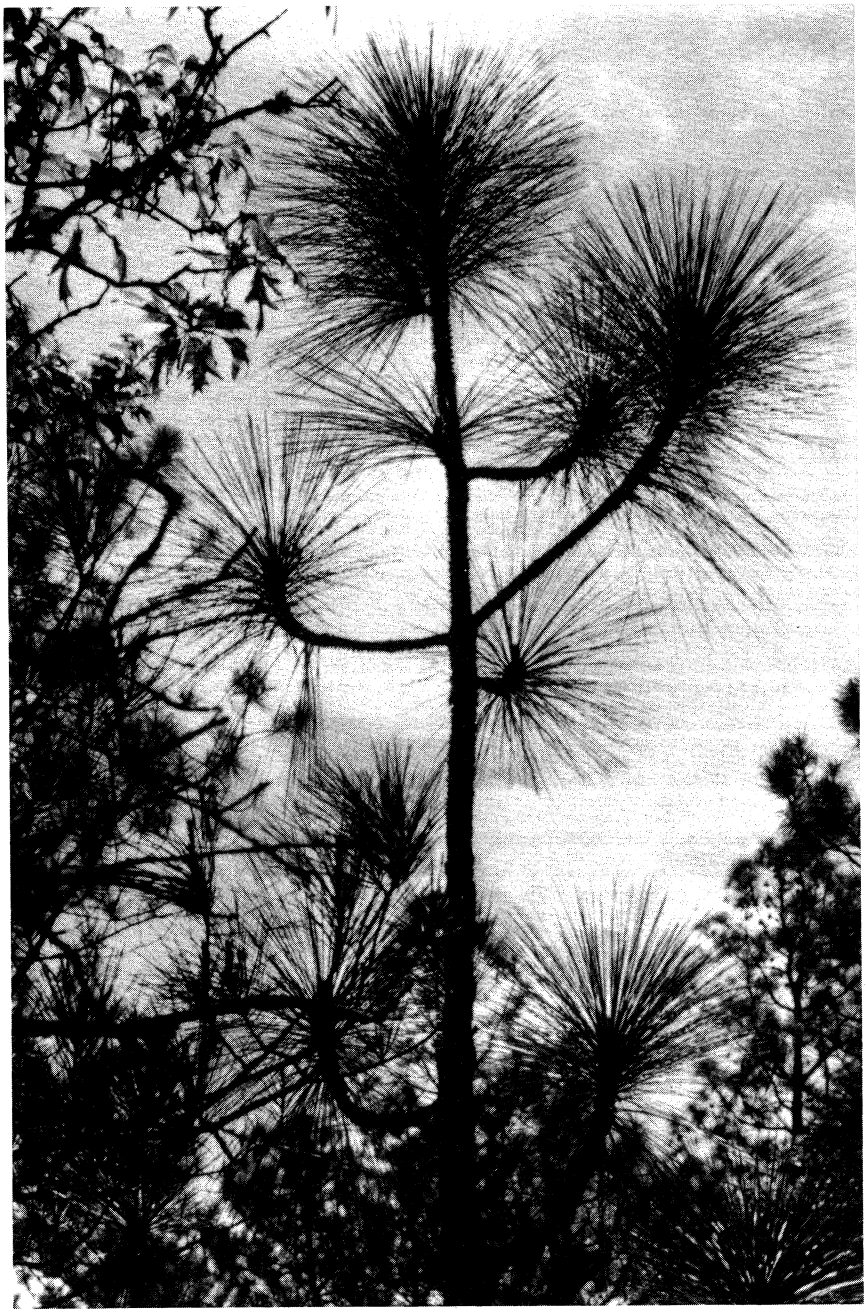

"Longleaf Pine."

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History and Vegetation of the Blackwater Ecologic Preserve

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ABSTRACT

The Blackwater Ecologic Preserve includes the northernmost stand of *Pinus palustris* in the United States as well as several associated species unique in Virginia. The following two relict pyrophytic communities are recognized: *Pinus palustris/Quercus laevis*/mixed ericads on a sand ridge and *Pinus serotina/Pinus serotina-Quercus laevis*/mixed ericads or *Pyxidanthera barbulata* on a moist sand flat. Other communities include a mixed oak-pine slope, a black gum swamp, a river bluff, and an alluvial flat. Vegetation analyses of each community are presented. The history of botanical exploration, presettlement vegetation of the area, and importance of *Pinus palustris* in Virginia are discussed.

INTRODUCTION

On May 11, 1985, a 319-acre tract of land was donated to Old Dominion University by Union Camp Corporation through The Nature Conservancy. Included on this property are some of the most unique plant communities and rarest species in the state of Virginia. In this report, we discuss the vegetation ecology and history of botanical exploration of the area generally known as the Zuni Pine Barrens and now incorporated in the Blackwater Ecologic Preserve. We also describe the general ecology of the preserve and present a catalog of species of vascular plants and bryophytes known from the preserve and vicinity.

MATERIALS AND METHODS

Much of this paper is adapted from a natural area survey conducted during the summer and fall of 1982 (Frost 1982). Community classifications and vegetational surveys were carried out according to the methods in Radford et al (1981). Canopy and subcanopy were analyzed by the quarter point method (Curtis and Cottam 1962). Shrub and herb layers were sampled using the relevé method (Mueller-Dombois and Ellenberg 1974). The data reported are cover and sociability values, e.g., value of 5.2 for a species in a relevé represents a cover value of 5 (greater than 75% cover) and sociability index of 2 (plants growing in clumps). Studies on the flora were initiated ten years ago with specimens deposited at Old Dominion University (ODU) and the University of North Carolina at Chapel Hill (NCU). Botanical nomenclature for vascular plants is that of Harvill et al (1977 and 1981) or Radford et al (1968). Bryophyte nomenclature follows Crum and Anderson (1981) and Conard and Redfearn (1979).

BOTANICAL EXPLORATION

Botanical exploration of southeastern Virginia came remarkably late, considering the long history of settlement in the area. The Zuni Pine Barrens are less than 30 miles south of John Smith's 1607 settlement at Jamestown. Substantial plantations appeared along the south side of the James River within 25 years after original settlement, but the divide between the James and the Blackwater represented a substantial barrier in colonial times when most transportation was by water.

The landing at South Quay, a major trading point a few miles downstream from the preserve, appears on the Comberford map of 1657 (Cumming 1966), along with a road leading from Tidewater Virginia to North Carolina. Assuming that settlement of the area must have preceded road building by a few years, the region near Zuni has been occupied by Europeans for about 330 years. In the three centuries preceding the work of M.L. Fernald in the 1930's, a number of botanists may have collected south of the James, including the Rev. John Clayton, John Bannister, Mark Catesby, John Clayton of Gloucester, John Mitchell, John Bartram, James Greenway, M.A. Curtis, and Frederick Pursh. Through a remarkable series of accidents and lost or unfinished works, little information has filtered down to the present other than a few specimens in herbaria (Berkeley 1977).

Frederick Pursh is perhaps most likely to have explored the natural area, having stayed for a time in 1806 in Southampton County on the other side of the Blackwater River from Isle of Wight. Fernald rediscovered a number of Pursh's species from Virginia, including *Silphium compositum, Leersia lenticularis* and *Lobelia glandulifera* (= *L. elongata*) during the 1936 collecting season. On finding the *Lobelia* in July, he commented, ". . . it is certainly gratifying to feel that in our summer's collecting we had been so closely on the trail of the pioneer botanist, Frederick Pursh, 131 years ago" (Fernald 1937).

Fernald's exploration of southeastern Virginia was exhaustive. It commenced in 1933 and covered 14 field seasons, spanning the years of his life from around age 60 to 73. He published more than 1,200 pages of botanical literature on Virginia, mostly centered on the area south of the James River, from the coast inland to Brunswick County. The last trip to Virginia was in 1946. Harvill et al (1977) commented: "Some of Fernald's most famous plant locales have already been destroyed, and were it not for those fourteen years of persisting and masterful field work we would never have known of many of Virginia's most ecologically and phytogeographically significant habitats, with their many rare and fastidious species."

On a warm July evening in 1936, three botanists and an entomologist had become lost on the last day of a collecting trip in southeastern Virginia. Fernald, Bayard Long, R.J. Smart, and Carroll Williams found themselves unexpectedly at Franklin.

"The obvious way home for most normal individuals was via Courtland, 10 miles away, thence by the very familiar Jerusalem Plank Road; but, having set our faces this last day in another direction, we could not tolerate further anticlimax and defeat. Consequently we chose to drive after dark by a dirt road northward to Zuni, a back road that was destined on our next two trips to

be our most used artery through the country. Near Walters we suddenly realized that we were passing through as beautiful and unspoiled pineland as we had anywhere met. It was dark but, getting out to investigate, we promptly walked into a carpet of the tropical *Crotalaria rotundifolia* [= *C. angulata*], here at its northern limit. Obviously the region must be explored on the next trip." Fernald returned on August 19, this time with his colleague from Cambridge, Ludlow Griscom. Meeting Long and Williams at Richmond the party reached Zuni on the 20th. Since the afternoon was spent botanizing the short distance along SR 614 from Antioch Swamp to the edge of the Zuni Pine Barrens, their progress to the site and its location are well documented.

"Taking the road south from Zuni, we soon came to the dammed up brook in the woods. [This small mill pond in Antioch Swamp on SR 614 is still extant]. Here we tried our luck, getting a few desirable but scarcely notable plants. Along the road here, however, as in open woods near Kilby and near Yorktown, where Long, Fogg and I had collected it a year before, there was a fruiting species of Privet. Its small, membranous, and (when dried) caducous leaves show it to be *Ligustrum sinense* Lour., recorded by Small as an escape in southern Louisiana. Much farther north, in southeastern Virginia, it is making itself quite at home. A little farther on we stopped to investigate the roadside ditches, where *Lipocarpha maculata* and a complex series of species of *Hypericum* abound. Among the latter was *H. dissimulatum* Bicknell, apparently not previously found in Virginia, though next day we found it abundant at the station of *Juncus brachycarpus* near New Bohemia. Long and Griscom wandered across some swales while I followed a wood road, where, mixed with the common *Juncus repens* in a pocket of *Sphagnum, Proserpinaca pectinata* abounded. We have met it nowhere else in eastern Virginia nor is it represented in the Gray Herbarium from the state; it was, however, collected in Virginia by Clayton, his material, according to Asa Gray's memorandum, being a mixture of *P. palustris* and *P. pectinata.* Kearney also reported it from Northwest in Norfolk County. The party of two brought in a series of *Xyris, X. difformis* and *X. ambigua,* and a few plants of the new one which Long and I had got in July near New Bohemia. We all went back for more and during the quest found *Desmodium tenuifolium* T. & G., which has not been recorded from north of North Carolina.

"Moving on to the south we came to extensive white sands in the open, suggestive in their small way of the dunes of the outer coast, in Princess Anne County, toward 50 miles away. [This would be the sandy area along SR 614, just south of the low place where Horse Swamp crosses the road]. And here, in the interior, *Panicum Commonsianum* and *Cyperus filiculmis,* var. *oblitus* Fern. & Grisc. of Cape Henry and, new to us, the southern *Aristida virgata.* Searching the dry woods for novelties and collecting variations of *Panicum lancearium* and *Paspalum setaceum* which were here very abundant, and the first ordinary northern (even Hudsonian) Sheep Laurel, *Kalmia angustifolia,* we had ever seen on the Coastal Plain of Virginia, we were soon rewarded by great clumps with lilac pink heads suggesting those of *Liatris* but in broad corymbs, the stems of the plants cespitose and without bulbous bases. This was surely something novel for us, our first representatives in the manual range of

the southern genus *Carphephorus,* in this case *C. bellidifolius* (Michx.) T. & G." (Fernald 1937).

The party returned to the area on August 22. Previous collecting had taken place only along the road, but the barrens are about a mile wide at this point, extending from the road, west to the Blackwater River. Following directions from a local farmer, Fernald left the main road, entering this tract to discover the heart of the Zuni Pine Barrens, now the Blackwater Ecologic Preserve.

"At the next farm the description of the country was confirmed and, following the cart-road to which we were directed, we entered one of the botanical paradises of the summer, and confirmed an often forgotten axiom: 'it pays to ask the native.'

"The thin woods of *Pinus taeda* and *Quercus laevis* Walt. (*Q. catesbaei* Michx.) were carpeted with white sand, with a dense thicket of the usual shrubs of sandy woods, but wherever there was an opening exciting herbs were growing. *Carphephorus bellidifolius* abounded and on the more open sands *Euphorbia Ipecachuanhae* occurred. . . . I was happy to collect these plants, which seemed interesting to me; but, while I was thus wasting time, Long shouted 'Here's Pyxie' and Griscom replied 'Here's another *Liatris*-like thing; and, before I could reach either of them, there came the report: '*Seymeria cassioides* again.' And so it went. We had stumbled into what we had sought for four years, real unspoiled pine barren in Virginia. *Pyxidanthera barbulata* literally carpeted the ground in many areas, at the first station discovered between southern New Jersey and North Carolina; *Carphephorus tomentosus* (Michx.) T. & G. was a second species of a genus, which, two days before, had been 'new to Virginia,' *C. tomentosus* not represented in the Gray Herbarium from North of Bladen County in southwestern North Carolina; *Seymeria cassioides* already found with *Schwalbea americana* in Greensville County, was here very abundant; its recorded northern limits otherwise in eastern and southeastern North Carolina. The wonderful cespitose *Xyris* of white sands, true *X. flexuosa* [= *X. caroliniana*], as shown by Harper, the plant with large spiraling castaneous bulbs, stiff and slender spiralling leaves and large acutish spikes of showy flowers (*X. arenicola* Small) soon appeared, again at its first station between New Jersey and North Carolina. In sphagnous depressions and thickets *Zigadenus glaberrimus* and *Sarracenia purpurea* var. *venosa* were both scattered, *Panicum Clutei* [= *P. dichotomum*] was frequent and *Habenaria blephariglottis,* var. *conspicua* was just flowering.

"Where the cart-road leads through an extensive sphagnous depression (undoubtedly one of the pondholes of early spring) two plants specially pleased us: *Rhynchospora distans* (Michx.) Vahl [= *R. fascicularis*], heretofore recorded only from the West Indies and Florida to South Carolina; and *Juncus abortivus* Chapm. a beautiful tall relative of the northern *J. pelocarpus* with coarse rhizomes (*J. pelocarpus* var. *crassicaudex* Engelm.), primarily of Florida but known, very rarely indeed, northward to a single station in Darlington County, South Carolina (Coker, Plant Life of Hartsville, S.C., p. 28). Long epitomized the situation as we were all conceiving it: 'This is real botanizing!' Thirst, hunger and heat had been forgotten, though toward 3 o'clock we returned to the car, but, still wanting more, the insatiable hunter of rarities

poked into one of the open bare white patches and brought us a collection of *Arenaria caroliniana* the first from between New Jersey and southeastern North Carolina." (Fernald 1937).

So ended a sterling day of collecting in the Zuni Pine Barrens. The botanists were rewarded with nine state record plants from this specific location, seven of them in one day. In all, Fernald recorded dozens of rare species from the natural area and the immediate surrounding area from Zuni to Walters. At least one more state record was to be obtained from the site. Here is Fernald's account (Fernald 1937) of the discovery of *Polygonella polygama* (October-flower) upon his return with Long and Williams on October 16, 1936: "... we found *Zigadenus glaberrimus* more widely dispersed than we had supposed, and with it *Sarracenia flava,* which we had not seen in August. *Carphephorus tomentosus,* too, proved to be fairly abundant; and just at dusk, when we could hardly see, I came upon a single plant which puzzled me. Obviously of the *Polygonaceae,* it looked like *Polygonella,* but not any known in the 'manual range.' I had found one plant, and Long, for obvious reasons, wanting another, we sought in the increasing darkness on hands and knees, repeatingly returning, as a check, to the site of the original plant. Finally, with Long's jocose reproof, 'You've destroyed the locality,' following me, I gave up and went as far as darkness would permit in search of something different. Returning after half-an-hour, I heard Long's gleeful shout: 'I've put up 17 sheets so far.' There, fully occupying one of the open plats of sand, and apparently only one, was a solid carpet of *Polygonella.* It proved to be *P. polygama* (Vent.) Engelm. & Gray, and this is the first station for it north of southeastern North Carolina (the Wilmington region). Again our great find was at twilight!"

PHYSIOGRAPHY

The Zuni Pine Barrens are located on the western boundary of Isle of Wight County, Virginia, about 4.5 miles south of the town of Zuni (Figure 1). The preserve is primarily situated on a remnant estuarine terrace, carved by wave action during the height of the Sangamon interglacial sea. This terrace is contained within the Blackwater River valley, which is located near the center of the Isle of Wight Plain. This plain is largely underlain by the Windsor Formation, the highest and oldest element of the Lower Coastal Plain. This landscape, in turn, is an element of the Coastal Plain Province of the Atlantic Plain, which is divided into Coastal Plain and Continental Shelf (Oaks and Dubar 1974). The specific origin of local features is discussed further under Geomorphology.

CLIMATE

Within the relatively flat-lying topography of the Zuni Pine Barrens, there is little variation from the local climate, with the exception of an area covered by Community Type E, (CT-E, Figure 2) along the Blackwater River. Here the low, but steep (up to 40°), west-facing river bluffs are partly sheltered and may receive some moderating influence from the river. An interesting population of *Calycanthus floridus* (spicebush) occurs here in a tiny ravine, where cold air drainage creates a microhabitat cooler and moister than that of the surrounding area. Southeastern Virginia is recognized as the northern extreme of typical southern Coastal Plain vegetation (Frost et al 1986, Ware et al

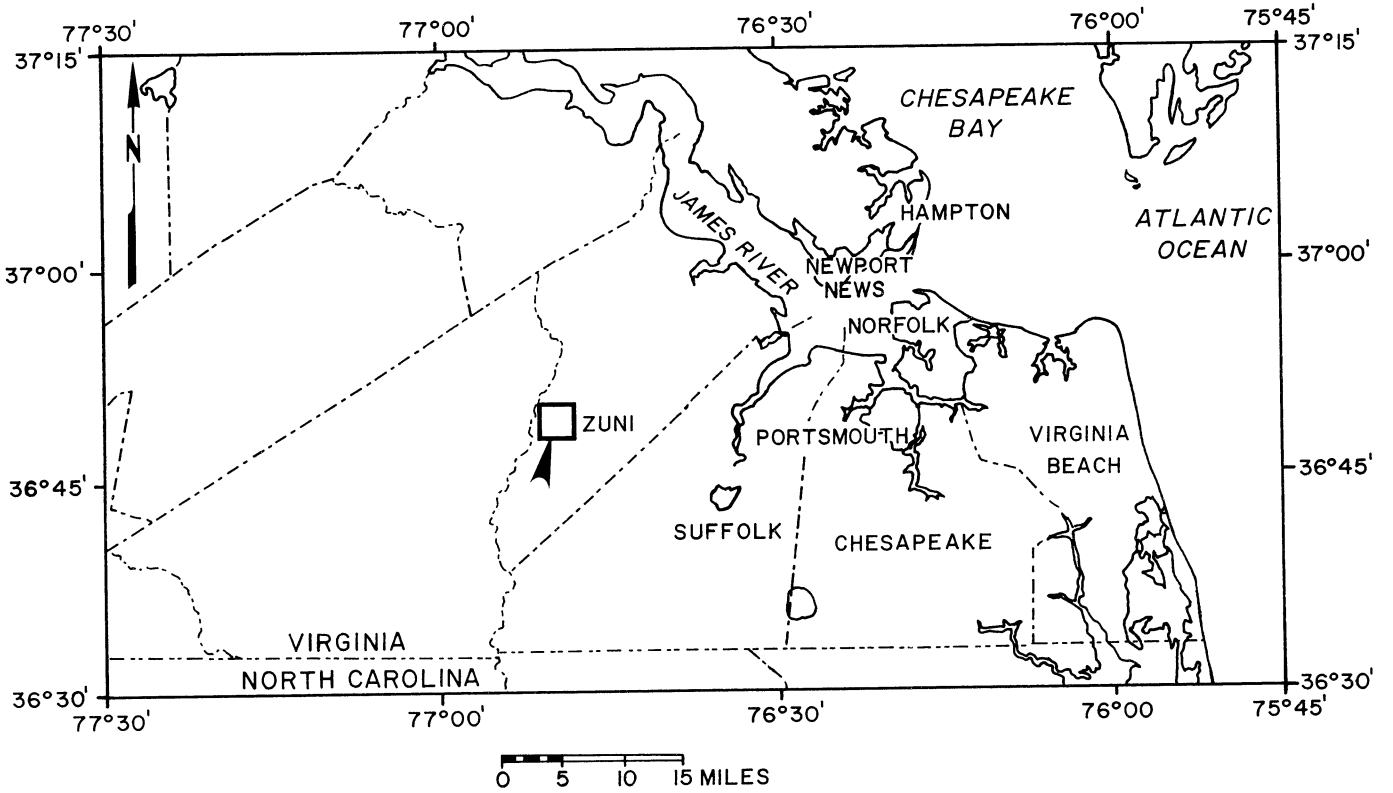

Figure 1. Location of the Blackwater Ecologic Preserve.

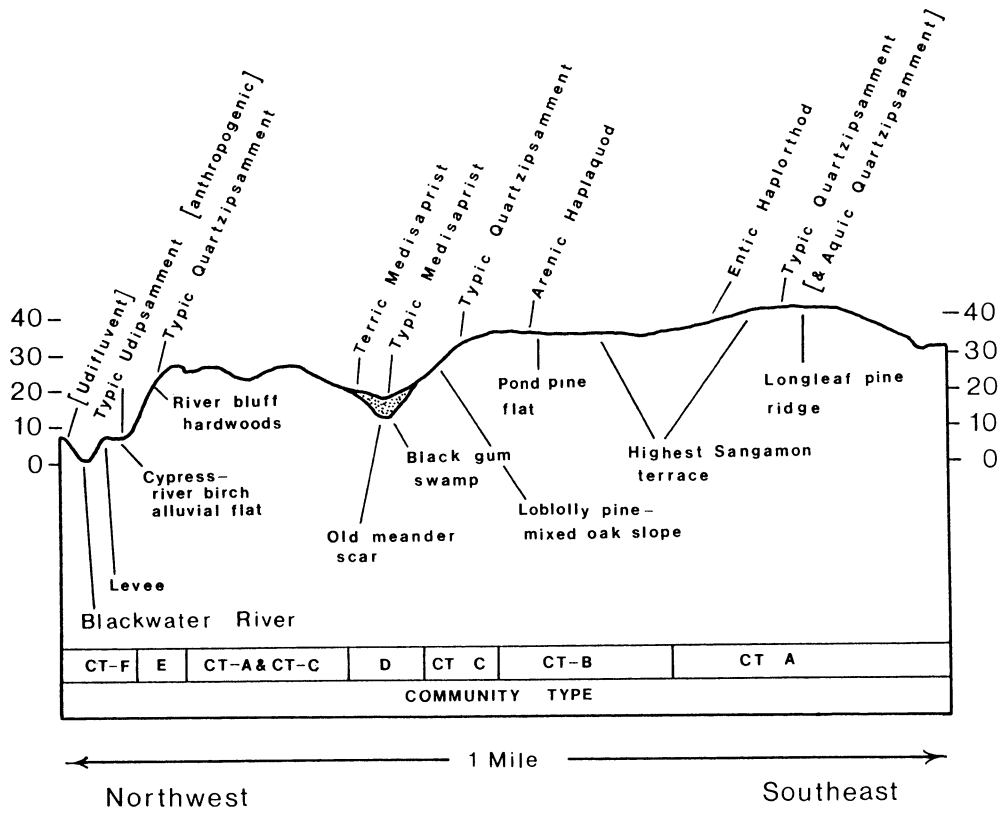

Figure 2. Plant communities and soil types of the Blackwater Ecologic Preserve. Elevation in feet MSL, vertical exaggeration 35x.

in press). A number of Coastal Plain plant species reach their northern limit at this site. The James River and a line passing just west of Zuni were used to delimit the northern edge of Quarterman and Keever's Southern Mixed Hardwood Forest (Quarterman and Keever 1962) and Braun's Southeastern Evergreen Forest (Braun 1950).

Since typical soils derived from Coastal Plain sediments continue to the north, climatic factors are probably responsible for control of this vegetation boundary. Several monthly temperature and precipitation patterns, as well as isopleths of ice storm frequency, follow the perimeter of Coastal Plain vegetation types. One in particular, the 32° isotherm for average minimum daily January temperature (Nelson and Zillgitt 1969), closely parallels the northern limits of southern vegetation, suggesting that intolerance of freezing temperatures is the most important variable separating the southeastern Coastal Plain formation from those of the north and west. A soil core at about 6 m elevation near the upper edge of the river bluff in Community Type E (CT-E) encountered a layer of stiff, impermeable clay overlain by sand. While the surficial sands largely date to the Sangamon interglacial, this clay, obviously a different geological formation, may be a member of one of the Pleistocene, Pliocene or Miocene deposits from which the Blackwater River valley was carved. It is unknown to what extent this impervious substrate underlies the natural area. Several attempts were made to see if such a formation underlay Community Type B (CT-B), but the high water table prevented coring deeper than 1.5 meters.

Ground water chemistry was sampled from water taken from a small pit in CT-B. The following values were obtained:

Conductivity: 56 micromhos/cm
pH: 4.5
Cl^-: 7.6 mg/L (as Cl^-)
Color: clear, light orange
Turbidity: 5 JTU

SOILS

The soils of Isle of Wight County had not been mapped with modern methods at the time of preparation of this report. Within the natural area, the 1941 soil map (Shulkcum et al 1941) depicts only three soils. The series of largest extent is mapped Norfolk fine sand. There is an outcrop of Plummer fine sandy loam, corresponding to Community Type A (CT-A)—the longleaf pine ridge. Wet soils are simply designated "swamp." Following is a tentative classification using current soil taxonomy. (See Figure 2.)

The longleaf pine sand ridge Community Type A (CT-A), was underlain by a sandy, thermic, Typic Quartzipsamment, verging on Aquic Quartzipsamment because of a high water table. The water table was encountered at a depth of about one meter in August, after a rainy period, and it is presumed that it would not remain at this height for the 60 days required for aquic designation at this specific point. However, topographic variation within the community type, and around its periphery, probably create a few small pedons which could be classified Aquic Quartzipsamments. An Entic Haplorthod was found on top of a shoulder slope on the northeastern periphery of the longleaf

pine ridge, adjacent to Horse Swamp. The dominant understory vegetation was mixed ericads, but species such as *Arundinaria gigantea* indicated a more mesic situation. The spodic horizon of this soil may have formed in the past under a more frequent fire regime.

The most puzzling community, the pond pine flat, Community Type B (CT-B), was found to lie over an Arenic Haplaquod. Despite its xeric appearance, the site has a high water table, and the spodic horizon was only 80 cm below the surface. Bordering this flat, on the upper shoulder of a slope supporting Community Type C (CT-C), a dryer, Typic Quartzipsamment was found. No spodic horizon was encountered and the water table was reached at 90 cm. The black gum swamp, Community Type D (CT-D) at the foot of this slope developed on a Typic Medisaprist. This soil was saturated and hummocky, with the water table at or above the surface. The subsurface was thickly interlaced with large roots and, possibly buried tree trunks which, along with standing water, made a deep core impossible with a standard auger.

Another Typic Quartzipsamment was found on the upper slope of the river bluff Community Type E (CT-E). This was the core, under hardwoods and *Galax,* where a subsurface clay was found which probably corresponds to the Pliocene or late Miocene Yorktown Formation.

At the base of this slope is a small alluvial flat, community Type F (CT-F), often inundated by high water, which appears to have formed partly by natural fluvial processes, and in part from disturbance. There is a natural levee adjacent to the river, but behind this feature is a Typic Udipsamment, where a Fluvent should ordinarily be expected. There is a thin epipedon of fluvial silt, but this overlies a thick bed of sand, lacking the irregular vertical distribution of organic matter and particle size typical of low bottoms. A layer of sand several cm thick was deposited after a hurricane-induced flood in 1985.

It was subsequently noticed that an old ditch, draining the sandy uplands, had its outfall through the river bluff onto this flat, and there was the visible shape of a sandy alluvial fan originating from this source. This process appears to have stopped at some time in the past since the ditch and adjacent uplands are now vegetated, and the sands have been buried under 22 cm of fluvial fine silt.

REGIONAL GEOLOGY

The area just to the north and east of Zuni has been the subject of some of the most intensive geological studies to date on the Atlantic Coastal Plain (Oaks and Coch 1963, Oaks and DuBar 1974). While only a small portion of the Blackwater River drainage was mapped, the geology of the preserve can be extrapolated from these studies and other sources.

By contrast, little geologic work has been done on the Middle and Upper Coastal Plain of southern Virginia. These formations, with exception of a few known patches of Cretaceous age, are designated simply "Tertiary undivided" on the general geologic map of Virginia (Calver and Hobbs 1963). Oaks and DuBar (1974) mention that ". . . the Fall Line shown on almost all geologic maps actually indicates the contact between Cretaceous and Paleogene sediments of the coastal plain and crystalline rocks of the piedmont. It ap-

parently does *not* mark the original western extent of post-Miocene coastal plain sediments." The likelihood of coastal sediments far to the west of the present Fall Zone has been demonstrated in North Carolina by Daniels et al (1966, 1971, 1971b, 1972, 1978) and Parker (1979), who found remnants, including limestone, at elevations of over 500 feet, at some distance west of the Fall Line indicated on the geologic map of the state.

The lowest coastal plain sediments known from the region are Cretaceous deposits over the southeastward-sloping Precambrian basement. The Cretaceous is overlain by a marine Eocene formation, the upper surface of which occurs at about −21 m mean sea level (MSL) in the vicinity of the natural area (local well data, Virginia Division of Water Resources 1970). This is overlain unconformably by the Yorktown Formation. The Yorktown-Eocene contact is much lower in northern Isle of Wight County (−55 m) and near the Isle of Wight-Nansemond County (now City of Suffolk) line (−52 m), suggesting a terrestrial landscape of considerable relief carved from Eocene sediments during the Oligocene—probably the longest erosional period in the Tertiary.

Post-Miocene geology of the Lower and part of the Middle Coastal Plain of southeastern Virginia, south of the James River, has been mapped in detail. The Blackwater River valley is shown as undivided late Pliocene or late Miocene Yorktown and Pliocene Sedley Formations. These are overlain by the mid-Pleistocene Windsor Formation.

NATURAL AREA GEOLOGY

Within the Blackwater valley, the Cretaceous and Eocene are deeply buried beneath marine clays of the Yorktown Formation, which is at least 21 m thick at this point. The Windsor has been removed by late Pleistocene erosion, along with most or all of the Sedley. The base of the Sedley Formation would be around 12 m MSL in this vicinity. Maximum elevation in the natural area, however, is little more than 12 m, and this ridge (CT-A) is underlain by a meter or more of late Pleistocene sand. Therefore, the young surficial sands mantling the site are probably unconformably underlain throughout by the Yorktown. This is likely represented by the partially consolidated clayey silt contacted at the base of a soil core bored at about 4.5 m MSL on the face of the river bluff (CT-E). During times of low water beds of large scallops and other fossils typical of the Yorktown Formation are exposed in the bluff south of CT-F.

With the above exception, no formation older than Sangamon is exposed within the natural area. The largest surficial deposit is a fine sand, ranging in elevation from about 10.6 to 12.5 m under CT-A and CT-B, which probably is a fluvial/estuarine counterpart of the Norfolk Formation, deposited during the 15 m stillstand of the Sangamon sea. Two lower terraces at about 8 and 4.5 m respectively, may correspond to the time of deposition of the Kempsville, London Bridge or Sand Bridge Formations, resulting from post-Norfolk stillstands of the sea. The swamps (CT-D) are underlain by Holocene and recent peats, and the river bottom contains recent alluvium.

GEOMORPHOLOGY

While the terrestrial landscape which formed during the Oligocene developed at least 30 m of relief in the area, there is nothing to suggest that the

resulting irregular surface had any effect on later sea bottom topography after it was filled and buried under deep Yorktown sediments. There would have been further opportunity for filling and smoothing any topographic lows during deposition of the late Pliocene Sedley and Pleistocene Windsor Formations. The Blackwater River valley, even though carved to a depth of 30 m, may be entirely Pleistocene in origin, although its formation could have been patterned on an incompletely filled erosion remnant from a previous emergence. Other possibilities include some landscape formation during an erosion interval 5.2 million years ago at the Miocene-Pliocene boundary. If so, this event could have initiated formation of a drainage pattern precursor to the present valley. There were, however, three more periods of deposition related to marine transgressions in the regions, corresponding to the Pliocene or early Pleistocene Bacon's Castle Formation, the early or middle Pleistocene lower Windsor Formation, and the middle Pleistocene upper Windsor. Each of these were probably interrupted by relatively brief erosional periods which may have made a contribution of unknown extent to present relief.

There is little evidence to indicate presence of the modern drainage pattern before the Windsor. The Blackwater flows from north or south through the preserve. A few miles upstream, it turns abruptly to the west, suggesting that the late Windsor stillstand of sea may have truncated a previous east-west drainage pattern, and implying, in turn, that the present course of the river below that point is mid or post-Windsor.

Within the river valley there are terrace remnants at about 21 m elevation which might have been carved at the time of the late Windsor stillstand at about +24 m. If so, this would imply that at least a shallow drainage pattern had developed during the mid-Windsor emergence or before. At any rate, much of the present valley depth and width may have been carved during the late Windsor (Aftonian Interglacial?), the Illinoian glacial period and the early Sangamon.

The extensive sands and flat terraces within the river valley suggest widening of a pre-existing valley during the Sangamon. Oaks and Coch (1963) showed that sea level in the area reached a relative maximum elevation of about 15 m above present sea level at the height of the Sangamon. This high stand of the sea inundated the land to the east of the Suffolk Scarp and may have caused formation of the Hazleton Scarp by wave action in a shallow estuary. This scarp has a toe elevation of about 15 m MSL. The Blackwater River valley is bounded on either side by an abrupt scarp, carved into the Isle of Wight Plain, with toe elevation of 15 m, which can be traced downstream and may correspond to the Hazleton scarp in age and manner of formation. The extent of Sangamon impounding of the Blackwater valley can easily be seen on a map of generalized topography (Oaks and Dubar 1974).

Presumably, there was considerable widening of the river valley at this time because of stream channel migration and wave action around the edges of this brackish estuary. Similar, ongoing processes can be seen today in some of the lower tributaries of the James River. The sands of the uppermost terrace (CT-A, Longleaf Pine) in the Zuni Pine Barrens correspond in elevation with

the Norfolk Formation at the toe of the Hazleton Scarp and probably constitute a fluvial/estuarine counterpart.

This would place the age of the oldest deposit within the natural area at around 70,000 years ago, at the height of the Sangamon. CT-B, on the slightly lower terrace, is only about 1.5 m lower in elevation. This and most of the rest of the natural area appear to have been shaped from sandy estuarine deposits by fluvial meandering as the Sangamon sea receded.

Oaks et al (1974) document several stages which represent oscillations and stillstands of the sea toward the close of the Sangamon. There are several terraces within the natural area and the river valley which may correspond to certain of these. There are, in addition, a number of sand ridges which probably represent estuarine sands reworked by the river, separating old meander scars.

There appears to have been little additional landscape formation after the Sangamon. During the Wisconsin glacial period sea level fell to around 106 m below the present (Vail and Hardenbol 1979). There is no evidence within the valley to suggest the Wisconsin as a major period of erosion but the Blackwater River may have become entrenched in a deeper channel, and the ravines in the steep walls of the escarpment on either side may have been carved during this time. The past 15,000 years have seen the sea level rise to its current height.

ORIGINAL EXTENT AND FATE OF LONGLEAF PINE IN VIRGINIA

The original northern limits of the range of longleaf pine (*Pinus palustris*) are unknown. It often has been stated that the species occurred only as far north as southeastern Virginia, below the James River. The accepted botanical range is shown in Little (1971) extending as far north as Isle of Wight County. There is some evidence, however, that longleaf pine was found north of the James, perhaps as far as southern Maryland (Frost unpublished). The species is especially vulnerable to several types of human activity, and its apparent absence is probably a result of the lack of botanical work or other records from the early colonial period.

The disappearance of longleaf pine from Virginia can be summarized as the consequence of the cumulative effects following activities over three and a half centuries of European civilization (Frost unpublished):

1. Introduction of feral hogs. Starting from the time of Smith's arrival in 1607, until they reached a saturation population in the woods some time prior to 1800, hogs consumed pine mast and, more importantly, the "grass stage" seedlings, thereby eliminating reproduction.

2. Small-scale removal of mature trees for lumber, all through the colonial period.

3. Destruction of mature trees by boxing for turpentine, beginning in the mid-eighteenth century and continuing, with increasing intensity, until exhaustion of the pine orchards of the state in the 1840's (Because of its high resin content, longleaf was the only species of pine regularly used for naval stores).

4. Removal of most of the remaining trees for sawtimber in the mid-nineteenth century.

5. Elimination of habitat, as a consequence of modern fire suppression, beginning in the first three decades of the twentieth century.

6. Removal of the stands established in the brief period between the end of open range in the late 1800's, and establishment of efficient fire suppression around 1920. The last such stand in the state was cut in Nansemond County (now city of Suffolk) around 1979.

Perhaps because it was overshadowed by production of tobacco and other products; perhaps because the industry ran its course here before extensive records were kept, the extent of naval stores production (tar, pitch, turpentine and rosin) in Virginia is not generally appreciated. Enough glimpses of the past can be gleaned, though widely scattered through the historical literature, to understand the utilization and eventual near extirpation of the species from the state.

John Smith's settlement in Virginia was largely intended as a commercial venture, and experimental ". . . tryalls of Pitch, Tarre. . . ." etc. were made the first season, with the first export of several dozen barrels shipped to England in 1608 (Smith 1624). Production of these essential commodities primarily by burning tar kilns of collected, dead longleaf pine "lightwood," was carried out, on a small scale, virtually from this time until around 1850. Customs records still on file in the British Public Records Office from ports around the Chesapeake Bay (Norfolk, Hampton, Yorktown) list barrels of naval stores as one of the most common exports from the colony from the late 1600's until the Revolution.

In a report to the Lords of Trade, William Gooch, Governor of Virginia from 1727 to 1749, listed an annual export of 10,000 barrels of pitch and tar. The scale of the industry in the region before the Revolution may perhaps be illustrated by an article in the Virginia Gazette (1771) offering property for sale on the Nansemond River:

> ". . . Also a Lot of LAND near the River, with about three Acres of Marsh, through which a Creek is cut to the River, and a Causeway on the side of the Creek, with a good Wharf to the best Water; a Pitch Kettle on the said Lot, set very conveniently, and a Tar House that will contain two Thousand Barrels of Naval Stores."

This facility, located only about 15 miles east of the Zuni Pine Barrens, may have been a receiving and shipping point for Nansemond as well as Isle of Wight and other neighboring counties.

Sometime before the Revolution, the process of boxing live trees for turpentine became widespread, and Michaux (1871) reported that spirits of turpentine were distilled from the crude resin in copper retorts during the first decade of the nineteenth century. The more efficient copper still was introduced into the woods around 1834.

The very sketchy census of 1820 listed two distilleries in southeastern Virginia producing about 300 barrels of spirits of turpentine annually. The census of 1840, which was the first in the history of the country to collect detailed statistics of industry, reported a startling 934 barrels of tar, pitch, turpentine and rosin produced in Isle of Wight County (Table 1). An annual production of this magnitude must have represented a heavy drain on the longleaf pine re-

sources of the county. While longleaf pine probably occurred on a variety of upland situations, the several sandy areas along the Blackwater River were prime sites and some of this production may well have come from the Zuni Pine Barrens. Since there were no records kept in the county before the above dates, it is impossible to tell how long and on what scale the industry had been carried on.

Table 1. Production of naval stores in southeastern Virginia. From compendium of the sixth census 1840

County	Barrels of Tar, Pitch Turpentine, Rosin
Isle of Wight	934
Nansemond	2,253
Southampton	1,238
Surrey	40
Sussex	547

As documented by later censuses, introduction of the copper still initiated a wave of intensive naval stores production which spread southward from Virginia into the Carolinas and beyond. The boom lasted some 80 years, moving southward decade by decade as more northerly forests were exhausted.

Failure of later censuses to list naval stores products from Virginia suggests that the period 1840 to 1850 saw the major destruction of longleaf pine in Isle of Wight and the region. W. W. Ashe (1894), surveying the pine barrens of the Gates County, North Carolina "Sand Banks," noted that they continued northward into Virginia along the Blackwater River, and that essentially all the original stands of longleaf had been removed around the middle of the century.

Ashe further commented that an observer in 1890 would not have been able to conceive the original extent of longleaf pine in the region but for remnant trees and the tar kilns which dotted the landscape for miles around. These low, bowl-shaped depressions, 20 or 30 feet in diameter, were used to burn pine lightwood for collection of tar. A few can still be found today in the rare patch of woods that has not been plowed at some time for agriculture or given silvicultural site preparation by heavy equipment.

The last few large trees in the Zuni Pine Barrens were removed only recently. The stump of one specimen had 171 annual rings, placing its date of establishment at around 1809, the time of Pursh's exploration of the area. A few persistent old stumps show scars of turpentine boxing perhaps dating to the nineteenth century. Along the Blackwater, south of the natural area, virtually all the sandy areas have been converted to pine plantation, primarily loblolly (*Pinus taeda*). Within the natural area, longleaf pine is represented by an even-aged stand near SR 614 and what appears to be scattered natural reproduction in the barrens (CT-B), with some individuals reaching reproductive size. Forty-three years ago Zuni still had some surviving old-growth trees and, apparently, considerable natural reproduction. This might be expected, since open

range grazing by semi-feral hogs had ended around 50 years earlier, and fire suppression had only been initiated in the preceding 15 to 20 years.

The presence and condition of longleaf in the Zuni Pine Barrens was not initially reported by Fernald, who made few notes on canopy species, since the trees of the region were well known and he was interested in discovering new species. The irrepressible Fernald ruefully described how this shortcoming was called to his attention on New Year's Day, 1939 (Fernald 1939).

"After the scientific meetings at Richmond, where, in conversation, doubt was raised by Dr. Roland Harper as to the exact status of *Pinus palustris* (Long-leaf Pine) in Virginia, Long and I induced Mr. and Mrs. Donovan S. Correll to drive with us to Harper's supposed station (seen from a train). December 31st was spent in wading in ice-water, for fruit of the various gentians of the bogs and flat pine-lands. On New Year's Day, Long and I started to exhibit some of our choice habitats. Slowing down at our old parking-spot in the pine barrens south of Zuni, we were startled and grieved to hear Mrs. Correll announce: 'Why there's Long-leaf Pine right there!' And there it was! Intent on *Carphephorus, Polygonella polygama, Pyxidanthera, Juncus abortivus* and the other pine-barren herbs and low shrubs new to Virginia, we had half-a-dozen times brushed by the great columnar young pines without their 'registering.' Not only young columns were there; plenty of old fruiting trees occur. We have not yet got over our chagrin, for we promptly remembered Long-leaf Pine south of Cleopus in Nansemond County; we later collected it from specimens we had several times jostled in passing, south of Franklin in Southampton County; and in western Nansemond (near the Blackwater) we now have an area where it and *Chamaecyparis* are rapidly coming back after intensive cutting. Long and I can't jeer each other by mentioning Long-leaf Pine; that score is even! The mention of it simply makes us sad and humble."

PLANT COMMUNITY TYPES OF THE BLACKWATER ECOLOGIC PRESERVE (Figure 2)

COMMUNITY TYPE A

PINUS PALUSTRIS/QUERCUS LAEVIS/MIXED ERICADS (LONGLEAF PINE RIDGE)

This community is found over dry to mesic sands on a flat, to slightly convex surface, here called a "ridge" because it occupies the highest landform in the natural area. The canopy is composed of an even-aged stand of longleaf and pond pine (*Pinus serotina*) which probably dates to a clearcut 25 to 30 years ago. The longleaf pine may have been planted. The high percentage of pond pine is likely the result of an accessible water table, which varies throughout the site from 70 to 100 cm in depth, and fire suppression.

The subcanopy is composed almost entirely of turkey oak (*Quercus laevis*) and pond pine transgressives; this over a dense shrub layer about knee high, consisting of seven species of ericads. These occur in an interesting mosaic, within which there are a few small openings of a few square meters in size, with carpets of *Cladonia* lichens and teaberry (*Gaultheria procumbens*).

The lack of open habitat makes herbs extremely rare, *Carphephorus bellidifolius* and *Heterotheca nervosa,* both losing the competition for space to

Table 2. *Canopy Analysis* **CT-A**

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Pinus palustris	157 (52%)	58.3	53	45.5
Pinus serotina	106 (35%)	33.3	36	36.4
Pinus virginiana	20 (7%)	4.2	7	9.1
Pinus taeda	17 (6%)	4.2	4	9.1

Number of quarter points: 6. Average distance: 6.7m. Number of individuals/ha 223.
CANOPY SPECIES PRESENT, BUT NOT IN ANALYSIS: None.

Table 3. *Shrub Analysis* — **CT-A**

Species	COVER									
	1	2	3	4	5	6	7	8	9	10
Shrubs:										
Gaylussacia baccata			3.2	4.3	5.3	5.4	3.2			
Gaylussacia frondosa	5.5	5.5		1.1	3.3	2.2	2.2	5.4	3.3	2.2
Kalmia angustifolia	2.2		+.2	5.3	2.2		5.4		5.3	5.4
Vaccinium corymbosum										+.2
Vaccinium tenellum	+.1							1.2	2.2	1.1
Gaylussacia dumosa	2.2	+.1	+.1	1.2	+.1					
Gaultheria procumbens			2.1				+.1			
								+.1	1.1	1.1
Tree seedlings:										
Nyssa sylvatica							+.1			
Vines:										
Smilax glauca	3.1					1.1	1.1			

Number of relevés: 10 Relevé Size: 1m x 1m

ericads, being the only species found in the study plot. Understandably, there was no reproduction of longleaf pine, since canopy, subcanopy and shrub layers all were closed.

COMMUNITY TYPE B

PINUS SEROTINA/PINUS SEROTINA-QUERCUS LAEVIS/MIXED ERICADS or *PYXIDANTHERA BARBULATA-POLYTRICHUM* spp. (POND PINE FLAT)

Because of the open canopy, small stature of vegetation, and exposed patches of sand, this site most deserves the designation "barrens" at present. The plant community is developed on a flat terrace underlain by moist white sand with a fluctuating water table. Despite the open texture of the soil, the water table took 1½ months to fall from the surface to a depth of 57 cm after a few heavy rains in August, suggesting perching, perhaps by the underlying fine-textured Yorktown Formation.

The canopy (Table 4) is an open, uneven-aged stand of pond pine, up to 12

Table 4. *Canopy Analysis* — **CT-B**

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Pinus serotina	238.8 (79.6%)	83.3	84.1	71.4
Pinus taeda	37.2 (12.4%)	12.5	10.4	14.3
Quercus laevis	24.0 (8.0%)	4.2	5.5	14.3

Number of quarter points: 6. Average distance: 10.7 m.
Number of individuals/ha: 87.
CANOPY SPECIES PRESENT BUT NOT IN ANALYSIS: *Pinus palustris.*

Table 5. *Subcanopy Analysis* — **CT-B**

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Pinus serotina	171.1 (57%)	68.8	57.9	44.4
Quercus laevis	85.4 (28.5%)	18.8	33.3	33.3
Oxydendrum arboreum	24.3 (8.1%)	6.2	7.0	11.1
Pinus palustris	19.0 (6.3%)	6.2	1.7	11.1

Number of quarter points: 4. Average distance: 7.0 m.
Number of individuals/ha: 204.
SUBCANOPY SPECIES PRESENT, BUT NOT IN ANALYSIS: *Pinus taeda, Acer rubrum, Liquidambar styraciflua, Quercus nigra, Quercus alba, Nyssa sylvatica, Pinus virginiana, Quercus velutina, Carya tomentosa, Quercus rubra,* most of these rare, often stunted.

inches dbh, and 41 years old. The subcanopy (Table 5), also open, is mostly pond pine transgressives, with a lesser amount of turkey oak.

Canopy tree reproduction is pond pine, turkey oak, and longleaf pine, in that order. The ericaceous shrub layer is closed in many places, but interspersed within it are fairly large open patches, ranging in cover from bare sand to carpets of *Pyxidanthera, Gaultheria, Cladonia* and *Polytrichum* sp. (Table 6).

This and CT-A are the most important communities in the preserve because of their significance as the last xerophytic, pyrophytic longleaf pine/turkey oak communities in the state, and because of the associated rare sandhills and savanna herbs first recorded here by Fernald. Four of these occur only in CT-B.

Pyxie Moss (*Pyxidanthera barbulata*) is abundant at this one spot, but was not seen elsewhere. It occurred at the edges of ericad stands and along wildlife trails. *Polygonella polygama* also occurs only here, in small stands on disturbed open, sandy spots. *Carphephorus tomentosus* was represented by only a few isolated individuals, competing unsuccessfully with ericaceous shrubs, while *Carphephorus bellidifolius* was a little more common, being

Table 6. *Shrub Analysis* — **CT-B**

Species	COVER 1	2	3	4	5	6	7	8	9	10
Shrubs:										
Vaccinium atrococcum								5.2		
Vaccinium corymbosum					4.2	2.2	5.2			+.1
Myrica cerifera						1.1	1.1			
Gaylussacia baccata		1.1	5.4	5.4	5.4	5.4	5.4	3.2		
Gaylussacia frondosa	5.5									5.5
Kalmia angustifolia	1.1	5.5	4.2	1.2	2.2	2.2	1.2	3.2	2.2	5.4
Vaccinium tenellum		2.2	2.2	2.2	1.2	1.2			4.2	
Lyonia mariana	1.1					1.1			2.2	
Gaylussacia dumosa	1.1	1.2	3.2	3.2	2.2	1.2				
Gaultheria procumbens	1.1	1.1	+.1	1.1	1.1	1.1	1.1	1.1	+.1	1.1
Herbs:										
Arundinaria gigantea	1.1									
Pteridium aquilinum	1.1									1.1
Tree seedlings:										
Sassafras albidum								1.1		
Amelanchier canadensis								1.1		
Vines:										
Smilax glauca										1.1

Number of relevés: 10 Relevé Size: 1m x 1m

SHRUB SPECIES PRESENT, BUT NOT IN ANALYSIS: *Ilex glabra, Clethra alnifolia, Rhus radicans, Rhus copallina.*

found also in CT-A. *Xyris caroliniana* was also rare, with only a few individuals seen.

COMMUNITY TYPE C

PINUS TAEDA/QUERCUS ALBA-MIXED OAKS-COASTAL PLAIN UPLAND HARDWOODS/MIXED MESIC SHRUBS, HERBS, VINES (MIXED OAK PINE SLOPE)

Loblolly pine occurs here as a second-growth stand after logging about 33 years ago. It was classed as canopy since it just overtopped the oak layer, although the age of establishment is about the same. The subcanopy is a dense hardwood stand dominated by six species of oaks. *Carya pallida* had an importance value of 16% on the lower slope (Table 7).

The understory included a considerable quantity of *Arundinaria gigantea* and *Clethra alnifolia.* This disturbance community is still sorting out into a mature stratified forest. In the absence of fire, it appears that it will be

Table 7. *Subcanopy analysis* — **CT-C**
(Top of slope)

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Quercus alba	117 (39%)	37.50	51.21	28.57
Quercus falcata	51 (17%)	12.50	24.47	14.29
Quercus nigra	34 (11%)	12.50	6.80	14.29
Acer rubrum	32 (11%)	12.50	4.84	14.29
Liquidambar styraciflua	16 (5%)	6.25	2.42	7.14
Nyssa sylvatica	16 (5%)	6.25	2.42	7.14
Oxydendrum arboreum	19 (6%)	6.25	5.44	7.14
Ilex opaca	16 (5%)	6.25	2.42	7.14

Subcanopy analysis
(Lower and mid slope)

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Quercus alba	99 (33%)	37.50	36.34	25.00
Quercus nigra	64 (21%)	12.50	34.97	16.67
Carya pallida	47 (16%)	12.50	17.76	16.67
Acer rubrum	33 (11%)	12.50	4.22	16.67
Quercus falcata	24 (8%)	12.50	3.11	8.33
Ilex opaca	18 (6%)	6.25	3.11	8.33
Cornus florida	15 (5%)	6.25	0.49	8.33

Number of quarter points: 8. Average distance: 3.0 m.
Number of individuals/ha: 1,111.
SUBCANOPY SPECIES PRESENT, BUT NOT IN ANALYSIS: *Quercus velutina, Quercus rubra, Pinus palustris* (top of slope only), *Liriodendron tulipifera, Magnolia virginiana, Carya tomentosa.*

dominated by white oak. There appears to have been little sorting as yet along the distinct moisture gradient from top of slope to bottom.

COMMUNITY TYPE D

NYSSA SYLVATICA BIFLORA/ACER RUBRUM/CLETHRA ALNIFOLIA (BLACKGUM SWAMP)

This is a swamp forest heavily dominated by *Nyssa sylvatica* var. *biflora* in an almost pure stand over a subcanopy of red maple (Table 8).

The shrub layer is dominated by *Clethra alnifolia.* The composition and structure are very similar to one of the more extensive communities of the Dismal Swamp. The soils of both are Typic Medisaprists. This site appears to be noticeably wetter, having been little affected by artificial drainage.

Depth of the histosol supporting the *Nyssa* community could not be determined, but is at least 75 cm. The swamp is lined on either side by very large (up to 91 cm dbh) loblolly pine stumps on 45 cm of saturated sapric material over sand. The *Nyssa* stand is very dense and most trees are 30-38 cm dbh, with a few older individuals and conspicuous large stumps. The herb layer is thin and consists primarily of scattered *Osmunda cinnamomea, Saururus cernuus* and *Viola* sp.

Table 8. *Canopy Analysis* — **CT-D**

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Nyssa sylvatica var. *biflora*	205 (68%)	75	72.86	57.14
Acer rubrum	95 (32%)	25	27.14	42.86

Number of quarter points: 4. Average distance: 3.66 m.
No. of individuals/ha: 747
CANOPY SPECIES PRESENT, BUT NOT IN ANALYSIS: (along edges) *Liriodendron tulipifera, Pinus taeda, Liquidambar styraciflua, Quercus nigra.*

COMMUNITY TYPE E
MIXED COASTAL PLAIN HARDWOODS AND CONIFERS-MIXED OAKS/*GALAX URCEOLATA* (RIVER BLUFF)

While there were no canopy dominants, beech was notable for having the highest importance value, although scarcely to be found in the rest of the natural area, except as recent seedlings. This community had the highest species diversity of any of the six types examined (Tables 9, 10).

Table 9. *Canopy Analysis* — **CT-E**

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Fagus grandifolia	45.2 (15%)	18.75	13.12	13.33
Acer rubrum	40.96(14%)	12.50	15.13	13.33
Liquidambar styraciflua	38.37(13%)	12.50	12.54	13.33
Quercus laurifolia	34.52(12%)	12.50	8.69	13.33
Quercus alba	32.72(11%)	6.25	19.80	6.67
Taxodium distichum	38.57(13%)	12.50	12.74	13.33
Quercus nigra	19.25(6%)	6.25	6.33	6.67
Ulmus americana	19.25(6%)	6.25	6.33	6.67
Quercus falcata	16.75(6%)	6.25	3.23	6.67
Pinus taeda	14.99(5%)	6.25	2.07	6.67

Number of quarter points: 4. Average distance: 4.82 m.
No. of individuals/ha: 430
CANOPY SPECIES PRESENT BUT NOT IN ANALYSIS: *Platanus occidentalis, Quercus phellos, Betula nigra, Carya tomentosa, Carya glabra, Liriodendron tulipifera, Quercus stellata, Quercus velutina.*

Interesting species included *Galax urceolata, Epigaea repens* and *Calycanthus floridus,* the last in a small ravine with cold air drainage to the river. This same phenomenon occurs upstream on the other side of the river, beyond the natural area, where maidenhair fern (*Adiantum pedatum*) and other more mesic species are found in a very deep ravine cut into a bluff 18.25 m high. The canopy trees are uneven-aged and are somewhat irregularly distributed, except along the moisture gradient. There was no evidence of logging

Table 10. *Shrub Analysis* — **CT-E**

Species	COVER 1	COVER 2
Sassafras albidum		4.1
Vaccinium elliottii	2.1	
Calycanthus floridus	5.4	5.4
Vaccinium atrococcum	2.1	
Vaccinium stamineum		2.1

Number of relevés: 2 Relevé size: 5 m x 5 m
SHRUB SPECIES PRESENT BUT NOT IN ANALYSIS: None.

but only a few large individuals were found. The bluff lies along an outside bend of the river, and periodic bank slumping from stream undercutting, as was observed in several places, probably accounts for the irregularity of canopy structure.

COMMUNITY TYPE F

BETULA NIGRA-MIXED ALLUVIAL BOTTOMLAND HARDWOODS AND *TAXODIUM DISTICHUM/CARPINUS CAROLINIANA* (ALLUVIAL FLAT)

This small alluvial flat was under about 30 cm of water in August, but when analyzed later, on October 31, was 122 cm above the river. River birch was the canopy dominant, while the four other species, sweet gum, cypress, water hickory and laurel oak, had about equal importance values, the latter represented by a single large tree (1 m dbh) growing on the levee (Table 11). [This tree was undermined and fell into the river in 1985.]

Table 11. *Canopy Analysis* — **CT-F**

Species	Importance Value	Relative Density	Relative Dominance	Relative Frequency
Betula nigra	111.72(37%)	50.00	25.36	36.36
Liquidambar styraciflua	59.66(20%)	18.75	22.73	18.18
Taxodium distichum	47.33(16%)	12.50	16.65	18.18
Carya aquatica	41.30(14%)	12.50	10.62	18.18
Quercus laurifolia	39.99(13%)	6.25	24.65	9.09

Number of quarter points: 4. Average distance: 5.34 m.
No. of individuals/ha: 351.
CANOPY SPECIES PRESENT BUT NOT IN ANALYSIS: *Acer rubrum, Quercus nigra, Platanus occidentalis, Quercus lyrata.*

The subcanopy was composed almost entirely of ironwood (*Carpinus caroliniana*). *Vaccinium elliottii,* growing robustly along the ecotone between alluvial flat and river bluff, is here at its northernmost known location. *Carya aquatica* is near the northern end of its range also, being known to the north

from only one vicinity, and the station here is an addition to the range shown in Little (1971).

PRESETTLEMENT VEGETATION

The reconstruction of original vegetation of the pine barrens is based on the following sources of information:

1) Historical records, notes of Fernald (1937, 1939) and W.W. Ashe (1894) (CT-A, CT-B).

2) Remnant large trees in CT-C, CT-D, CT-E, CT-F.

3) Stumps of 100-200 yr. old longleaf pine (CT-A, CT-B) and loblolly pine (CT-D).

4) Remnants of old-growth forest in surrounding lands (CT-D, CT-E, CT-F).

5) Present vegetation and successional trends, determined from vegetation analysis and color infrared aerial photography.

6) Examination of soils throughout the site.

7) Observations of pyroclimax communities elsewhere on the southeastern Coastal Plain.

CT-A. *PINUS PALUSTRIS/QUERCUS LAEVIS*/MIXED ERICADS-XEROPHYTIC HERBS (LONGLEAF PINE RIDGE)

This community type occurred on the main site at the southeastern end of section A-A' and probably extensively on a number of other small xeric ridges to the west (Figure 2). This is the most fire-prone site in the natural area, being part of a continuous series of sandy flats running north-south along the Blackwater River. These barrens are separated only by small swamps and would be subject to fires originating at some distance.

The dense, almost continuous ericad layer is obviously fire-prone, and its present density is due the result of fire suppression. Beneath is a litter accumulation of leaves and pine needles to a depth of 30 cm. Although the water table is not deep, the upper half meter of soil is well-drained and easily dry enough to permit fires during most of the year. There is also a heavy pine needle accumulation on the branches of shrubs and transgressive trees around the more mesic boundary, where the water table is closer to the sand surface. Under a natural fire regime this site originally should have supported an uneven-aged stand of longleaf pine with at least some turkey oak in the understory. Fernald (1937) described the area as having "open sands" in 1936. Ericads were apparently much less prominent, so there would have been more available habitat for xerophytic herbs like *Carphephorus* and *Polygonella.* Fire also would have maintained a zone of habitat for *Pyxidanthera* and other pyrophytic but mesophytic herbs by eliminating the dense, flammable tangle of shrubs and saplings around the moist periphery.

CT-B. *PINUS PALUSTRIS*/SAVANNA HERBS AND SHRUBS (LONGLEAF PINE SAVANNA)

This community, now dominated by pond pine, is probably the most changed in the natural area. The original cover was longleaf pine, as demonstrated by large stumps remaining on the site. One of these, of average size and well enough preserved to count annual rings, was 171 years old when cut. Competition by pond pine, turkey oak and ericads has limited reproduction

since logging, to a few widely scattered individuals in all size classes from grass stage to about 30.5 cm dbh. The larger trees are reproductive.

The water table is often near the surface, but the sandy texture of the soil would facilitate fire after a few weeks of dry weather at any time of the year. The largest pond pines on the site were 39 and 41 years old, dating to about 20 years after fire suppression was initiated in southeastern Virginia, and their present increase on this site is probably due to that fact. Designation of the understory as savanna is debatable, but by Fernald's description, herbs were much more abundant than now, and he reported a number of grasses, including a species of *Aristida*, from the area. Grasses are rare now. The higher parts of the site probably supported patches of xerophytic vegetation, but it seems likely that, under a natural fire regime, there would have been savanna-like patches and zones, especially around the periphery to the south and east, where the water table grades closer to the sand surface. A study to observe readjustment in population densities and distribution after yearly burning has been initiated.

Pond pine occurs in a number of upland sloughs, such as one between CT-B and CT-A where the water table is at or near the surface and there is some accumulation of organic soil. This pocosin community was probably the original habitat for the species in the pine barrens.

CT-C. MIXED OAK-PINE SLOPE

The second-growth plant community (CT-C) presently occupying this site, has clearly encroached upon some of the xeric habitat above the oak slope, on the margin of CT-B. Remnant individual longleaf pines and turkey oaks occur on the edge of the flat, now overtopped by, and looking quite out of place in, mesophytic forest. Old stumps of large longleaf pines also occur within this fringe. The mesophytic loblolly/oak forest at its upper extent, became established in the wake of fire control, and it seems unlikely that this vegetation could have survived under a natural fire regime.

It is presumed that most of the species now present originally occurred on the site, but were confined to the mid and lower slope, and perhaps sorted downslope along a moisture gradient in relation to fire tolerance.

Old stumps of loblolly pine at the slope toe support this suggestion. Some of these are in excess of 91 cm dbh and may have been 200 years old at time of cutting. They occur in a distinct zone only a few meters wide, where a Terric Medisaprist feathers onto wet sand. This is probably the principal original habitat for the species within the natural area.

Further evidence of past fire is the scarcity of fire-intolerant beech and tulip poplar. It is assumed that these, along with red maple, sweet gum and swamp black gum would have been excluded from the slope by fire, and that the last three species have seeded in from trees naturally occurring in the adjacent swamp or with the big pines on its hydric margins.

CT-D. *NYSSA SYLVATICA* VAR. *BIFLORA/ACER RUBRUM/ CLETHRA ALNIFOLIA* (BLACK GUM SWAMP)

The hydrology of the natural area appears to be virtually intact (a rarity in coastal plain freshwater wetlands). There is no evidence of hydrologic

change in the swamp bottom, which had water standing at the peat surface at time of survey. It could not have been higher in the original forest or the large loblolly pines would have been flooded beyond even their high tolerance. It could not have been much lower or fire would have killed the large *Nyssa* (stumps and individuals up to 76 cm dbh). Since there were no *Taxodium* stumps or trees, or any other evidence of change, it was concluded that the present forest represents the original type on this site.

CT-E. MIXED COASTAL PLAIN HARDWOODS AND CONIFERS-MIXED OAKS/*GALAX URCEOLATA* (RIVER BLUFF)

As in CT-C, it appears that the mesophytic slope community has "escaped" onto the top of its sandy ridge along the river. There are, however, some notable differences in species composition on the slopes themselves. No species was dominant, but beech had the highest importance value, in contrast to its scarcity in the more fire-prone CT-C. Large individuals of *Fagus* and other fire-intolerant species on the river bluff indicate that this steep, moist slope has always been naturally fire-protected.

There was virtually no flammable litter accumulation and the ground was carpeted with evergreen *Galax,* probably a relict of cooler glacial times which would not likely be able to reestablish itself in this climate if destroyed by fire. There was no evidence on the site to suggest that there had been any change in species composition from that of the presettlement forest.

CT-F. *TAXODIUM DISTICHUM/BETULA NIGRA*-MIXED BOTTOMLAND HARDWOODS/*CARPINUS CAROLINIANA* (ALLUVIAL FLAT)

It is possible that the small river birch flat has never been logged. The largest trees are a cypress 112 cm in diameter and a single laurel oak of about the same size, growing on the levee. The river is actively meandering at this point. Freshly undercut banks, levees, and other results of fluvial processes are conspicuous. Since the flat is low-lying and frequently inundated by high water, it is probably quite young. It could be that the trees on the site were the first to become established after its deposition.

Since the trees were large and there were no stumps or other indicators of vegetation change, it was assumed that the present assemblage represents the original community type, if not the original community. Additional stratification could eventually take place, with tall cypress becoming emergent over river birch. Natural river processes, however, or additional amplification of the river cycle by human activities may shorten the life span of this geologically temporary landform before this stage is reached.

MANAGEMENT

According to the deed of trust the preserve is to be managed for perpetuation of the longleaf community type. This involves a program of prescribed burning. The first burn of approximately 55 acres of CT-A was done on 24 January 1986. Regular burning of this area is planned.

CATALOG OF SPECIES

The following list of species is based mainly on collections by the authors. Species recorded by Fernald but not seen by the authors and pre-

sumed extirpated are also included and noted by an asterisk (*). This list includes species found within the 319-acre preserve as well as contiguous areas.

PLANTS OF THE BLACKWATER ECOLOGIC PRESERVE

MONOCOTS

AMARYLLIDACEAE

Hypoxis hirsuta (L.) Coville var. *leptocarpa* (Engelm. & Gray) Fern.

ARACEAE

Arisaema triphyllum (L.) Schott

CYPERACEAE

Bulbostylis capillaris (L.) Clarke
B. ciliatifolia (Ell.) Fern.
Carex alata Torr.
C. caroliniana Schweinitz
C. glaucescens Ell.
C. joorii Bailey
C. nigromarginata Schweinitz var. *floridana* (Schweinitz) Kukenthal
C. physorhyncha Liebmann
C. stricta Lam.
Cyperus filiculmis Vahl
C. ovularis (Michx.) Torr.
C. polystachyos var. *texensis* (Torr.) Fern.
Liphocarpha maculata (Michx.) Torr. *
Rhynchospora capitellata (Michx.) Vahl
R. corniculata (Lam.) Gray
R. debilis Gale
R. fascicularis (Michx.) Vahl *
R. inexpansa (Michx.) Vahl

DIOSCOREACEAE

Dioscorea villosa L.

IRIDACEAE

Iris verna L.
Sisyrinchium albidum Raf.
S. mucronatum Michx.

JUNCACEAE

Juncus abortivus Chapm.
J. coriaceus Mackenz.
J. effusus L.
J. repens Michx.
J. scirpoides Lam.
Luzula acuminata Raf.
L. multiflora (Retzius) Lej.

LEMNACAEAE

Lemna valdiviana Philippi

LILIACEAE

Polygonatum biflorum (Walt.) Ell.
Smilacina racemosa (L.) Desf.
Smilax auriculata L.
S. laurifolia L.
S. rotundifolia L.
S. walteri Pursh
Uvularia pudica (Walt.) Fern.
Yucca filamentosa L.
Zygadenus glaberrimus Michx. *

ORCHIDACEAE

Cypripedium acaule Ait.
Habenaria blephariglottis (Willd.) Hook. *
H. ciliaris (L.) R. Brown
Orchis spectabilis L.
Spiranthes cernua (L.) Richard
Tipularia discolor (Pursh) Nutt.

POACEAE

Andropogon scoparius Michx.
A. virginicus L.
Aristida curtissii (Gray) Nash
A. dichotoma Michx.
A. virgata Trinius *
Arundinaria gigantea (Walt.) Muhl.
Cenchrus longispinus (Hackel) Fern.
Cinna arundinacea L.
Danthonia sericea Nutt.
Eleusine indica (L.) Gaertner
Eragrostis spectabilis (Pursh) Steudel
Panicum commonsianum Ashe
P. hians Ell.
P. lancearium Trinius *
P. laxiflorum Lam.
P. scoparium Lam.
Paspalum setaceum Michx.
Triplasis purpurea (Walt.) Chapm.
Uniola laxa (L.) BSP

SPARGANIACEAE

Sparganium americanum Nutt.

XYRIDACEAE

Xyris ambigua Beyrich *
X. caroliniana Walt.
X. difformis Chapm. *
X. jupicai Richard

DICOTS

ACANTHACEAE

Justicia lanceolata (Chapm.) Small
Ruellia caroliniensis (Walt.) Steudel

ACERACEAE

Acer rubrum L.

ANACARDIACEAE

Rhus copallina L.
R. radicans L.

ANNONACEAE

Asimina parviflora (Michx.) Dunal
A. triloba (L.) Dunal

APIACEAE

Hydrocotyle umbellata L.
Ptilimnium capillaceum (Michx.) Raf.
Sanicula canadensis L.

APOCYNACEAE

Amsonia tabernaemontana Walt.

AQUIFOLIACEAE
Ilex glabra (L.) Gray
I. opaca Ait.
I. verticillata (L.) Gray
ARALIACEAE
Aralia spinosa L.
ARISTOLOCHIACEAE
Hexastylis virginica (L.) Small
ASCLEPIADACEAE
Asclepias tuberosa L.
A. variegata L.
ASTERACEAE
Ambrosia artemisiifolia L.
Aster lateriflorus (L.) Britt.
A. pilosus Willd.
A. puniceus L.
A. simplex Willd.
Carphephorus bellidifolius (Michx.) T. & G.
C. tomentosus (Michx.) T. & G.
Coreopsis verticillata L.
Elephantopus caroliniana Willd.
E. nudatus Gray
E. tomentosus L.
Erechtites hieracifolia L. Raf.
Erigeron annuus (L.) Pers.
E. canadensis L.
E. pulchellus Michx.
Eupatorium capillifolium (Lam.) Small
E. coelestinum L.
E. pilosum Walt.
E. rotundifolium L.
E. serotinum Michx.
Gnaphalium obtusifolium L.
Heterotheca gossypina (Michx.) Shinners
H. mariana (L.) Shinners
H. nervosa (Willd.) Shinners
Hieracium gronovii
H. venosum L.
Krigia virginica (L.) Willd.
Liatris graminifolia (Walt.) Willd.
Mikania scandens (L.) Willd.
Pluchea camphorata (L.) DC
Senecio tomentosus Michx.
Silphium compositum Michx. *
Solidago erecta Pursh
S. microcephala (Greene) Bush
S. odora Ait.
S. tenuifolia Pursh
BETULACEAE
Alnus serrulata (Ait.) Willd.
Betula nigra L.
Carpinus caroliniana Walt.
Corylus americana Walt.
BIGNONIACEAE
Anisostichus capreolata (L.) Bur.
Campsis radicans (L.) Seeman
BRASSICACEAE
Cardamine pensylvanica Muhl.
Lepidium virginicum L.
Teesdalia nudicaulis (L.) R. Brown
CACTACEAE
Opuntia compressa (Salisb.) Macbride
CALYCANTHACEAE
Calycanthus floridus L.
CAMPANULACEAE
Lobelia cardinalis L.
L. elongata Small *
L. spicata Lam.
Specularia perfoliata (L.) A.DC
CAPRIFOLIACEAE
Lonicera japonica Thunb.
L. sempervirens L.
Viburnum acerifolium L.
V. nudum L.
CARYOPHYLLACEAE
Arenaria caroliniana Walt. *
Paronychia riparia Chapm.
CELASTRACEAE
Euonymus americanus L.
CHENOPODIACEAE
Chenopodium album L.
C. ambrosioides L.
CISTACEAE
Helianthemum canadense (L.) Michx.
Lechea leggettii Britt. & Hollick
CLETHRACEAE
Clethra alnifolia L.
CONVOLVULACEAE
Bonamia humistrata (Walt.) Gray
Calystegia sepium (L.) R. Brown
Cuscuta compacta Juss.
C. pentagona Engelm.
Ipomoea pandurata (L.) G.F.W. Mey.
CORNACEAE
Cornus amomum Mill.
C. florida L.
CRASSULACEAE
Penthorum sedoides L.
DIAPENSIACEAE
Galax urceolata (Poir.) Brumitt (= *G. aphylla* L.)
Pyxidanthera barbulata Michx.
EBENACEAE
Diospyros virginiana L.
ERICACEAE
Chimaphila maculata (L.) Pursh.
Epigaea repens L.
Gaultheria procumbens L.
Gaylussacia baccata (Wang.) K. Koch
G. dumosa (Andrz.) T. & G.
G. frondosa (L.) T. & G.
Kalmia angustifolia L.

Leucothoe racemosa (L.) Gray
Lyonia ligustrina (L.) D.C.
L. mariana (L.) D. Don
Monotropa uniflora L.
Oxydendrum arboreum (L.) D.C.
Rhododendron atlanticum (Ashe) Rehder
R. nudiflorum (L.) Torr.
R. viscosum (L.) Torr.
Vaccinium arboreum Marsh.
V. atrococcum (Gray) Heller
V. corymbosum L.
V. elliottii Chapm.
V. stamineum L.
V. tenellum Ait.
V. vacillans Torr.

EUPHORBIACEAE

Acalypha gracilens Gray
Cnidoscolus stimulosus (Michx.) Engelm. & Gray
Euphorbia ammannioides HBK
E. ipecacuanhae L.

FABACEAE

Apios americana Medic.
Cassia fasciculata Michx.
Centrosema virginianum (L.) Benth.
Clitoria mariana L.
Crotalaria angulata Mill. *
Desmodium nudiflorum (L.) DC.
D. tenuifolium T. & G. *
Galactia regularis (L.) BSP
Lespedeza capitata Michx.
L. hirta (L.) Hornemann
L. repens (L.) Bart.
Lupinus perennis L.
Tephrosia spicata (Walt.) T. & G. *
T. virginiana (L.) Pers.
Zornia bracteata J.F. Gmelin

FAGACEAE

Castanea pumila (L.) Mill.
Fagus grandifolia Ehrh.
Quercus alba L.
Q. coccinea Muenchh.
Q. falcata Michx.
Q. laevis Walt.
Q. laurifolia Michx.
Q. lyrata Walt.
Q. margaretta Ashe
Q. nigra L.
Q. phellos L.
Q. rubra L.
Q. stellata Wang
Q. velutina Lam.

GENTIANACEAE

Bartonia virginica (L.) BSP
Gentiana catesbaei Walt.
Sabatia calycina (Lam.) Hell.

HALORAGACEAE

Proserpinaca pectinata Lam.

HAMAMELIDACEAE

Liquidambar styraciflua L.

HYPERICACEAE

Hypericum gentianoides (L.) BSP
H. hypericoides (L.) Crantz
H. mutilum L.
H. stragalum P. Adams & Robson
H. virginicum L.
H. walteri J.F. Gmelin

HYDROPHYLLACEAE

Hydrolea quadrivalvis Walt.

JUGLANDACEAE

Carya aquatica (Michx.) Nutt.
C. glabra (Mill.) Sweet
C. pallida (Ashe) Engelm. & Graeb.
C. tomentosa Nutt.
Juglans nigra L.

LAMIACEAE

Lycopus virginica L.
Monarda punctata L.
Scutellaria integrifolia L.
Trichostema dichotomum L.

LAURACEAE

Lindera benzoin (L.) Spreng.
Persea borbonia (L.) Spreng.
Sassafras albidum (Nutt.) Nees

LENTIBULARIACEAE

Utricularia gibba L.
U. subulata L.

LOGANIACEAE

Gelsemium sempervirens (L.) Ait. f.
Polypremum procumbens L.

MAGNOLIACEAE

Liriodendron tulipifera L.
Magnolia virginiana L.

MELASTOMATACEAE

Rhexia virginica L.

MYRICACEAE

Myrica cerifera L.

NYSSACEAE

Nyssa sylvatica Marsh. var. *biflora* (Walt.) Sarg.
N. sylvatica var. *sylvatica* Marsh.

OLEACEAE

Chionanthus virginicus L.
Fraxinus caroliniana Mill.

ONAGRACEAE

Circaea lutetiana ssp. *canadensis* (L.) Aschersson & Magnus
Oenothera fruticosa L.

OXALIDACEAE

Oxalis florida Salis.

PAPAVERACEAE

Sanguinaria canadensis L.

PASSIFLORACEAE
Passiflora incarnata L.
P. lutea L.
PHRYMACEAE
Phryma leptostachya L.
PHYTOLACCACEAE
Phytolacca americana L.
PLATANACEAE
Platanus occidentalis L.
POLEMONIACEAE
Phlox paniculata L.
POLYGALACEAE
Polygala lutea L.
POLYGONACEAE
Polygonella polygama (Vent.) Engelm. & Gray
Polygonum setaceum Baldwin ex Ell.
Rumex acetosella L.
Tovara virginiana (L.) Raf.
PORTULACEAE
Claytonia virginica L.
PRIMULACEAE
Lysimachia quadrifolia L.
RANUNCULACEAE
Aquilegia canadensis L.
Ranunculus laxicaulis (T. & G.) Darby
R. recurvatus Poiret
ROSACEAE
Agrimonia pubescens Wallr. var. *microcarpa* (Wallr.) Ashe *
A. rostellata Wallr.
Amelanchier canadensis (L.) Medic.
A. obovalis (Michx.) Ashe
Aronia arbutifolia (L.) Ell.
Aruncus dioicus (Walt.) Fern.
Potentilla canadensis L.
Prunus serotina Ehrh.
Rubus flagellaris Willd.
RUBIACEAE
Diodia teres Walt.
D. virginiana L.
Galium aparine L.
G. circaezans Michx.
G. obtusum Big. var. *filifolium* (Wieg.) Fern.
G. uniflorum Michx. *
Houstonia caerulea L.
Mitchella repens L.
Oldenlandia uniflora L.
SALICACEAE
Populus alba L.
P. deltoides Marsh.
P. heterophylla L.
Salix caroliniana Michx.
SANTALACEAE
Comandra umbellata (L.) Nutt.
SARRACENIACEAE
Sarracenia flava L. *
S. purpurea L.
SAURURACEAE
Saururus cernuus L.
SAXIFRAGACEAE
Heuchera americana L.
Itea virginica L.
SCROPHULARIACEAE
Agalinis purpurea (L.) Penn.
A. tenuifolia (Vahl) Raf.
Aureolaria virginica (L.) Penn.
Gratiola pilosa Michx.
G. virginiana L.
Linaria canadensis (L.) Dumont
Lindernia anagallidea (Michx.) Penn.
Micranthemum umbrosum (Walt.) Blake
Penstemon australis Small
Seymeria cassioides (Walt.) Blake
SYMPLOCACEAE
Symplocos tinctoria L'Her.
ULMACEAE
Ulmus alata Michx.
U. americana L.
VERBENACEAE
Callicarpa americana L.
VIOLACEAE
Viola affinis Le Conte
V. primulifolia L.
VISCACEAE
Phoradendron serotinum (Raf.) M.C. Johnston
VITACEAE
Parthenocissus quinquefolia (L.) Planch.
Vitis riparia Michx.
V. rotundifolia Michx.

GYMNOSPERMS

PINACEAE
Pinus echinata Mill.
P. palustris Mill.
P. serotina Michx.
P. taeda L.
P. virginiana Mill.
TAXODIACEAE
Taxodium distichum (L.) Rich.
CUPRESSACEAE
Juniperus virginiana L.

FERNS AND FERN ALLIES

ASPIDIACEAE
Onoclea sensibilis L.
Polystichum acrostichoides (Michx.) Schott.
ASPLENIACEAE
Asplenium platyneuron (L.) Oakes
Thelypteris hexagonoptera (Michx.) Weatherby
BLECHNACEAE
Woodwardia areolata (L.) Moore
W. virginica (L.) Oakes
EQUISETACEAE
Equisetum hyemale L.
LYCOPODIACEAE
Lycopodium flabelliforme (Fern.) Blanch.
L. obscurum L.
OPHIOGLOSSACEAE
Botrychium biternatum (Sav.) Underw.

OSMUNDACEAE
Osmunda cinnamomea L.
O. regalis var. *spectabilis* (Willd.) Gray
POLYPODIACEAE
Polypodium polypodioides (L.) Watt.
PTERIDACEAE
Adiantum pedatum L.
Pteridium aquilinum (L.) Kuhn.
SCHIZAEACEAE
Lygodium palmatum (Bernh.) Swartz (Observed along SR 614 but not collected.)
SELAGINELLACEAE
Selaginella apoda (L.) Spring.

BRYOPHYTES
MUSCI (MOSSES)

AMBLESTEGIACEAE
Platydicta subtile (Hedw.) Crum
AULACOMNIACEAE
Aulacomnium palustre (Hedw.) Schwaegr.
BARTRAMIACEAE
Bartramia pomiformis Hedw.
BRACHYTHECIACEAE
Bryoandersonia illecebra (Hedw.) Robins
CALYMPERACEAE
Syrrhopodon incompletus Schwaegr.
CLIMACIACEAE
Climacium americanum Brid.
DICRANACEAE
Dicranella heteromalla (Hedw.) Hampe
Dicranum condensatum Hedw.
D. scoparium Hedw.
ENTODONACEAE
Entodon seductrix (Hedw.) C. Muell.
FABRONIACEAE
Clasmatodon parvulus (Hampe) Hook & Wils. ex Sull.
FISSIDENTACEAE
Fissidens taxifolius Hedw.
FONTINALIACEAE
Brachelyma subulatum (P. Beuv.) Schimp. ex Card.
HYPNACEAE
Platygyrium repens (Brid.) B.S.G.
Isopterygium tenerum (S.W.) Mitt.
LEUCOBRYACEAE
Leucobryum albidum (Brid. ex. P. Beauv.) Lindl.
LEUCODONTACEAE
Leucodon julaceus Brid.
MNIACEAE
Mnium cuspidatum Hedw.
POLYTRICHACEAE
Atrichum angustatum (Brid.) B.S.G.
P. juniperinum Hedw.
P. ohioense Ren. & Card.
SEMATOPHYLLACEAE
Sematophyllum adnatum (Michx.) Britt.
SPHAGNACEAE
Sphagnum perichaetiale Hampe
S. torreyanum Sull.
TETRAPHIDACEAE
Tetraphis pellucida Hedw.
THELIACEAE
Anomodon attenuatus (Hedw.) Hueb.
Thelia lescurii Sull
THUIDIACEAE
Thuidium delicatulum (Hedw.) B.S.G.

HEPATICAE
(LIVERWORTS)

JUBULACEAE
Frullania inflata Gatt.
F. kunzei Lehm. & Lindemb.
LOPHOCOLEACEAE
Lophocolea heterophylla (Schrad.) Dum.
PALLAVICINACEAE
Pallavicinia lyelli (Hook.) Carruth
PORELLACEAE
Porella pinnata L.
RADULACEAE
Radula australis Aust

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