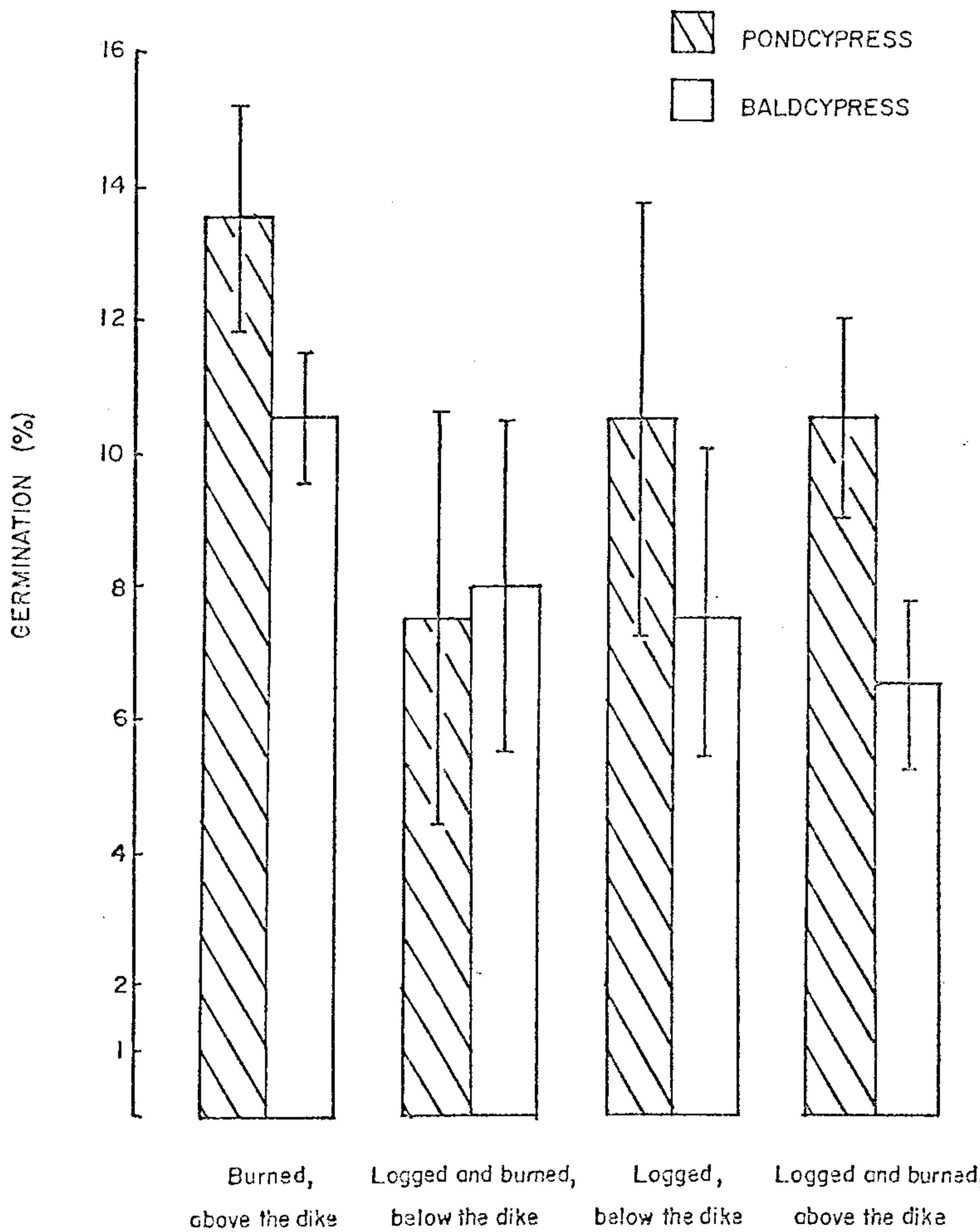


Figure 14. Germination of pondcypress and baldcypress seed sown in greenhouse flats following soaking at study sites. Values are means; bar indicates ± one standard error.

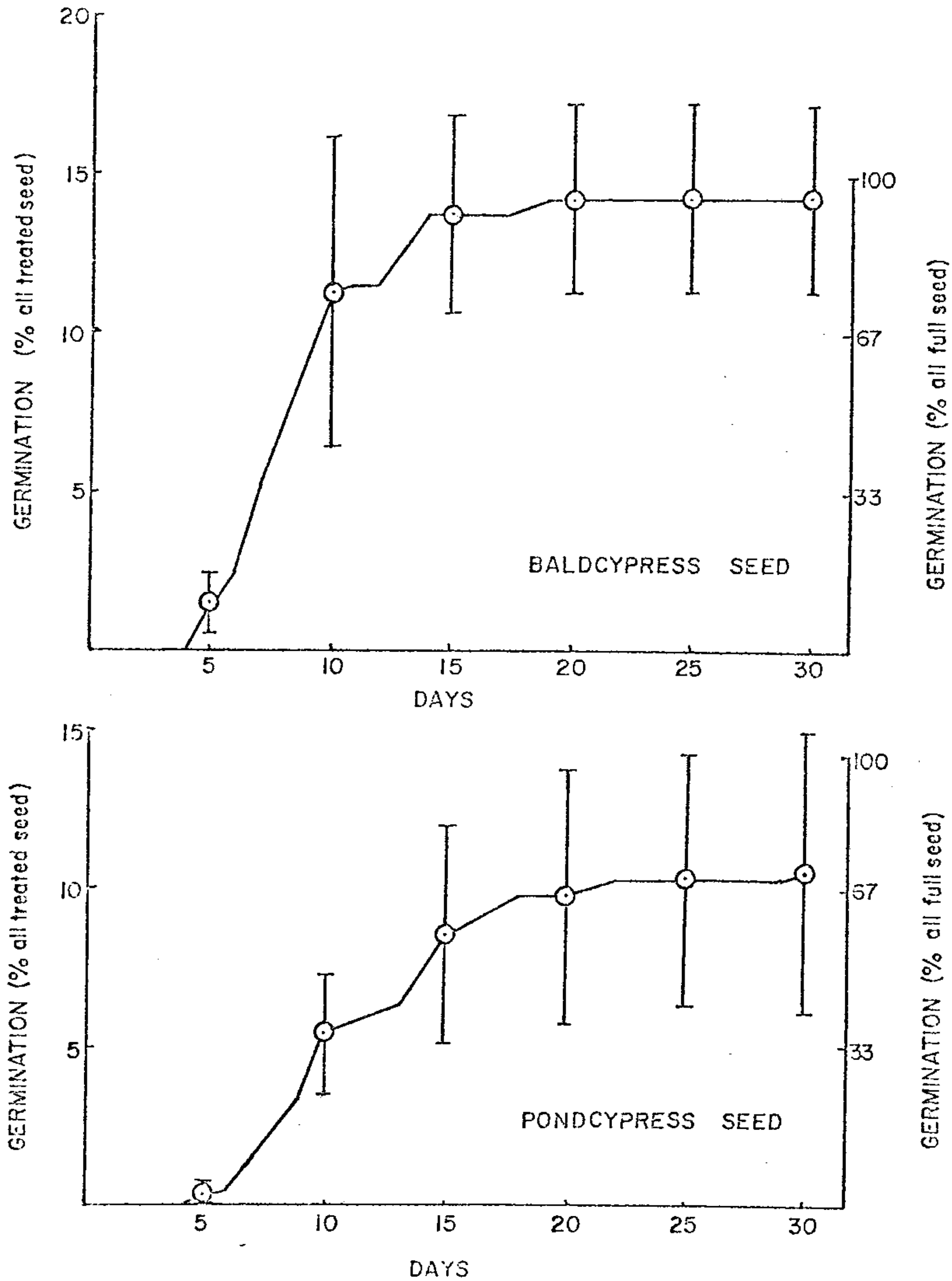


Figure 15. Cumulative germination of pondcypress and baldcypress seed in incubator following acid scarification. Percentages are based on all treated seed and on all full, ungerminated seed. Values are means, ± one standard error.

pondcypress and baldcypress seed using a t-test (Mendenhall, 1974).

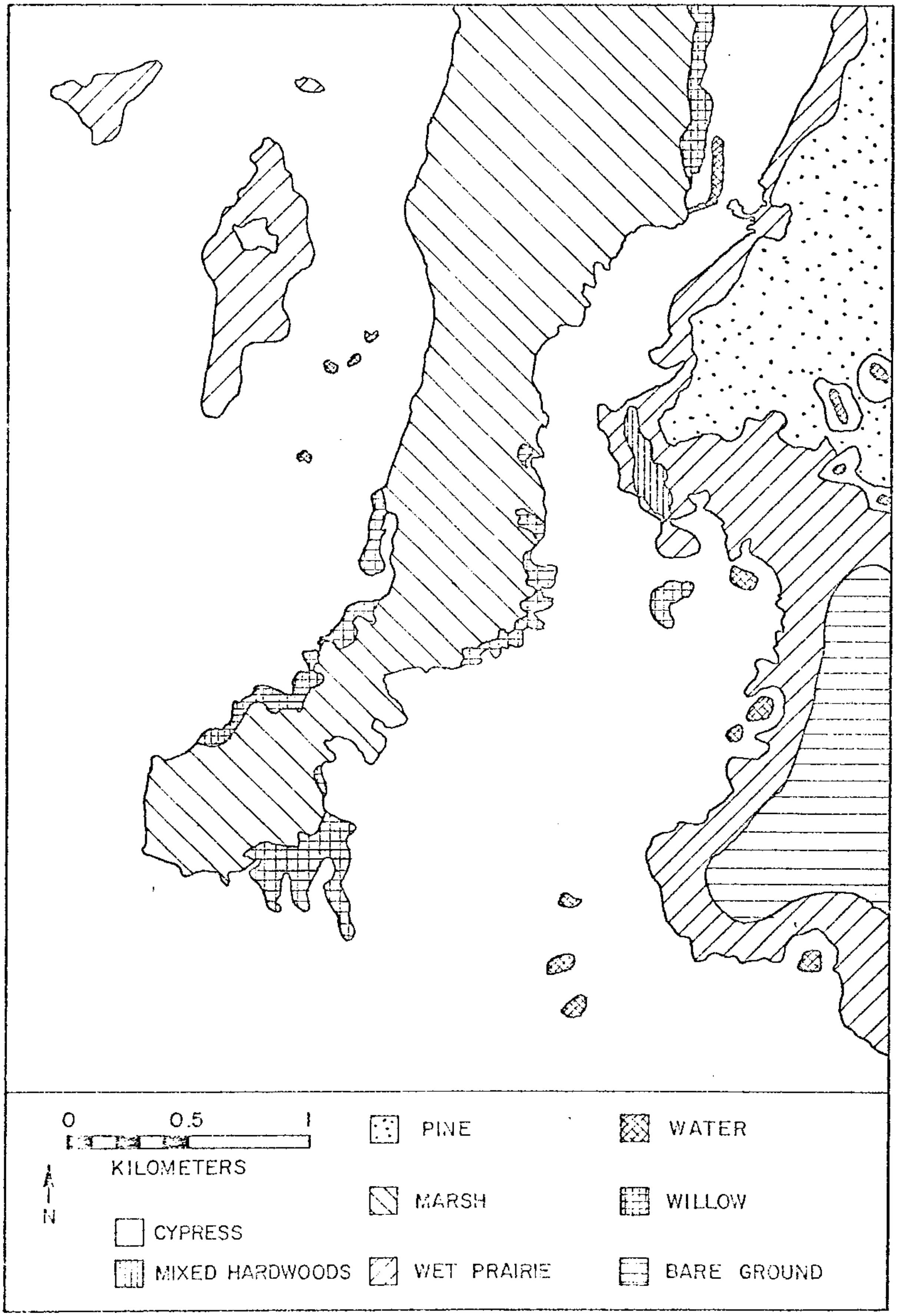
After thirty days, the remaining ungerminated seeds were cut open and examined to determine the number of full seed (as evidenced by fleshy endosperm). Germination based on full seed was 97% for baldcypress, whereas only 72% of the full pondcypress seed had germinated.

Aerial Photographs

The vegetation map made from photographs taken in 1953 (Fig. 16) shows an extensive Taxodium-dominated forest prior to logging. The cypress closer to the central marsh had larger crowns than those closer to the wet prairies. Also, there were more cypress per unit area near the central marsh than there were near the wet prairies. Willow (Salix) was found on the border between the cypress strand and the central marsh. Prominent features on the 1953 photographs included a mixed hardwood stand within the cypress east of the central marsh, plus the recently cutover pine land.

The map from 1963 photographs (Fig. 17) indicates that mixed hardwoods were present on the former cypress-dominated strand approximately nine years following lumbering. Six months after the burn there were extensive amounts of bare ground in the logged areas. The tram roads and scars from skidding were distinguishable on the photographs and remnant, uncut cypress were visible on the fringes of the central marsh. Willow still bordered the central marsh, but was not as extensive as it had been in 1953. The remaining cypress close to the tram roads had small diameters and were closely spaced. Agricultural fields were prominent on the eastern border of the map.

The map in Figure 18 (from photographs taken in 1972) indicates that unburned mixed hardwoods still persist eighteen years after logging. The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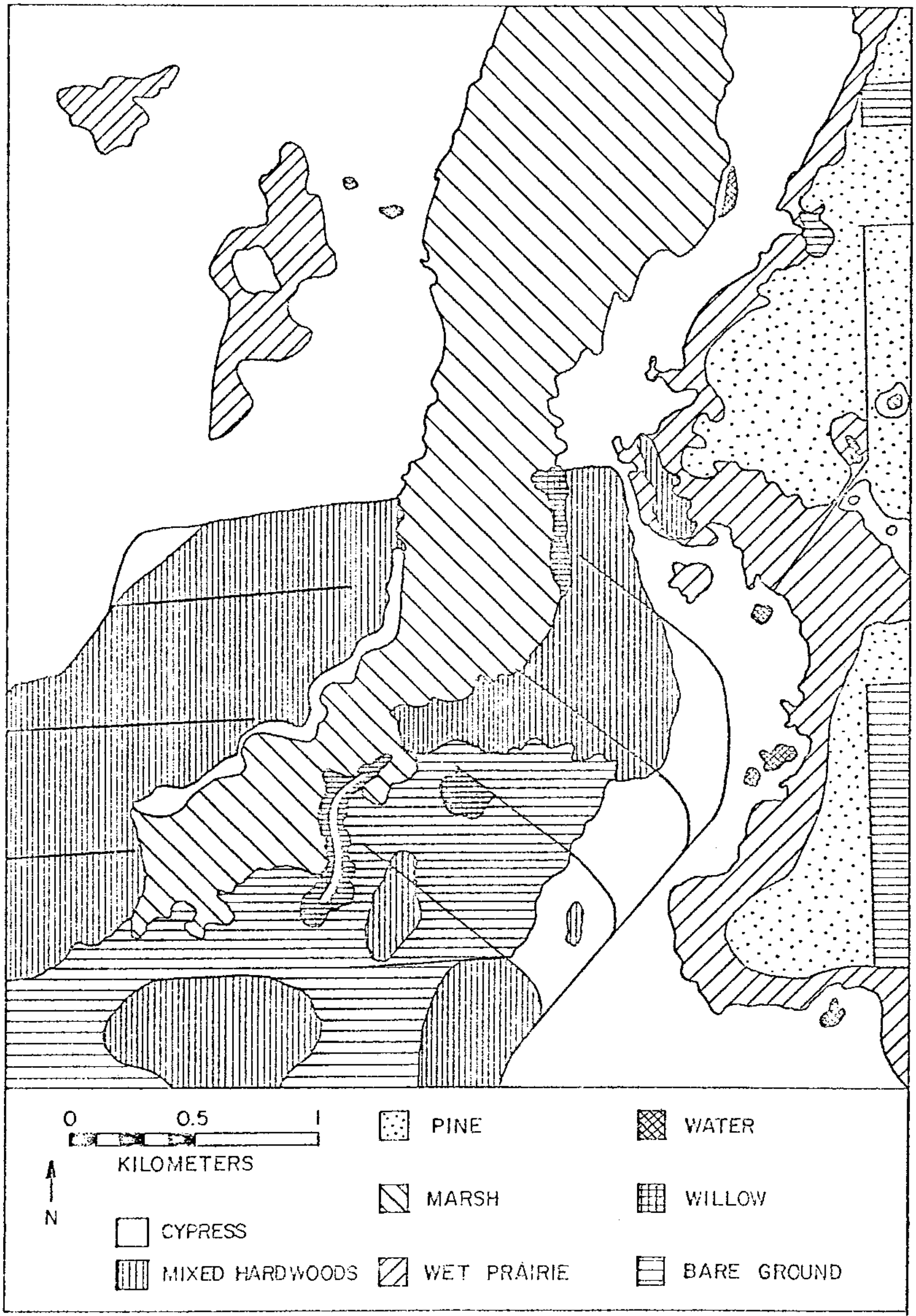
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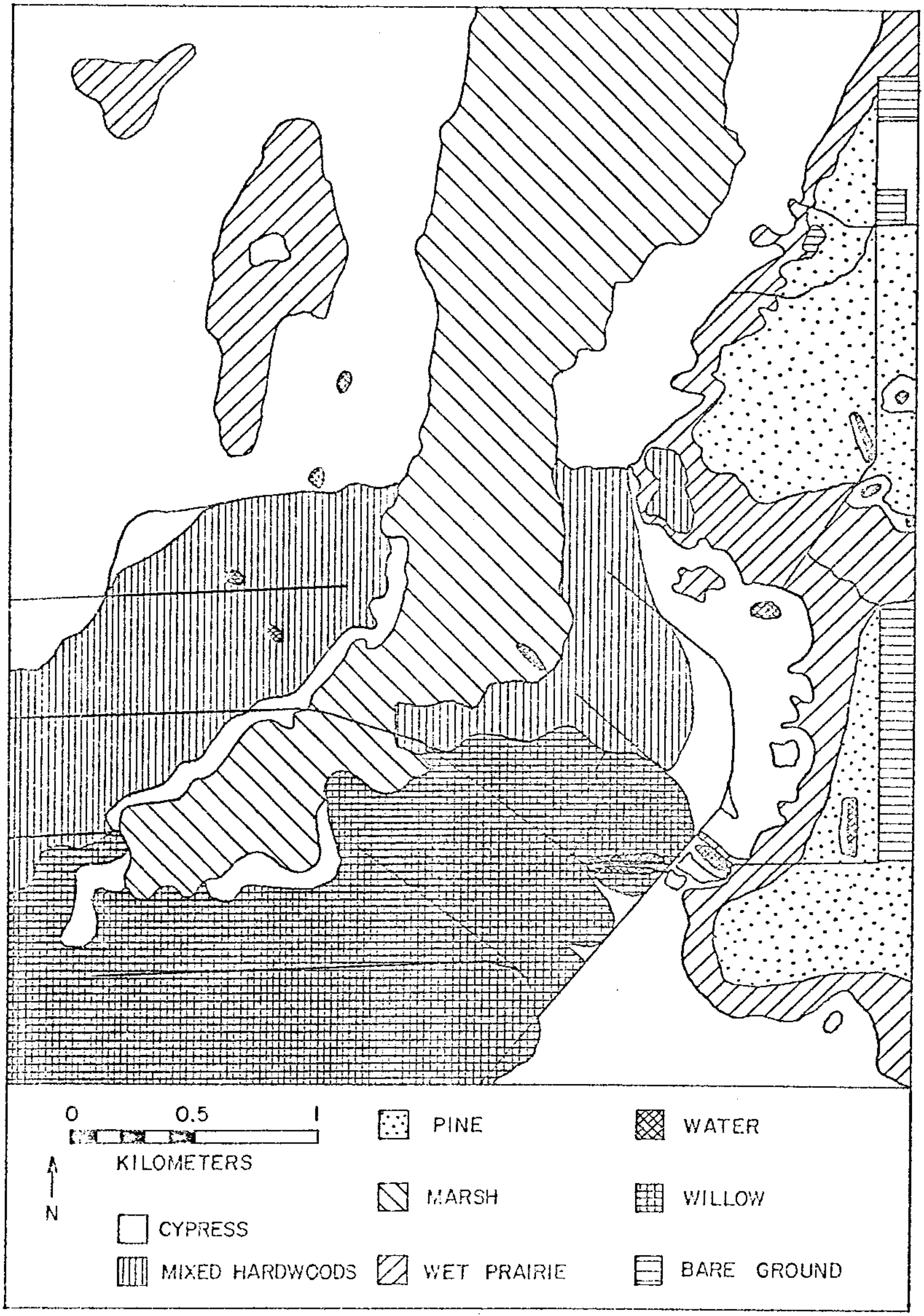
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logged-and-burned area, which was bare ground in 1963 was colonized by willow. An area of unlogged, small diameter cypress (north of twin lakes in lower middle right) which was burned also became dominated by willow. Cypress still dominates north and west of the logged area, and is found on the fringes of the marsh in the logged area. Noticeable is the addition of the levee across the central marsh and the creation of four new lakes: borrow pits for the soil used in the dike construction.

DISCUSSION

Cypress trees are scarce in the former cypress-dominated communities which were logged, burned, and logged-and-burned at Corkscrew Swamp Sanctuary. Very limited regeneration of cypress is occurring in the strand that was logged and the strand that was burned, but there is no cypress regeneration in the area that was both logged and burned. Requirements for seed germination and seedling survival may have been altered by the disturbances of logging and burning. Because little or no cypress regeneration is occurring in the logged and burned swamp, it may not return to its original floristic composition. If the requirements for cypress regeneration are known, management schemes may be devised which could result in the reestablishment of cypress as a component of these disturbed systems.

Cypress Regeneration

Very little regeneration of cypress in the logged areas and burned areas of Corkscrew Swamp has been from vegetative propogation. Recovery of the forest by vegetative means after logging was eliminated because the trees were girdled prior to felling, a practice which reduces coppicing (Mattoon, 1915). The fire killed or damaged the root systems of the trees in the burned areas, also eliminating regeneration by coppice. Therefore, the natural regeneration which has occurred, and can be expected to occur, has been from seed.

Natural regeneration from seed is dependent upon a variety of factors which affect the seed availability, germination and seedling survival (Smith, 1962).

Seed Availability

An adequate supply of seed for abundant regeneration is not available to the disturbed sites. The scattered remaining cypress trees produce a limited amount of seed and the seed which is produced in situ may be infertile or consumed by animals. The disturbed areas are isolated from areas where much seed is produced due to the immobility of cypress seed.

Some seed is produced by a cypress tree every year, but good production occurs only about once every three years (Mattoon, 1915). The trees at the burned study area and logged study area were not observed to produce a good seed crop during the year of study, and no regeneration was noticed during this year. The presence of cypress saplings at these sites, however, indicates that sufficient seed is produced for limited regeneration during certain years.

The seeds that are produced may be less fertile than seed produced in undisturbed areas. Taxodium is monoecious, but cross pollination by wind accounts for most fertilization (Weier et al., 1970). Fertilization is not as likely to occur in the disturbed area, where less pollen is produced, as in a dense uncut or unburned stand of trees. Also, squirrels consume cypress seed in Corkscrew Swamp. Predation on seed in the disturbed areas decreases an already limited supply of seed available for regeneration.

Viable cypress seeds, which are produced in the undisturbed portions of the strand, do not move in the disturbed areas. Cypress seeds move only while floating on water (Fowells, 1965). The slow flow rates of water in Corkscrew Swamp limit the distance the seed can travel.

Obstructions such as vegetation, felled logs or the abandoned tram roads also impede movement of the seed. The seeds do not float more than a couple of days and consequently do not move much beyond the shadow of the parent tree.

Germination

The water requirements for germination of cypress seed are met at the study sites, but low seed viability limits natural regeneration.

Cypress seed must have an abundant moisture supply for one to three months after seed fall (Mattoon, 1915), which occurs from October to December (Fowells, 1965). Standing water was observed at the study sites from one to three months after seedfall and water levels were lower than ground level beginning in February at the site with the shortest hydroperiod. Other sites remained flooded until March. At all study sites, the seeds were inundated long enough to imbibe a sufficient amount of water for germination. The number of seed which germinated did not seem to be affected by the length of time the seed was inundated.

The germination of the seed from Corkscrew Swamp was low, averaging 10 to 15% of all incubated seed. Only 15% of all seed collected was full, indicating low viability. No difference in viability was noted between pondcypress seed and baldcypress seed. The percentages of full seed which germinated during the thirty day test period were comparable to those measured by Bonner (1974) and Murphy and Stanley (1975). Low viability of the cypress seed at Corkscrew accounts for low percent germination of seeds planted in greenhouse flats and in the field, and is a limiting factor in cypress regeneration.

Survivorship During the First Year

A survivorship curve (Fig. 19) was constructed for the study period

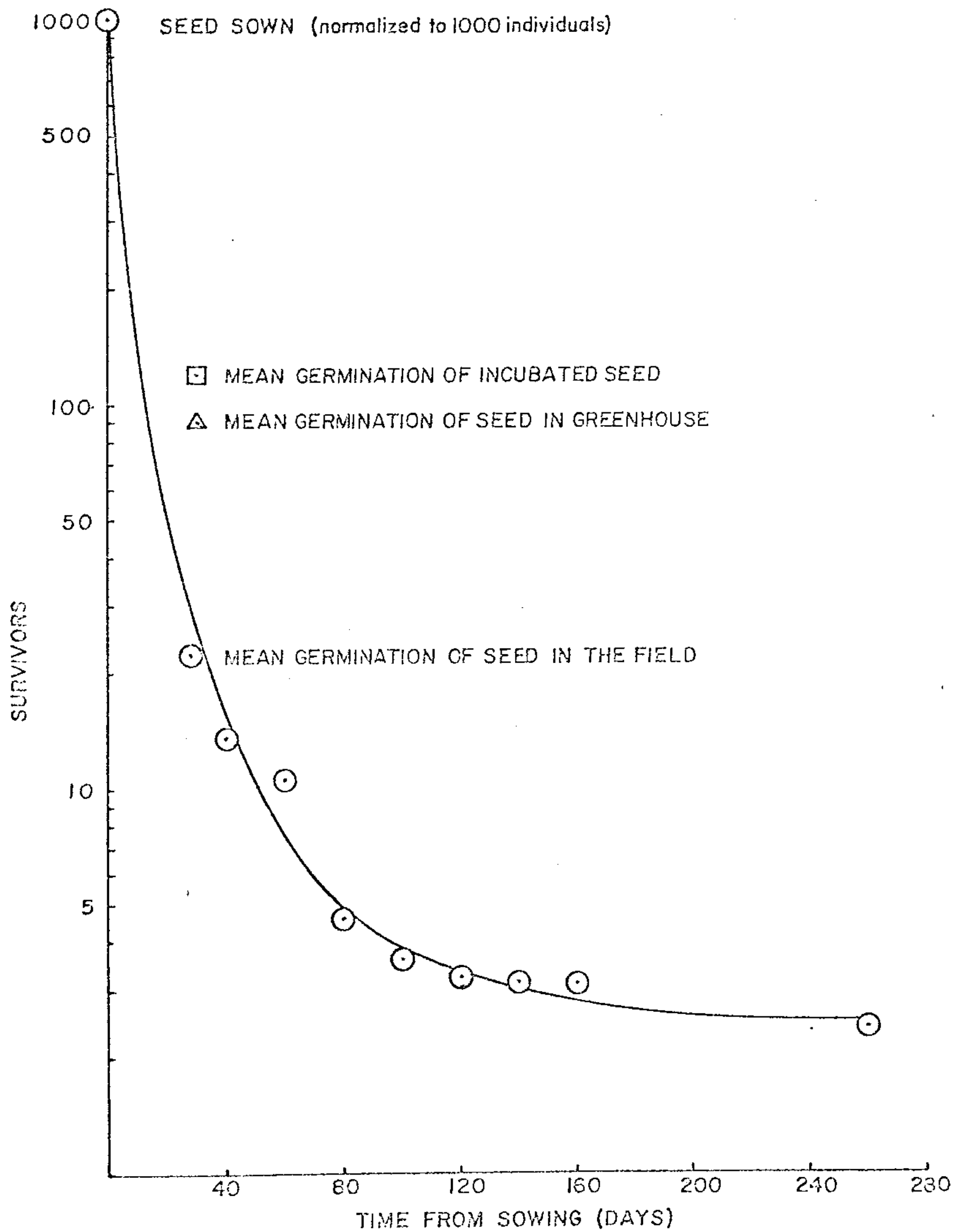


Figure 19. Mean survivorship of cypress seed sown at study sites.

to estimate a mean survival rate of cypress seed sown in the field. The mean number of germinated seedlings surviving to a given day was calculated based upon all seed sown. Although the curve is for less than one year, it probably covers the most crucial time of seedling development. The curve is a Type III (Deevey, 1947), typical of a species with high infant mortality. It is similar to the survivorship curve of _Acer saccharum_ seedlings (Hett and Loucks, 1971) in that the mortality rate is not constant during the first year of existence.

A variety of factors influence the survival of cypress during the year following seedfall. Immediate survival is determined by the number of seed which germinate. Some of the newly germinated seedlings die as a result of drought conditions created by receding water levels. The seedling must grow tall enough during the dry season to escape inundation as water levels rise. Abundant natural regeneration occurs only on years when the proper conditions for survival coincides with a good seed crop (Bull, 1949; Rathborne, 1951; Stubbs, 1972).

Survival through dry season. Initial mortality of the newly germinated seedling occurs during the dry season as water levels recede. Demaree (1932) and Langdon (1958) both indicate that sufficient growth to escape inundation is crucial for cypress seedling survival. At Corkscrew Swamp, lack of soil moisture is a greater cause of first-year mortality than inundation. A total of 148 seedlings sprouted from seed sown at the study sites. Of that total, 123 (83%) died during the dry season, 15 (10%) suffered inundation mortality and 10 (7%) survived (Fig. 20). The older transplanted seedlings survived the dry season better than the newly germinated seedlings. The transplanted seedlings probably maintained root contact with the subsurface water, and as a

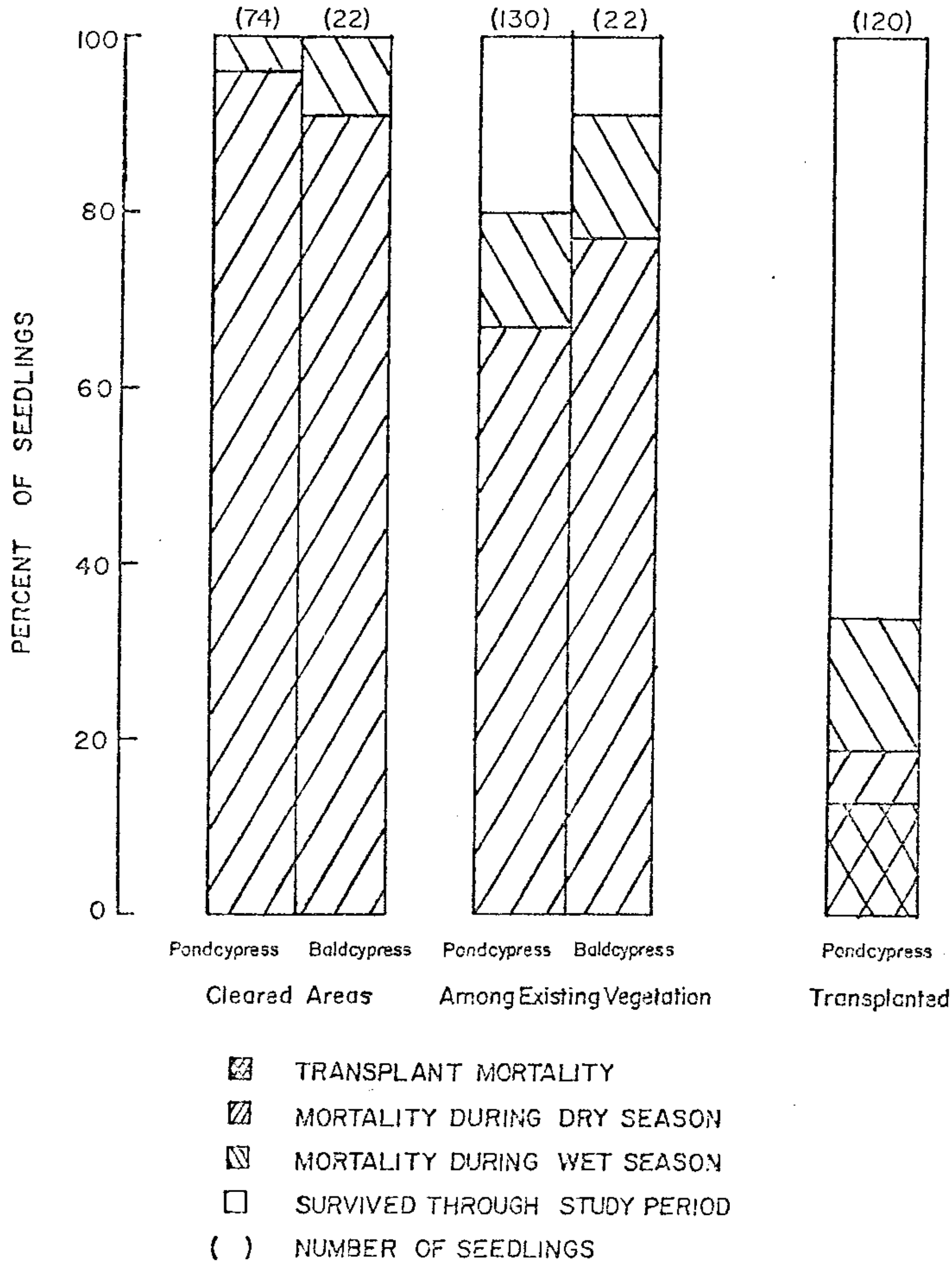


Figure 20. Fate of transplanted seedlings and seedlings germinated from seed sown at study sites.

only 17% of the seedlings died during the dry season. Root contact with water is imperative, because irreversible wilting occurs in cypress seedlings 3-4 hours following loss of soil moisture (Dickson and Broyer, 1972).

The seedlings are more likely to be eaten by animals, such as rabbits (Fowells, 1965), during the dry season because the seedlings are more accessable.

Inundation mortality. Demaree (1932) and Bull (1947) report that *Taxodium* cannot survive prolonged submergence. Welch (1932) observed resprouting following a six-week inundation. All seedlings that died at Corkscrew Swamp were submerged for longer than six weeks. The survivors (both planted and transplanted seedlings) were on higher, drier sites and therefore able to escape inundation.

Competitive Ability of Cypress Seedlings

The existing vegetation at each study site appears to inhibit, but not prohibit, cypress regeneration. Growth and survival of the transplanted seedlings tended to be higher in cleared areas than among existing vegetation (Fig. 21), but the differences were not statistically significant. Any significant difference in growth which reflects tolerance or intolerance of competition may take years to detect because of the slow growth rates of cypress. Post et al. (1975) measured a difference in growth rates of cypress seedlings after two years (but not after one year) following transplanting into cypress domes receiving secondarily treated sewage and domes receiving groundwater inputs near Gainesville, Florida. The difference in growth between cleared areas and uncleared areas (Fig. 21) is masked by high variation. Over a longer study period, the difference might have become significant. The

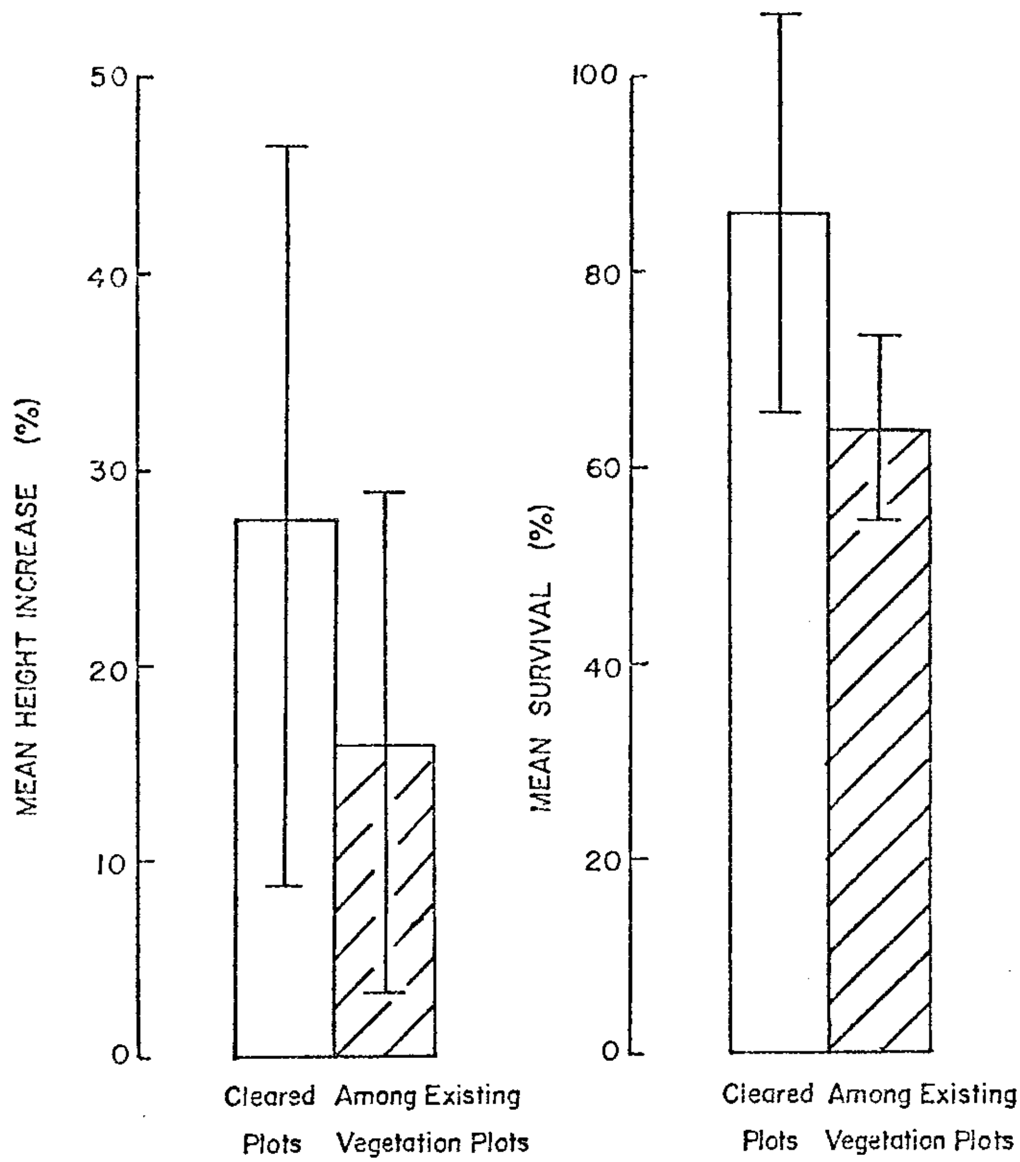


Figure 21. Summary of competition effects on growth and and survival of transplanted seedlings. Values are means; bars represent ± one standard deviation.

developing seedlings might grow better in cleared areas, indicating that the existing vegetation inhibits regrowth of cypress. The presence of cypress seedlings at sites where there is an overstory of cypress indicates, however, that regeneration is not entirely excluded by overstory vegetation.

The existing vegetation may act as a shelter early in the life of a seedling, but once the seedling is tall enough to escape inundation the effects seem to be detrimental. The seedlings which germinated under existing vegetation survived better than seedlings which germinated in cleared areas (Fig. 20). The vegetation probably decreases the transpirational demand on the seedling by increasing the humidity and decreasing the sunlight.

More transplanted seedlings survived in cleared plots than in plots among existing vegetation (Fig. 21). Percent survival based on the highest number of leafed-out seedlings for each treatment at each site was calculated to separate transplant death from death due to competition. The mean percent survival of all seedlings transplanted into cleared areas, excluding deaths due to transplant shock, was 86%, whereas only 64% of seedlings transplanted among existing vegetation survived. The two means are not statistically different, yet suggest that survival may have been higher in cleared areas.

Taxodium exhibits morphological plasticity in response to microclimatic variables. The seedlings transplanted into the cleared areas had leaves appressed to the branch and branches that were ascending. These characteristics are probably a response to water stress created by increased evapotranspiration. The leaves of the seedlings planted among existing vegetation were flattened away from the branch and the branches were flattened away from the main axis. The seedlings in the cleared areas leafed out before seedlings planted among existing vegetation. Seedlings grown in the greenhouse leafed out prior to seedlings in the field, indicating that temperature, but not photoperiod or water relations, may be an important part of the triggering mechanism. Two of the three observed characteristics, leaf and branch orientation, varied with microclimate, whereas leaf shape remained constant. Seedlings which grew under similar conditions in the greenhouse, but germinated from pondcypress and baldcypress seed, exhibited differences in morphology. Thus, my observations of seedlings produced from seeds harvested from known parent trees, plus my observations of cypress trees of various ages and on a variety of sites in the field, convince me that pondcypress and baldcypress are different. Until definitive genetic, cytological, and taxonomic studies are conducted, it is probably advisable to continue to regard them as two distinct species.

Successional Status of Cypress Forests

A generalized scheme of succession in south Florida swamps is proposed in Figure 22; it includes four communities with cypress present and two without cypress present. The largest remnant of the cypress-mixed hardwood community in south Florida is in Corkscrew Swamp Sanctuary. This community is characterized by large-diameter cypress trees forming an overstory above an understory of mixed hardwoods. This vegetation type was probably the historically ubiquitous swamp forest in south Florida, subject to change by natural forces such as hurricanes, frosts, and fire.

Changes due to Fire

A surface fire in the cypress-mixed hardwood forest usually kills

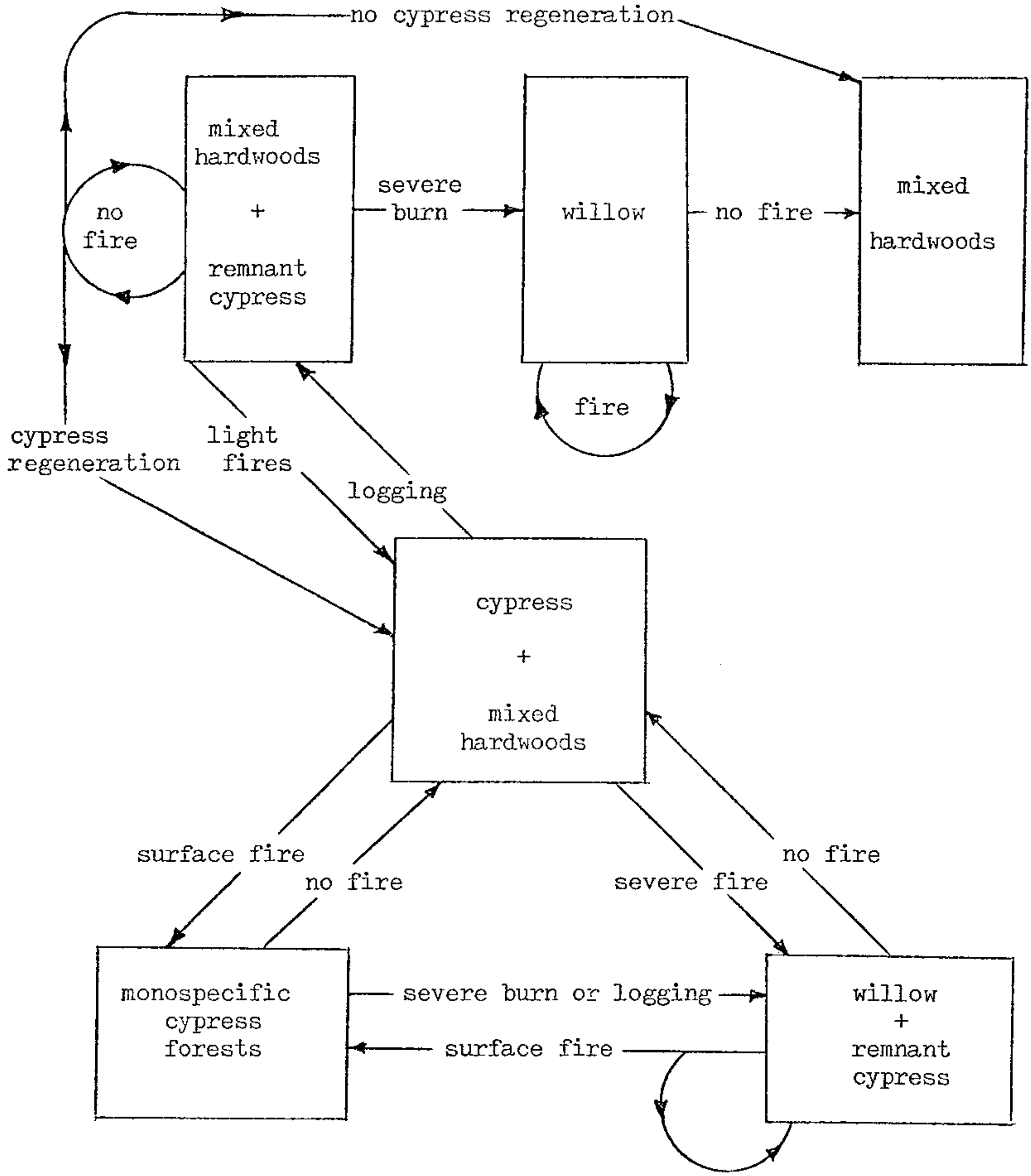


Figure 22. Generalized succession scheme in south Florida swamps.

the hardwoods. Cypress is more tolerant of a surface burn than most hardwoods (Cypert, 1961; Ewel and Mitsch, 1975), so surface burns tend to weed out the hardwoods, leaving monospecific stands of cypress. If the cypress is unburned for a long period of time, the hardwoods invade and reestablish a cypress - mixed hardwood forest.

A severe fire in the cypress - mixed hardwood type will not only kill the hardwoods, as in a surface burn, but will also kill some or all of the cypress. Cypert (1961) and Alexander and Crook (1973) state that consumption of the peat substrate by severe fires destroys the root systems of all trees, eliminating recovery by coppice. Removal of the organic soil also alters soil properties of water retention and nutrient availability. The elimination of trees and vegetative regrowth leaves the site open for invasion by other species.

Swamp forests denuded by a severe burn in south Florida are often colonized by willow, Salix caroliniana. Willow has readily dispersed seed and rapidly invades seasonally flooded sites after disturbances such as burning (Robertson, 1953) or logging (Allen, 1962) have altered the substrate, provided that some soil organic matter remains (Loveless, 1959). Willow stands are maintained by frequently recurring fires (Craighead, 1971). If remnant cypress are present and if surface burns recur, the willow-dominated communities once again become cypress-dominated. If fire is excluded from the willow-and-remnant-cypress community, then invasion of hardwoods coupled with cypress regeneration will continue until a mixed forest of cypress and hardwoods persist.

Thus, the natural patterns expressed in Figure 22 can be summarized as follows: fire in south Florida swamp forests has long been one of the determinants of vegetation change. Prior to man's intervention, the wetland forests were probably one of three general types depending upon the frequency and severity of burning. Swamps which were not burned for long periods of time were mostly cypress - mixed hardwoods. Surface fires killed the hardwoods, leaving pure cypress forests. Severe fires would destroy all of the vegetation, allowing invasion by willow. The willow forests were, and are, maintained by frequent fire, but change into a cypress - mixed hardwood forest if fire is excluded.

Changes due to Logging or Logging-and-Burning

Succession in cypress - mixed hardwood swamps following lumbering results in communities dominated by mixed hardwoods. The large-diameter cypress are removed by logging, leaving a few small-diameter cypress. The hardwoods are released from overstory competition and capture the site.

A surface fire in the mixed hardwood, remnant-cypress forest may enhance cypress regeneration by reducing competition from the hardwoods. The cypress can then successfully regenerate if proper conditions for germination and seedling survival are present.

A stand of mixed hardwoods, with remnant cypress, should persist if fire is excluded. Red maple, *Acer rubrum*, and dahoon holly, *Ilex cassine*, are the dominant trees at the logged sites within Corkscrew Sanctuary and both species are regenerating actively. Red maple may live up to 150 years (Fowells, 1965), so this tree may continue to dominate for a long time if fire is excluded. *Annona*, *Cephalanthus*, *Myrsine*, *Persea* and *Myrica* are also actively regenerating. Remnant cypress should remain in the community for long periods of time, with or without regeneration, because of the longevity of cypress.

If sufficient numbers of cypress are present in the mixed hardwoods after logging, the cypress will reproduce and the community will return to the pre-logging cypress - mixed hardwood status. If insufficient seed are present and/or competition from the hardwoods eliminates cypress regeneration, the forest will become a stand of mixed hardwoods with no cypress.

Cypert (1961) and Alexander and Crook (1973) agree that logged swamps are damaged much more by fire than unlogged swamps. The hardwoods are all killed by the burn, which is more intense because of the thick undergrowth, and the resultant bare area is open to invasion by willow.

The willow community is maintained by frequent fires and unchanged water levels (Craighead, 1971). With the elimination of fire, hardwoods invade the logged-and-burned, willow-dominated stand. Seedlings of *Annona*, *Acer* and *Persea* were found within the logged-and-burned study area. Alexander and Crook (1973) reported similar observations, indicating succession toward a mixed hardwood forest which is devoid of cypress.

Cypress is difficult, but not impossible, to reestablish once removed by lumbering. Cypress-free mixed hardwood forests, however, are a likely long-term sequel to logging followed by a severe burn.

Management

Restoration of the *Taxodium* dominated community in the disturbed areas of Corkscrew Swamp Sanctuary may be one desirable goal of sanctuary management; actions are available by which the problems associated with cypress regeneration may be overcome. Cypress seem to be reproducing naturally in areas where seed sources remain, but logging and burning removed most of the seed sources and cypress seeds do not move from the undisturbed areas into the disturbed areas. Low seed viability, high seedling mortality and slow growth rates of seedlings seem to limit regrowth in areas where seed is present. If cypress is reestablished in the disturbed areas, the resultant community may be more resistant to change following burning. Also, it would eventually replace some of the rookery habitat lost by logging.

Two methods could be employed in restoring the Taxodium: direct seeding or seedling planting. Sowing seed would be less expensive and labor intensive, but the expected survivorship would be very low. In this study less than 1 seed out of every 1000 planted survived the first year, indicating that application rates of seed would have to be very high for abundant regeneration. Purchased seed may be higher in viability than seed collected on-site, but drought and inundation mortality would limit the number of survivors.

The other method of reforestation would be to transplant year-old seedlings in the disturbed sites, a method which has worked successfully in Louisiana (Bull, 1947; Rathborne, 1951). To maintain the genetic stock, seed could be harvested in the area, scarified with acid to increase the germination rate, and sown in pots. One-year-old seedlings, which were raised from the seed germinated in greenhouse flats, averaged 1 m in height: tall enough to escape inundation if planted in the disturbed areas. Transplanting of potted seedlings into the field should probably be done from January through March, when the seedlings are still leafless and water levels are low enough so that much of the swamp is readily accessible. Bull (1947) recommended a 5 m x 5 m planting distance. Natural densities of trees in cypress strands at Corkscrew Swamp range from 6 m^2 per tree in the pondcypress region to 100 m^2 per tree in the baldcypress regions (Duever et al., 1975). Assuming first year mortality to be 33% of all transplanted seedlings (this study), the recommended planting would result in a density of 38 m^2 per tree one year following planting. If the disturbed area (175 ha) is planted at this density (25 m^2 per tree or 400 trees per ha), then 70,000 seedlings would have to be planted. Planting of seedlings at lower densities would decrease the amount of labor required, but would increase the regrowth time. Seedlings planted at a lower density would, in time, serve as seed sources for additional cypress reforestation.

The water impounded by the dike seems to be affecting the vegetation in the cutover and burned areas of Corkscrew Sanctuary. The impact seems to result from higher water levels above the dike rather than increased duration of the hydroperiod. Because the water is deeper above the dike during the wet season, less substrate -- including soil, hummocks, and stumps -- is exposed than below the dike. Cypress seeds require exposed substrates for germination, so the increased depth of water above the dike may be retarding the already limited amount of natural regeneration occurring there. Removal of the boards blocking the culverts which traverse the dike might result in lower water levels and thus increase the amount of substrate available for recolonization by cypress.

The regeneration of cypress on lands which were once dominated by Taxodium in Corkscrew Swamp Sanctuary is constrained by biological factors, including seed availability and viability, narrow germination and seedling establishment requirements, inherent differences between pondcypress and baldcypress, and site capture by successional vegetation. Within these constraints, however, there are tools available to the Sanctuary management. They include the potential for artificial regeneration, water level manipulation, and the use of fire. Used together in the proper combinations, these tools should make possible the reestablishment of cypress forests on much of its former range within Corkscrew Swamp Sanctuary.

LITERATURE CITED

Allen, P.H. 1962. Black willow dominates baldcypress-tupelo swamp eight years after cutting. U.S.D.A. Forest Service, Southeastern Forest Experimental Station Research Note 177. 2 p.

Alexander, T.R. and A. Crook. 1973. Vegetation changes in south Florida, Appendix G. In South Florida Environmental Study, National Park Service. 827 p.

Applequist, M.B. 1959. Longevity of submerged tupelo and baldcypress seed. Louisiana State University Forestry Note 27. 2 p.

Beaven, G.F. 1939. Pocomoke Swamp: A study of a cypress swamp in Maryland. Bull. Torrey Bot. Club 66: 367-389.

Betts, H.S. 1960. Baldcypress. U.S. Forest Service, American Woods Serial. 6 p.

Bonner, F.T. 1974. *Taxodium*, p. 796-798. In Seeds of Woody Plants in the United States. U.S.D.A. Forest Service. Agriculture Handbook No. 450.

Bull, H. 1949. Cypress planting in southern Louisiana. Southern Lumberman 179: 227-230.

Carter, M.R., L.A. Burns, T.R. Cavinder, K.R. Dugger, P.L. Fore, D.B. Hicks, H.L. Revells, and T.W. Schmidt. 1973. Ecosystem Analysis of the Big Cypress Swamp and Estuaries. Report U.S. Environmental Protection Agency, Region IV. 374 p.

Craighead, F.C. 1971. The Trees of South Florida; Vol. I: The Natural Environments and their Successions. Univ. of Miami Press, Coral Gables, Fla. 212 p.

Craighead, F.C. 1974. Hammocks of south Florida, pages 53-60. In P.J. Gleason, (ed.), Environments of south Florida: past and present. Memoir 2: Miami Geological Society.

Curtis, J.T. 1959. The Vegetation of Wisconsin: An ordination of plant communities. Univ. of Wisconsin Press, Madison. 657 p.

Cypert, E. 1961. The effects of fire in the Okeefenokee Swamp in 1954 and 1955. Amer. Midl. Nat. 66: 485-503.

Cypert, E. 1973. Plant succession on burned areas in Okeefenokee Swamp following the fires of 1954 and 1955. Proc. Ann. Tall Timbers Fire Ecol. Conf. 12: 199-218.

Davis, J.H. 1943. The Natural Features of Southern Florida, especially the Everglades. Florida Geological Bull. No. 25. 311 p.

DeBell, D.S., J. Stubbs, and D.D. Hook. 1968. Stand development after a selection cutting in a hardwood bottomland. Southern Lumberman 217: 126-128.

Deevey, E.S. 1947. Life tables for natural populations of animals. Quart. Rev. Biol. 22: 283-314.

Demaree, D. 1932. Submerging experiments with Taxodium. Ecology 13: 258-262.

Detwiler, S.B. 1916. The baldcypress (Taxodium distichum), identification and characteristics. Amer. Forestry 22: 577-581.

Dickson, R.E. and T.C. Broyer. 1972. Effects of aeration, water supply and nitrogen source on growth and development of tupelo and baldcypress. Ecology 53: 626-635.

Duever, M.J., J.E. Carlson, and L.A. Riopelle. 1975. Ecosystem analyses at Corkscrew Swamp Sanctuary, p. 627-725. In H.T. Odum, (ed.), Cypress Wetlands for Water Management, Recycling and Conservation. 2nd Annual Report, Center for Wetlands, Univ. of Fla., Gainesville.

Egler, F.E. 1954. Vegetation science concepts I: initial floristic composition, a factor in old-field vegetation development. Vegetatio Acta Geobotanica 4: 412-417.

Ewel, K.C. and W.J. Mitsch. 1975. The effect of fire on the species composition of trees in two cypress domes, p. 215-222. In H.T. Odum, (ed.), Cypress Wetlands for Water Management, Recycling and Conservation. 2nd Annual Report, Center for Wetlands, Univ. of Fla., Gainesville.

Fowells, H.A. 1965. Silvics of Forest Trees of the United States. U.S.D.A. Forest Service. Agriculture Handbook No. 271. 762 p.

Gooch, F.S. 1953. Nursery culture of cypress. Southern Lumberman 186: 37-38.

Harper, R.M. 1927. Natural Resources of South Florida. 18th Annual Report State Geological Survey, Tallahassee, Fla. p. 25-206.

Hett, J.M. and O.L. Loucks, 1971. Sugar Maple (Acer saccharum Marsh.) seedling mortality. J. Ecol. 59: 507-520.

Johnson, R.L. 1972. Oak-Gum-Cypress in the Midsouth, p. 98-103. In Silviculture Systems of Major Forests Types in the U.S. U.S.D.A. Agriculture Handbook No. 445.

Kurz, H. and R.K. Godfrey. 1962. The Trees of Northern Florida. Univ. of Fla. Press, Gainesville, Fla. 311 p.

Langdon, O.G. 1958. Silvical characteristics of baldcypress. U.S.D.A. Forest Service, Southeastern station paper 94. 7 p.

Long, R.W. and O. Lakela. 1971. A Flora of Tropical Florida, A Manual of Seed Plants and Ferns of Southern Peninsular Florida. Univ. of Miami Press, Coral Gables, Fla. 962 p.

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

Mattoon, W.R. 1915. The Southern Cypress. U.S.D.A. Bulletin No. 272. 74 p.

Mattoon, W.R. 1916. Water requirements and growth of young cypress. Soc. Am. For. Proc. 11: 192-197.

Mendenhall, W. 1975. Introduction to probability and statistics. 4th ed. Wadsworth Publishing Co., Belmont, California. 460 p.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York. 547 p.

Murphy, J.B. and R.G. Stanley. 1975. Increased germination rates of baldcypress and pondcypress seed following treatments affecting the seed coat. Physiol. Plant 35: 135-139.

Oosting, H.J. 1956. The Study of Plant Communities. 2nd ed. W.H. Freeman and Co., San Francisco and London. 440 p.

Penfound, W.T. 1952. Southern swamps and marshes. Bot. Rev. 18: 413-446.

Post, D.M., C.A. Hollis, J.B. Murphy and G. Deghi. 1975. Forest growth seedlings and fertility, p. 483-554. In H.T. Odum, (ed.), Cypress Wetlands for Water Management, Recycling and Conservation. 2nd Annual Report, Center for Wetlands, Univ. of Fla., Gainesville.

Prestridge, J.A. 1947. The Big Cypress Swamp - where the modern and primitive meet. Southern Lumberman 175: 126-130.

Rathborne, J.C. 1951. Cypress reforestation. Southern Lumberman 183: 239-240.

Robertson, W.B. 1953. A Survey of the Effect of Fire in Everglades National Park. U.S. Dept. of Interior Report, National Park Service. 169 p.

Small, J.K. 1920. Cypress and population in Florida. Jour. N.Y. Bot. Garden 21: 81-86.

Small, J.K. 1931. The cypress, southern remnant of a northern fossil type. Jour. N.Y. Bot. Garden 32: 125-135.

Small, J.K. 1933. Manual of the Southeastern Flora. Univ. of North Carolina Press, Chapel Hill.

Smith, D.M. 1962. The Practice of Silviculture. 7th ed. John Wiley and Sons, New York, London and Sydney. 578 p.

Snedacor, G.W. and W.G. Cochran. 1967. Statistical Methods. 6th ed. The Iowa State University Press, Ames, Iowa. 593 p.

Sokal, R.R. and F.J. Rohlf. 1969. Biometry. W.H. Freeman and Sons, San Francisco. 776 p.

Sprunt, A. Jr. 1954. Florida Bird Life. Coward McCann, Inc., New York and the National Audubon Society. 527 p.

Sternitzke, H.S. 1972. Baldcypress: endangered or expanding species? Econ. Bot. 26: 130-134.

Stubbs, J. 1972. Atlantic Oak-Gum-Cypress, p. 89-93. In Silviculture Systems of Major Forest Types in the United States. U.S.D.A. Agricultural Handbook No. 445.

Weier, T.E., C.R. Stocking, and M.G. Barbour. 1970. Botany. John Wiley and Sons, Inc., New York, London, Sydney. 708 p.

Welch, W.H. 1932. An ecological study of baldcypress in Indiana. Proc. Ind. Acad. Sci. 41: 207-213.

West, E. and L.E. Arnold. 1956. The Native Trees of Florida. Univ. of Florida Press, Gainesville, Fla. 218 p.

BIOGRAPHICAL SKETCH

Lance H. Gunderson was born December 7, 1952 in Miami, Florida. He attended public schools in Lee County, Florida until graduation from Fort Myers Senior High School in June, 1970. In September, 1970 he entered the University of Florida. He received a Bachelor of Science degree, majoring in Botany, in June, 1975. Upon graduation he was accepted into the Graduate School in the Department of Botany.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

John J. Ewel, Chairman
Associate Professor of Botany

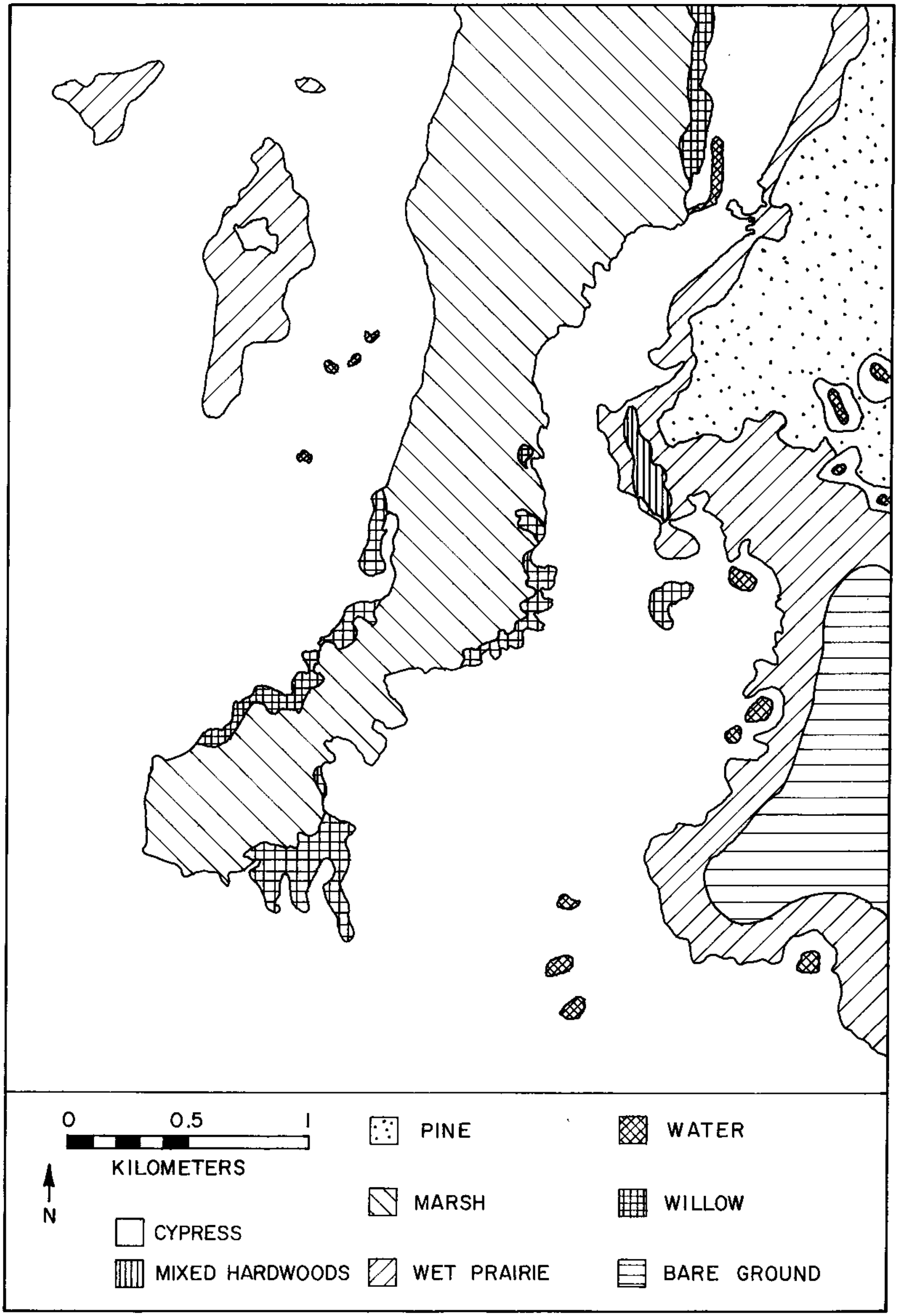
I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Ariel E. Lugo
Associate Professor of Botany

This thesis was submitted to the Graduate Faculty of the Department of Botany in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Master of Science.

August 1977

Dean, Graduate School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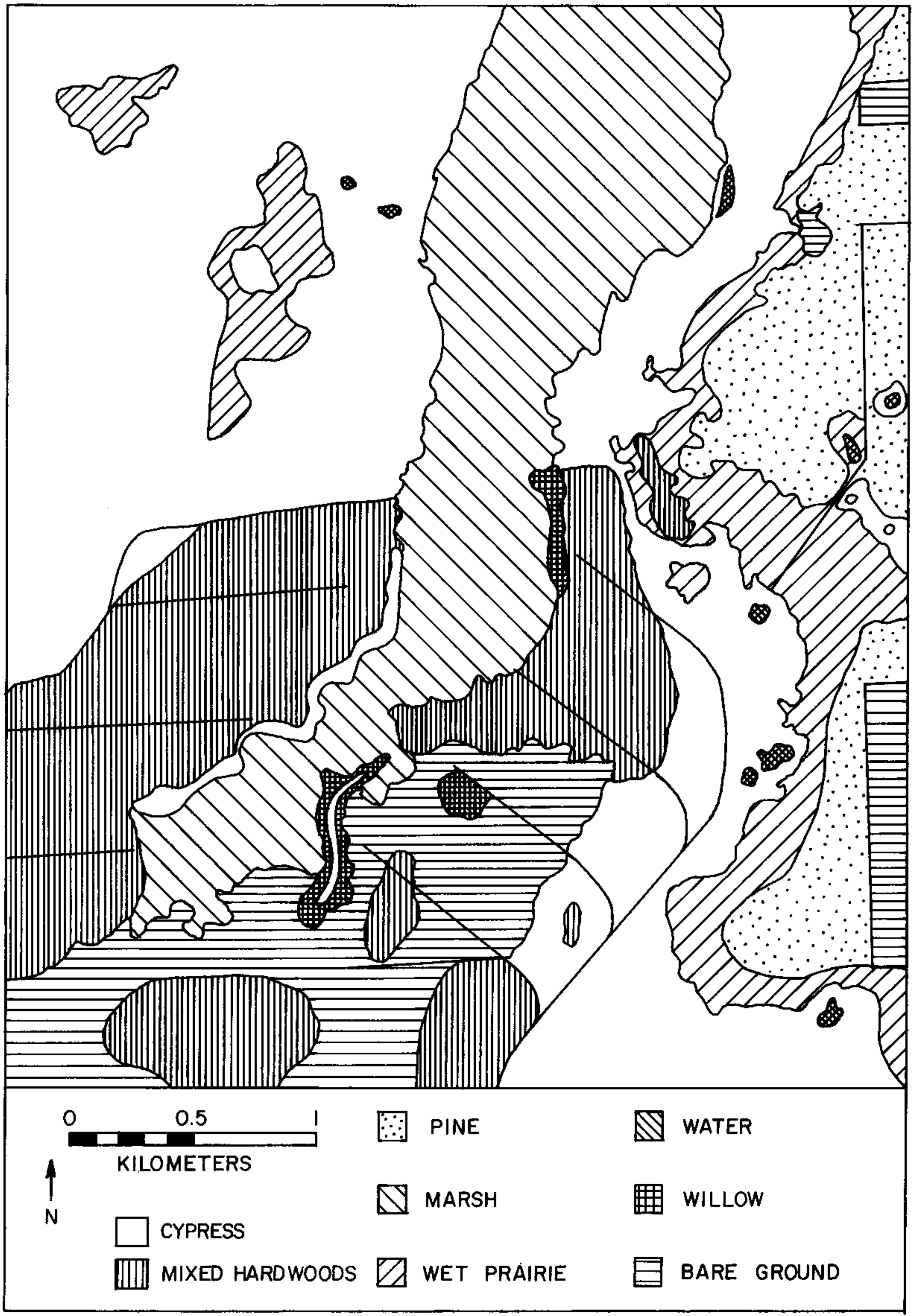

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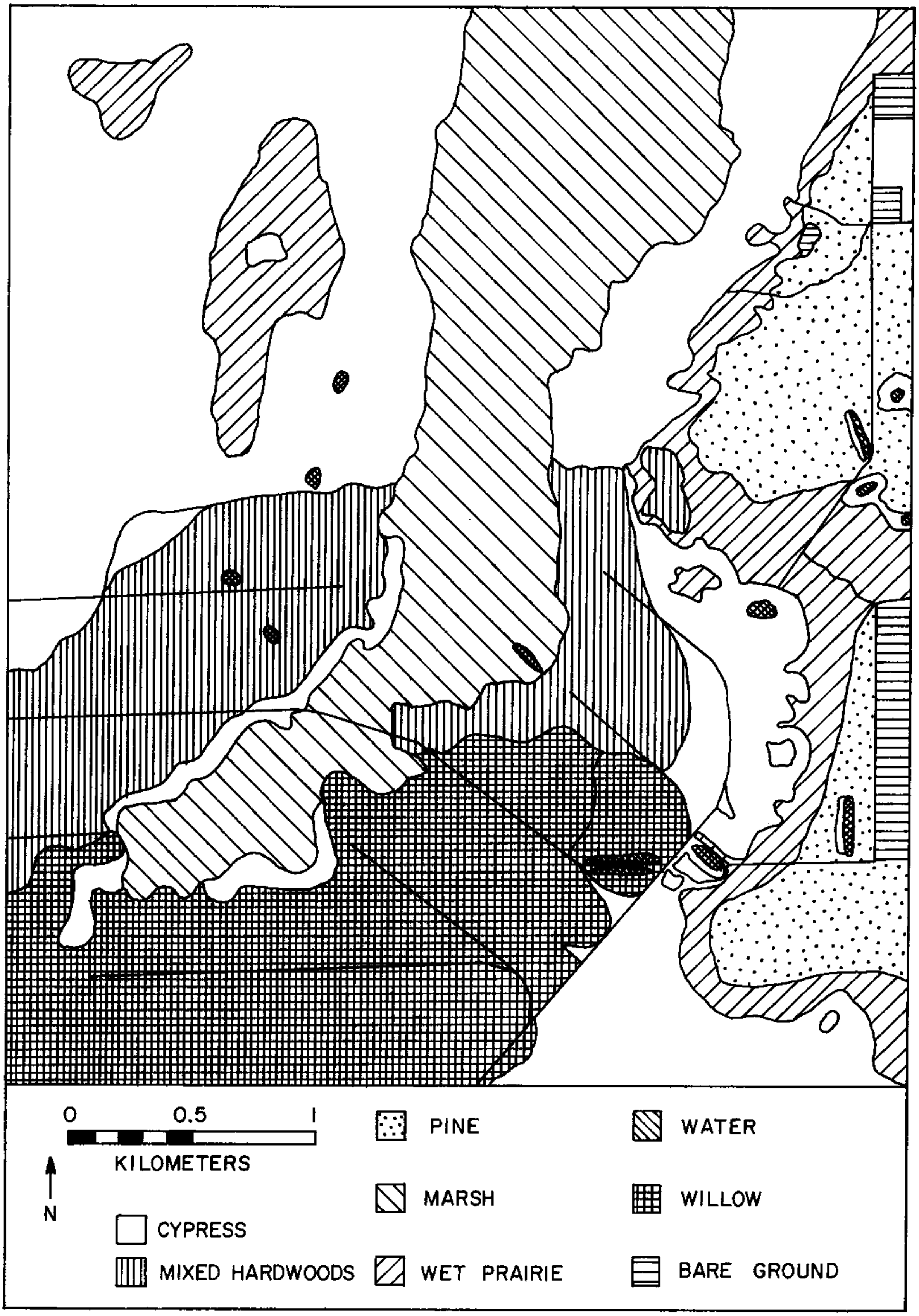
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