

Analysis of coastal plain vegetation, Croatan National Forest, North Carolina

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Analysis of Coastal Plain Vegetation,
Croatan National Forest, North Carolina

by

James R. SNYDER

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1. Introduction

The coastal plain vegetation of North Carolina has been the object of several studies in the last 50 years. The leading student of the coastal plain vegetation, B.W. WELLS, briefly outlined the major plant communities and their successional relations (WELLS 1928); in addition he has given detailed ecological descriptions of several of the more distinctive types of communities (WELLS 1946; WELLS and SHUNK 1928, 1931). However, until recently there has not been detailed analysis of a wide range of vegetation types found within a single area. The diverse wetland communities of the Green Swamp in the southern coastal plain have been described by KOLOGISKI (1977). The study presented here includes a wider range of vascular plant communities from hydric swamp to xeric sandhill vegetation, all found in a single section of Croatan National Forest. The areal extent of the communities is displayed in a vegetation map and their ecological relationships are discussed.

Acknowledgements

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1.1. *Study Site*

Croatan National Forest is an ideal study site because it is a centrally located area of public land with vegetation representative of the coastal plain of North Carolina. Croatan National Forest is located in the lower coastal plain south of the Neuse River estuary (Fig. 1). It occupies portions of Carteret, Craven, and Jones counties with U.S. 70 between New Bern and Morehead City traversing the eastern part. The National Forest is bounded on the north by the Trent River in addition to the Neuse, on the west by the White Oak River, on the south by N.C. 24 (Bogue Sound), and on the east by Harlowe and Clubfoot creeks.

The U.S. Forest Service began acquiring property about forty years ago and

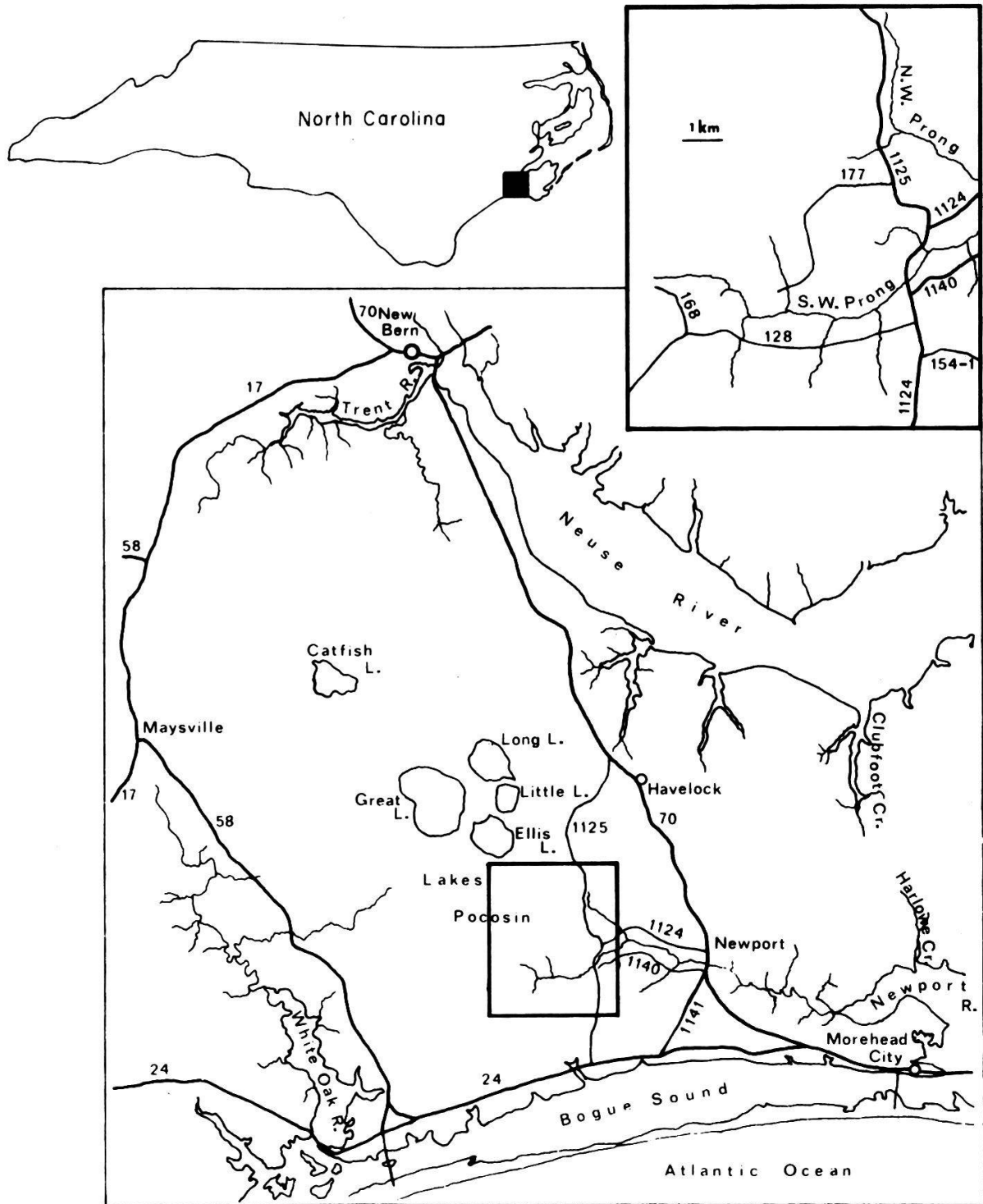


Figure 1. Location of study area (enlarged inset) within Croatan National Forest. Major highways and relevant minor roads are shown. U.S. highways: 17, 70; N.C. highways: 24, 58; County roads: 1124, 1125, 1140, 1141; Forest routes, unpaved: 128, 154-1, 168, 177.

now administers about 47,000 ha, somewhat less than half of which is managed for timber production. All of the productive forest land has been harvested at least once and most now supports second or third growth pine forest. Most of the nonproductive land is found in the center of the National Forest in a large expanse of shrub bog on organic soil known as Lakes Pocosin. This is one of many large areas of organic soil in the lower coastal plain of North Carolina which have an estimated total area of 600,000 ha (MAKI 1974).

The specific research area within Croatan National Forest was chosen because it contains representative examples of the major plant communities found in the coastal plain (exclusive of saltwater influenced communities). It is vegetated by shrub bog, loblolly and longleaf pine forest, and bottomland hardwood forest which together account for most of the natural vegetation of the coastal plain. The less common upland hardwood forest which is also found in Croatan National Forest could not be included because it was not available adjacent to a wide range of the more typical types.

The study area is a rectangular tract of about 7,050 ha lying southeast of Ellis Lake entirely within Carteret County (Fig. 1). The southern end is only about 3 km from the saltwater of Bogue Sound. The area is covered by the Masontown 7.5 minute topographic map and is bounded by $34^{\circ}45'$ - $34^{\circ}50'N$ and $76^{\circ}55'$ - $77^{\circ}W$. The highest elevation is less than 13 m above mean sea level and most of the area is between 8 and 12 m elevation. The lowest points are about 3 m above sea level and are found along the two main streams which drain the area, the Southwest and Northwest Prongs of the Newport River.

There is a paved road running north-south through the eastern part of the research area with two others heading eastward parallel to the Southwest Prong. A number of unpaved Forest Service and private roads provide the access to much of the area.

The recorded land-use history of Carteret County dates from about 1700 when the first European settlements were founded. At that time, the forest of the better drained areas consisted mainly of *Pinus palustris* (longleaf pine), but there was some *Pinus taeda* (loblolly pine) in the less well-drained areas. The boggy areas supported only *Pinus serotina* (pond pine). Agriculture developed both for local consumption and for export, and a naval stores industry built up around the *Pinus palustris*. Lumber, tar, pitch, and turpentine were exported but by about 1900 supplies dwindled due to over-exploitation (PERKINS et al. 1938).

In eastern Carteret County in the large expanse of pocosin known as the Open Grounds, drainage and farming of the organic soils were attempted as early as the 1920's (DACHNOWSKI-STOKES and WELLS 1929). These early attempts failed but recently a large "agribusiness" has begun large scale conversion to row crops and pasturage for raising cattle. Conversion to agriculture appears to be the fate of much of the organic soil land of coastal North Carolina (CARTER 1975). Within the study area there has been no attempt to farm organic soils although west of Catfish Lake inside the National Forest boundary there is agricultural activity on privately owned organic soil.

Today most of the study area remains forested, although much is of non-commercial quality. Only about 7 % of the area is under conventional cultivation, mainly in soybeans, corn, and tobacco.

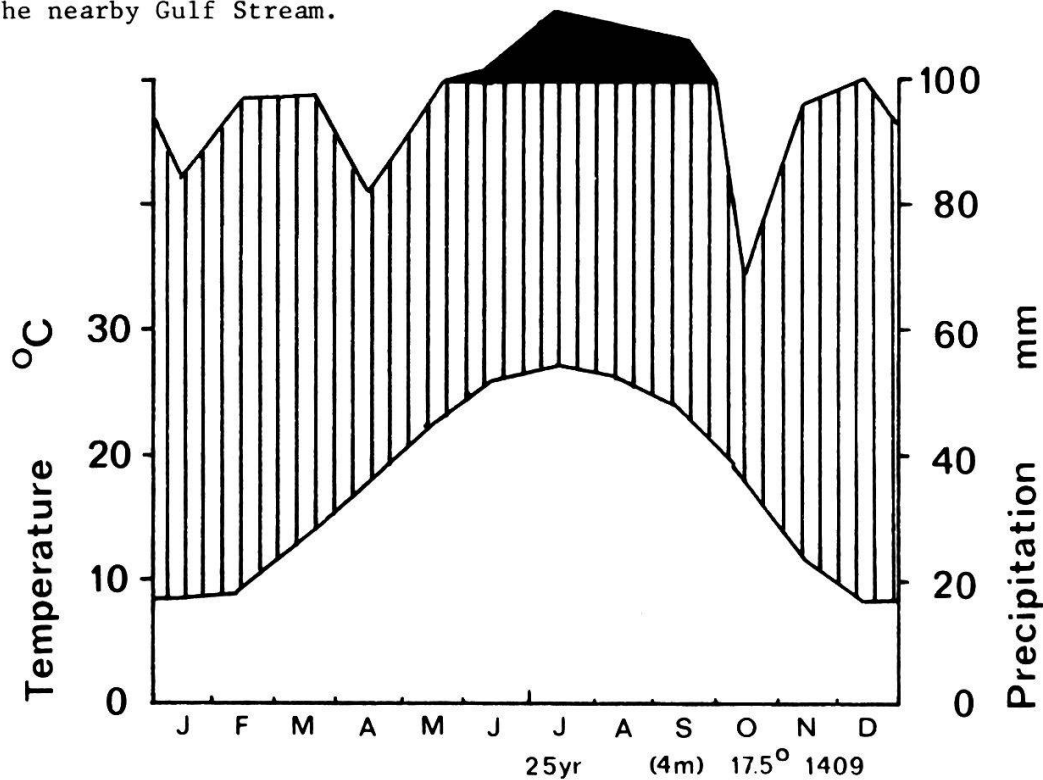
1.2. *Climate*

The climate of the North Carolina coastal plain is characterized by hot summers and cool winters with adequate moisture throughout the year; the region lies entirely within the humid mesothermal climate of Köppen (TREWARTHA 1954). Figure 2 is a climate diagram for the New Bern weather station which is about 35 km north of the study site and experiences similar weather patterns. Precipitation shows a pattern of high summer rainfall with the months of July, August, and September receiving over one third the annual average of about 1400 mm. Summer rainfall often occurs in the form of brief afternoon thunder-showers. Precipitation in the form of snow is recorded only in trace amounts in most years.

Lightning was historically a cause of natural fires and KOMAREK (1974) goes so far as to refer the southeastern coastal plain and piedmont to the "southern pine forest lightning fire bioclimatic region". Perhaps of greater significance is the frequent occurrence of periods of low rainfall in the fall and spring which coincide with the period of highest fire frequency. These fires, however, are at present largely man-caused.

Temperatures range from a July mean daily maximum of 33°C and mean daily minimum of 20.5°C to a January mean daily maximum of 14°C and mean daily minimum of 1°C. The highest temperature recorded at New Bern was 41°C and the lowest was -13.5°C for the period 1951-1960 (U.S. WEATHER BUREAU 1965). The mean length of the freeze-free period is greater than 240 days according to a

generalized map (NELSON and ZILLGITT 1967); winter temperatures are moderated by the nearby Gulf Stream.



New Bern, N.C.

Figure 2. Climate diagram for New Bern, Craven County, N.C. Lower line represents mean monthly temperature (degrees C) and upper line represents mean monthly precipitation (in mm). In the solid black area the scale is reduced 1/10. (After WALTER and LIETH 1960).

The high winds associated with tropical storms are undoubtedly responsible for many of the windthrown trees in the area and for the unusual sight of *Pinus palustris* trees growing with their trunks at an angle greater than 30° from the perpendicular. These storms passed through the Croatan area approximately 20 times in the period from 1901 to 1955 (BRADLEY 1972).

1.3. Geology

According to STEPHENSON (1912), the North Carolina coastal plain is composed of five marine terraces separated by scarps which represent the depositions of successively lower stands of the ocean. The sediments represent nearshore marine as well as estuarine and nearby river floodplain deposits. Croatan

National Forest is found almost entirely on the second lowest and therefore second youngest of these terraces, the Chowan formation, which corresponds to elevations of 7.5 to 14 m. The terrace is composed of a veneer of Quaternary sediments overlying Tertiary and Cretaceous sedimentary rocks which form a wedge increasing in thickness to the east and northeast (MIXON and PILKEY 1976).

MIXON and PILKEY (1976) provide the most recent treatment of the surficial geology of the Croatan area, including a map which covers the study site (Fig. 3). Their terminology and interpretations are followed here.

The research area shows relatively little relief. The northwestern third of the area is a very flat plain which is part of the large central bog (Lakes Pocosin) of the National Forest. The southeastern two thirds show a greater degree of relief but even here local changes in elevation are on the order of at most a few meters, and are greatest where downcutting by streams has occurred. These two geomorphologically differentiated areas are referred to by MIXON and PILKEY (1976) as the Newport Backbarrier Flat and the Newport Barrier respectively.

The Newport Barrier is a complex of old beach ridges and swales which run in a northeasterly direction toward the town of Newport. The parallel pattern is more pronounced just to the east of the research area and appears as striking bands of light and dark in aerial photographs (e.g., Fig. 3 in MIXON and PILKEY 1976) or as parallel contours on the Masontown and Newport topographic maps. The degree of relief is rather slight however, on the order of 1.5 m from ridge to swale. On the ground this pattern can be seen in cross section along county road 1141 and U.S. 70 south of Newport. The southwest-northeast trending ridge and swale topography is frequently interrupted by elliptical ridges of sand which probably represent the rims of Carolina bays (see later).

MIXON and PILKEY refer the Pleistocene sediments west of the Grantsboro scarp within their mapping area to the Flanner Beach formation. This formation corresponds closely to the area mapped as the Chowan formation by STEPHENSEN. MIXON and PILKEY avoid the use of the classic terrace formation terminology because the terraces as mapped over long distances may not represent valid stratigraphic units. The Flanner Beach formation is considered to be the deposition of a single transgressive-regressive cycle of the sea.

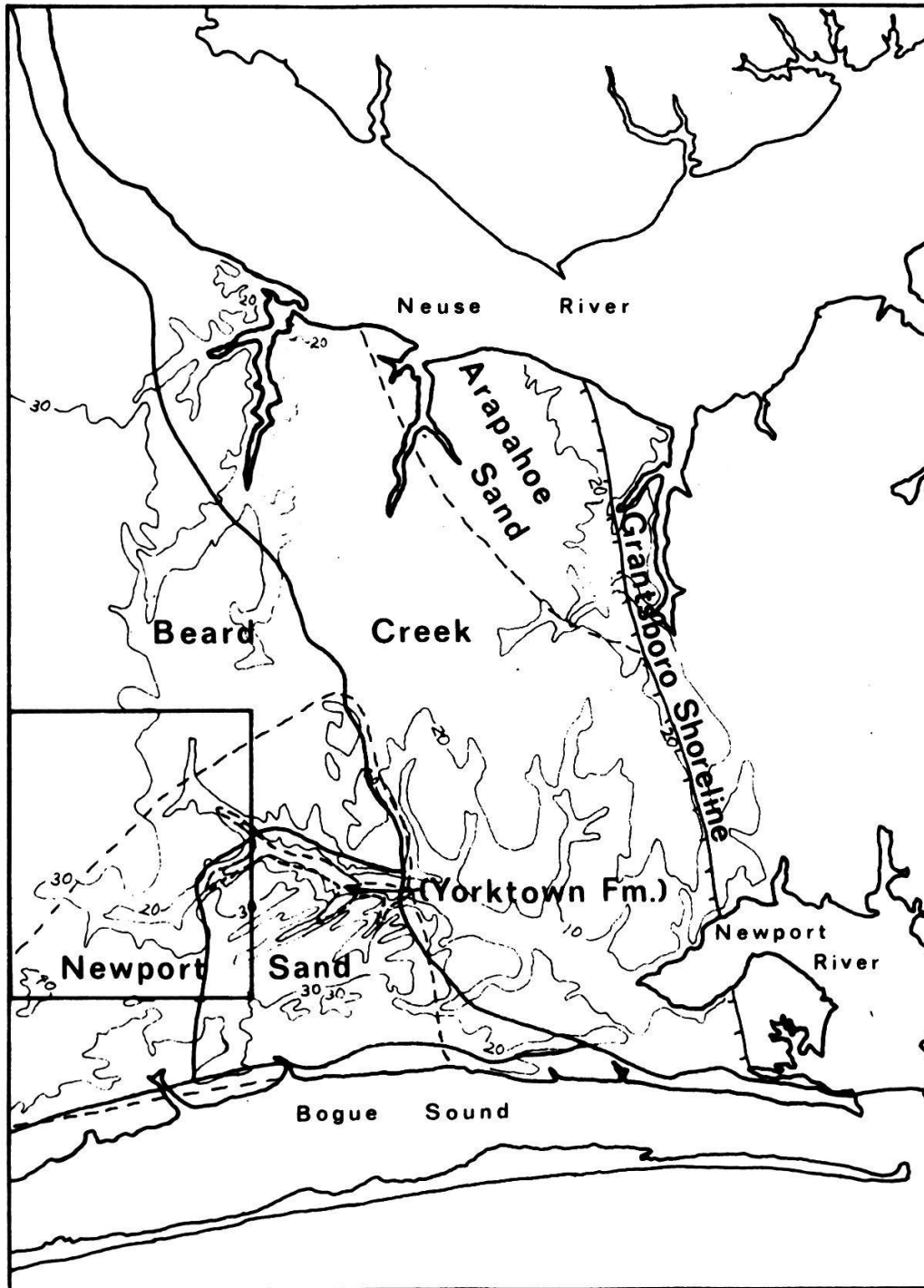


Figure 3. Geological map of the study area (small rectangle) and adjoining parts of Croatan National Forest. The area to the west of the Grantsboro shoreline is covered by Pleistocene sediments of the Flanner Beach formation, except for an area of outcropping of the Yorktown formation (Lower Pliocene and Upper Miocene) along the Newport River. The area of outcropping shown on the map is exaggerated. The Beard Creek and Newport Sand members of the Flanner Beach formation represent backbarrier flat and barrier deposits respectively. Ten foot contour intervals are shown completely only within the study area. (After MIXON and PILKEY 1976).

Within the Flanner Beach formation MIXON and PILKEY informally recognize three members or facies (Fig. 3). One of these, the Newport Sand member, is equivalent to the Pleistocene sediments of the Newport Barrier referred to above and a second is the Beard Creek member which represents the Newport Backbarrier Flat deposits. The third member, not found in the research area, is designated the Arapahoe Sand member. A tongue of the Beard Creek facies which separates the Newport and Arapahoe Sand facies is hypothesized to represent the former channel of the Neuse River.

The Newport Sand facies of the Flanner Beach formation is formed by the sandy sediments of the ridge and swale dune complex. The sediments are well-sorted to moderately well-sorted quartz sands which locally contain fine quartz and chert pebbles. The nonfossiliferous sands range in depth from 3 m or less where they integrate with the finer sediments to the northwest to about 12 m at the south near Bogue Sound. The ridge and swale complex is inferred to be beach deposits of a previous coastline of the mainland or of a barrier island.

To the northwest, the sandy deposits merge with the finer sediments of the Beard Creek member. The flat topography and the presence of clayey and silty sand, and smaller amounts of silt and clay, which today underlie the mantle of peat, indicate that this facies was a backbarrier region where deposition took place in the lower energy environment of an estuary or lagoon located landward of the Newport Barrier.

The elevations of the Newport Barrier and Backbarrier Flat correspond closely to those of a similar geomorphological structure described by THOM (1967) for South Carolina; MIXON and PILKEY note that a sea stand of 10.5 m in South Carolina has been dated at $147,000 \pm 13,000$ years before present.

The only pre-Quaternary rocks which outcrop in the research area belong to the Yorktown formation of late Miocene or Pliocene age. The deposits outcrop in very narrow areas along the Newport River and its tributaries, and the extent of the outcropping has been exaggerated on the map (Fig. 3). The Yorktown formation is composed of fossiliferous clayey sands and clays.

Carolina bays are a distinctive feature of the Carolina coastal plain and have inspired many suggestions and debates as to their origin. They are shallow elliptical depressions surrounded by a low sand rim and either contain standing water as some of the Bladen Lakes or more frequently are filled

with accumulated peat supporting pocosin or "bay" vegetation (BUELL 1946). In addition to their regular outlines they are unusual in that they are regularly oriented on a northwest-southeast axis. Within the research area south of forest route 128 a number of partial rims of Carolina bays are distinguishable as curved "islands" of longleaf pine in a "sea" of pocosin (Fig. 5*). THOM (1970) did extensive work on the geomorphology of Horry and Marion Counties, South Carolina, which contain many well-developed Carolina bays. The following quote is from his paper:

The hypothesis which has developed from this study is that Carolina bays are the result of the expansion of shallow water bodies. These water bodies were initially deflation hollows within dune fields, or depressions on poorly drained interfluves, or lake basins at the contact between two river terraces. Under the influence of strong unidirectional winds from the southwest, the bays expanded laterally with a northwest-southeast elongation. Sandy rims developed as beaches on the leeward side and at the ends of these shallow lakes No specific evidence has been found requiring in any theory of bay formation the effect of solution, artesian flow, slumping, periglacial conditions (for example, permafrost or thermokarst), meteor impact, gyroscopic eddies or spawning fish.

For further discussion of problems in Carolina bay formation and references to some of the above mentioned alternatives the reader is referred to THOM (1970).

Numerous small depressions which are not Carolina bays are present in the research area south of country road 1140, within the Newport Barrier region of MIXON and PILKEY. The depressions range in size from tiny pits about 4 m in diameter to those large enough to be visible on standard aerial photographs. Some of the larger depressions apparently contain permanent or semi-permanent ponds whereas the small ones only contain water after heavy rains, if ever. The origin of the depressions is probably due to a coastal dune process inasmuch as they occur in the Newport Barrier region. However, the steepness of the slope of the depressions and the almost circular outline of some of the smaller ones seems appropriate to solution holes. THOM (1970) describes water-filled depressions in the outer coastal plain of South Carolina which appear to be the result of dissolution of underlying calcareous strata. Dr. Walter WHEELER (pers. comm.) of the UNC Geology Department feels that solution hole formation is unlikely in the study area because rock capable of dissolution is found too deep beneath the Pleistocene sediments. Regardless of how they were

* in the pouched back-cover.

formed, the ponds in some of the larger depressions are noteworthy in that they contain a number of interesting vascular plants.

1.4. Soils

The soils found in the research area are to a large degree the result of the Quaternary geology, including topography, of the surficial deposits. In addition, the climate and vegetation have had primary influence on pedogenesis.

The parent material of the soils is in all cases unconsolidated coastal plain sediments. The mineral soils range in texture from sands to clays. The topography of the area is generally very flat due to the nature of the depositional process, and this has profound influence on the hydrology. Broad flat areas, especially of finer sediments, tend to be poorly drained, and this situation is here aggravated by the low elevation. Downcutting by the two major streams improves the drainage of only a small portion of the area. In contrast to the poorly drained soils there also exist much smaller areas of excessively-drained soils where deep deposits of sands from old dune systems are found.

The climate of the area influences both the physical-chemical processes and the biotic factors involved in soil development. Precipitation greatly exceeds evapotranspiration and this excess rainfall has a number of effects on soil genesis. Percolating rainfall coupled with relatively warm temperatures has served to leach nutrient cations from the soil and saturate the exchange complex with acidic species. The result is nutrient-deficient soils with low pH.

Soil is not only an important determinant of the type of vegetation found in an area, but in turn is influenced by the vegetation which it supports. Podzolization is a process characterized by the leaching out of organic matter and/or iron and aluminium from the upper part of the soil profile (A2 horizon) and the deposition of the leached material in the layer below (Bh horizon) (BUOL et al. 1973). Podzolization in quartzose sand is apparently favoured by certain types of vegetation which produce acid litter, including ericaceous species and the genera *Pinus* and *Quercus* (ETHERINGTON 1975).

In the southeastern coastal plain spodosol profiles develop in sandy sediments with water tables at or near the surface during part of the year. These

soils are the aquods or ground-water podzols. DANIELS et al. (1976) have studied the spodic horizons (Bh) of North Carolina soils in the Leon and related series. The spodic layers appear as dark brown to black layers composed of sand impregnated with organic matter, with almost no iron and little aluminium present. Apparently organic matter in the form of fulvic acids is released from the litter and the organic matter in the A1 horizon and is carried downward by percolating rainwater. The organic acids are then precipitated by some undetermined mechanism in the Bh horizon. That large amounts of organic acids are leached through these coastal plain soils is obvious from the tea color of the streams draining them.

The spodic horizon is often credited with slowing drainage (PERKINS et al. 1938) or even perching the water table (THOM 1970) and is commonly referred to as a hardpan. However, DANIELS et al. (1976) report that the water table moves freely through the Bh of soils in New Hanover County, North Carolina.

Another important way in which vegetation interacts with abiotic factors is in the process of paludization (BUOL et al. 1973), the accumulation of surface deposits of organic matter. This process might well be regarded as a geologic phenomenon as a pedogenic one. The accumulation of organic material occurs when the rate of litter production outstrips the rate of litter decomposition. The rate of decomposition is slowed down by a number of factors, especially waterlogging which creates anaerobic conditions which inhibit the activity of decomposer organisms. The low soil pH and paucity of nutrients also limit microbial activity. It should be noted that the peat formation here is due largely to accumulation of litter from trees and shrubs and not to a significant extent the presence of *Sphagnum*.

As accumulations of organic matter build up they tend to reinforce those conditions responsible for their formation. Much of Croatan National Forest is covered with peat deposits over 40 cm deep, and these constitute the histosols of the current U.S. soil taxonomy. The Lakes Pocosin in the center of the National Forest, which includes the research area, constitutes a raised bog (HEINSELMAN 1963). Organic matter accumulation began on a poorly drained, flat to concave, land surface and has continued to the point that the thickness of the peat deposits is often greater than one meter and the bog surface is highest in the center where the organic matter is assumed to

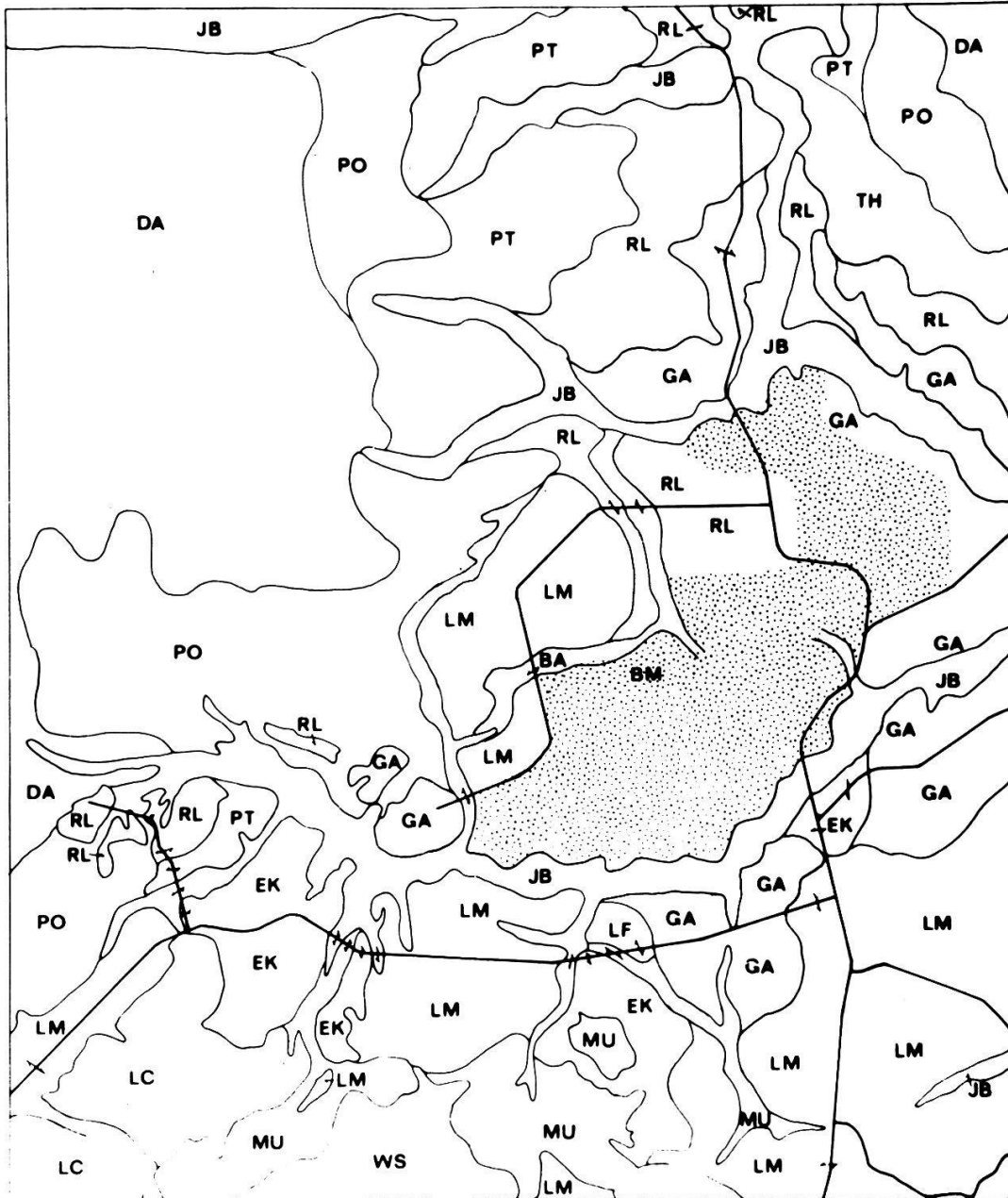


Figure 4. Soil map of the study area. The stippled area is inadequately mapped. Mapping unit descriptions are given in SNYDER (1978). The map was compiled from preliminary photomaps of a Forest Service soil survey (GREEN 1978).

- | | |
|---------------------------|----------------------|
| BA = Bayboro | LM = Leon-Murville |
| BM = Baymeade | MU = Murville |
| DA = Dare | PO = Ponzer |
| EK = Echaw-Kureb | PT = Pantego |
| GA = Goldsboro-Autryville | RL = Rains-Lynchberg |
| JB = Johnston-Muckalee | TH = Torhunta |
| LC = Leon complex | WS = Wasda |
| LF = Leaf | |

Table 1. Taxonomic classification of soil series.

| Series | Taxonomy | |
|------------|------------------------|---------------------------|
| Autryville | Arenic Paleudult | : loamy, siliceous |
| Bayboro | Umbric Paleaquult | : clayey, mixed |
| Baymeade | Arenic Hapludult | : loamy, siliceous |
| Dare | Typic Medisaprist | : dysic |
| Echaw | Entic Haplohumod | : sandy, siliceous |
| Goldsboro | Aquic Paleudult | : fine-loamy, siliceous |
| Johnston | Cumulic Humaquept | : coarse-loamy, siliceous |
| Kureb | Spodic Quartzipsamment | |
| Leaf | Typic Albaquult | : clayey, mixed |
| Leon | Aeric Haplaquod | : sandy, siliceous |
| Lynchberg | Aeric Paleaquult | : fine-loamy, siliceous |
| Muckalee | Typic Fluvaquent | : coarse-loamy, siliceous |
| Murville | Typic Haplaquod | : sandy, siliceous |
| Pantego | Umbric Paleaquult | : fine-loamy, siliceous |
| Ponzer | Terric Medisaprist | : loamy, mixed |
| Rains | Typic Paleaquult | : fine-loamy, siliceous |
| Torhunta | Typic Humaquept | : coarse-loamy, siliceous |
| Wasda | Histic Humaquept | : fine-loamy, mixed |

Table 2. Outline of soil series.

| Mineral Soils of Uplands | | | | | |
|--------------------------|---|-------------------------|------------------------------|----------------|--------------------------------|
| | Well drained | Moderately well drained | Somewhat poorly drained | Poorly drained | Very poorly drained |
| Fine-loamy | -- | Goldsboro | Lynchberg | Rains | Pantego/ Wasda ¹ |
| Loamy | Autryville ² | -- | -- | -- | -- |
| Coarse-loamy | -- | -- | -- | -- | Torhunta |
| Clayey | -- | -- | -- | Leaf | Bayboro |
| With spodic horizons | Baymeade ³ / Kureb ⁴ | Echaw | -- | Leon | Murville |
| Floodplains | | | Histosols | | |
| Sandy loam | Muckalee | | Organic surface 40-130 cm | Ponzer | |
| Muckey loam | Johnston | | Organic surface >130 cm | Dare | |

1 = with histic epipedon, 2 = with arenic surface, 3 = with Bh over argillic, 4 = excessively drained.

be the thickest. It is hypothesized that the 5 lakes in Croatan National Forest were actually formed by deep burning of the peat during severe drought (WELLS and BOYCE 1953).

Although soils with surface horizons of peat less than 40 cm thick are not classified as histosols they form an important part of the peatland landscape. For example, Wasda soils have histic epipedons which are not thick enough (less than 40 cm) to be called histosols. Most of the soil south of forest route 128 is spodosol with highly organic surface layers (Murville series) which make it ecologically part of the bog system.

The soils of Carteret County were last mapped in 1935 (PERKINS et al. 1938), long before the current soil taxonomy was formulated. A new county soil survey is currently in progress but is not yet available. However, the Forest Service has completed a reconnaissance soil survey of Croatan National Forest and the soil map (Fig. 4) was compiled from the photomaps produced in that survey. The mapping units are somewhat more broadly defined than those of a standard county soil survey but they provide sufficient resolution for soil-vegetation correlations. Table 1 gives the taxonomic classification of the soil series included in the mapping units, and Table 2 differentiates the series in a brief outline. A brief description of each of the mapping units is given in SNYDER (1978).

2. Methods

2.1. *Vegetation*

2.1.1. *Sampling*

The object of study within the circumscribed research area is the "natural vegetation". This excludes agricultural and residential areas and as defined here also excludes pine plantations in which evidence of site manipulations such as bedding is visible. Disturbed areas such as logging roads and plowed fire lines where the soil had been bared were not studied, but sites which had been prescription burned were included. Much of the *Pinus palustris* land has been cut in the last few years, but if there was evidence of regeneration and the ground cover appeared undisturbed it was considered natural vegetation.

The canopy of *P. palustris* forests is naturally somewhat open so that removal of trees does not cause a major change in the understory environment. The *P. palustris* sites also appear to be more resistant to disturbance in the sense that weedy species do not invade, probably because the sandy soils are not as easily altered by traffic as more loamy or organic soils. This does not hold however for the deep sands in the Kureb series.

The method used for sampling the vegetation was essentially the BRAUN-BLANQUET method as described by MUELLER-DOMBOIS and ELLENBERG (1974, see PITILLO 1979, in Vol. 1 of the 16th IPE report). The location of the relevés was partly by random selection of points and partly by subjective placement to include accessible sites and to represent the range of variation. A standard size relevé of 20 x 10 m was done at each point to permit direct comparison of species diversity. An area of 200 m² was more than adequate to sample all the vegetation types with the possible exception of the bottomland forest; even here there were rarely more than one or two additional species found outside the quadrat.

At each relevé a complete list of species present, the approximate heights of the various strata, and the importance of each species by stratum were recorded. Species importance was estimated by the use of a slightly modified BRAUN-BLANQUET cover-abundance scale as follows:

| | | | |
|---|--------------|---|-------------------------------|
| 5 | > 75 % cover | 1 | 1-5 % cover |
| 4 | 50-75 % | + | < 1 % |
| 3 | 25-50 % | R | one individual of < 1 % cover |
| 2 | 5-25 % | | |

Notes on the water table and evidence of past fires were recorded at each relevé. The depth of the water table was determined if it was less than 30 cm since that was the length of the soil auger used. Soil samples were collected and observations recorded at each relevé as described in the soil methods section. Other pertinent notes on such matters as the presence of stumps or additional species present outside of the plot were also recorded. In the rare cases in which there was appreciable slope, its degree and aspect were recorded.

2.1.2. *Synthesis of Phytosociological Tables*

The traditional method of table arrangement is normally done by hand which means that it is rather time-consuming. In addition to being rather slow,

there is constantly present the opportunity for copying errors as the tables are rearranged. There are available a number of computerized table methods which perform much of the tedious work formerly done by hand (LIETH and MOORE 1971, and several others mentioned in WESTHOFF and VAN DER MAAREL 1973). These computer methods can perform rearrangements quickly without errors in copying but in all cases require a subjective assessment and final touching up by the investigator.

In this study the computer program PHYTO (LIETH and MOORE 1971) was used to do the basic table work. The program provides for printout of a raw table and a presence or frequency table. The upper and lower frequency limits for delimiting species to be used in the clustering procedure are variable input parameters, and the rearranging is performed by a clustering algorithm. The program allows a final table to be printed in which the order of species and relevés is specified by the user. This permits the user to make improvements on the final differentiated table.

2.2. Soils

2.2.1. Sampling

Surface soil samples were collected at each relevé to permit making correlations between certain soil parameters and vegetation. The soil samples were composite samples of the upper 20 cm of the soil profile, excluding the litter layer. In general a subsample was collected one meter inside each corner of the relevé using either a soil auger or a machete, depending on soil texture and moisture content. The subsamples were pooled and transported in a plastic bag for later laboratory analysis. In some cases in very wet soils where there was difficulty in extracting samples only 2 subsamples were taken.

At each relevé a brief description of the soil color, texture, and consistency to a depth of 30 cm was recorded.

In addition to the sampling at each relevé a few more complete soil profiles were described within the research area. It was planned to do profiles in soils representative of each of the vegetation types but not all were done. These profiles were done from soil pits in the case of the drier areas or from cores extracted with an 8 cm bucket auger in wetter areas. The color of the fresh soils was determined with a Munsell color chart and then samples

of each horizon were collected in plastic bags for further analysis.

2.2.2. *Analysis*

Soils were generally close to field capacity or higher in moisture content when brought in from the field. Inasmuch as the literature suggests that drying and rewetting significantly affects pH values, especially in organic soils (FARNHAM and FINNEY 1965), the soil pH was measured before drying in a 1:2 (soil to distilled water by volume) slurry equilibrated for 30 minutes. The soils were then dried at 50 - 70°C and stored up to 3 months before further analysis.

The soils were crushed and sieved through a U.S. standard sieve no. 12 (mesh size 1.68 mm) before being sent to the Soil Testing Division of the North Carolina Department of Agriculture. Three of the surface soil samples and the profile samples were not sieved before being sent to the state lab and there they received the standard treatment of crushing and separation through a 2 mm screen. This difference in mesh size is insignificant since none of the soil samples contained any particles larger than 1.68 mm in diameter other than coarse pieces of plant material.

All further analysis was performed on dried and sieved material by the Soil Testing Division. The volume weight was determined on an unpacked sample and pH was measured in a 1:1 (water) slurry with an equilibration time of one hour. The amount of readily oxidizable organic matter was measured by a modification of the WALKLEY-BLACK wet combustion method. The buffer acidity was determined by a barium-triethanolamine method at pH 6.6.

Inorganic nutrients were analyzed by extracting 5 cm³ of soil with 25 ml of a solution of 0.5N HCl and 0.025N H₂SO₄. Calcium, magnesium, and manganese were measured by atomic absorption spectrophotometry, potassium by flame photometry, and phosphorus by a colorimetric method utilizing molybdate and ascorbic acid. Detailed methods are described in SOIL TESTING DIVISION (1972).

With these methods only a crude approximation of the cation exchange capacity and percentage base saturation of the soils can be calculated. The cation exchange capacity is found by summing the buffer acidity and the extractable quantities of the basic cations calcium, magnesium, and potassium. The percentage base saturation is calculated by dividing the sum of the basic

cations by the cation exchange capacity and multiplying by 100.

This approximation differs from a more suitable method such as the normal ammonium acetate saturation method conducted at soil pH. The acidity was determined at pH 6.6 which is well above soil pH and therefore tends to overestimate exchangeable acidity (BUOL et al. 1973). Also, the weak acid extraction procedure for the cations does not yield values particularly close to those found exchangeable by ammonium acetate extraction (cf. DOLMAN and BUOL 1967). However, this approximation can at least give an idea of the relative base status and exchange capabilities of the various soils.

3. Results and Discussion

3.1. *Vegetation*

3.1.1. *Phytosociology*

The data from 91 relevés (54 randomly and 37 subjectively chosen) was run through the PHYTO program to produce the preliminary species-relevé clusters. A number of clusters were evident, and the relevés of each cluster were then run separately to determine if there were subclusters or atypical relevés. It became evident through this analysis that some of the relevés did not meet the requirement of homogeneity. Almost all of these were randomly chosen relevés which were noted as being heterogeneous in the field. A total of 12 relevés were heterogeneous in habitat factors and species composition, and they were not included in further tables.

The 79 relevés that remained after removal of heterogeneous plots fell into five fairly distinct groups when ordered by the clustering algorithm. A few changes were made by hand when consideration of all the species found in a relevé (rather than only those considered by the algorithm) in my judgement made it more appropriate in another group. Only the 12 relevés which were initially excluded were not included in the final grouping. In no case were any relevés removed from the tables because they did not "fit" in any group. The five clusters produced on the large table represent unranked vegetation units, or plant community-types. These community-types are here referred to

as Xeric Longleaf Pine-Oak, Longleaf Pine Savanna, Pocosin, Loblolly Pine-Hardwoods, and Bottomland Forest. The only type with recognized subunits is the Pocosin in which Short, Tall, and Bay Pocosin are found.

The results of the phytosociological analysis are presented in the form of a summary table (Table 3). The original table for the Pocosin community-type is also given (Table 4), but for the other original tables the reader is referred to SNYDER (1978).

3.1.2. *Mapping*

The distribution of the five major plant community-types is shown in a vegetation map (Fig. 5)*. The base map for the vegetation map was an uncorrected photomosaic constructed from 1971 black-and-white infrared aerial photographs with a scale of 1:15,840 (U.S. Forest Service 5-4-71, EWZ). Units were drawn on the aerial photos and traced onto the base map. A few areas of National Forest land were cut subsequent to the May 1971 photography, and these revisions were made using 1975 color photography (ASCS 2-8-75, 37049).

The mapping units and approximate areas are as follows:

Natural vegetation

1. Xeric Longleaf Pine-Oak. 0.4 %
2. Longleaf Pine Savanna. Includes areas which were clearcut but the soil was left undisturbed. (May contain up to 20 % Pocosin). 6.1 %
3. Pocosin. 69.2 %
 - a. Short Pocosin. May contain up to 20 % Longleaf Pine Savanna in southern part of map area.
 - b. Tall Pocosin.
 - c. Bay Pocosin.
4. Bottomland Forest. 5.8 %
5. Loblolly Pine-Hardwoods. 5.4 %

Other areas

6. Agricultural fields and residential areas. Residential areas are quite small in relation to fields. Unit also contains small inclusions of natural vegetation. 7.3 %
7. Young pine plantations and clearcut or disturbed forest areas. Most of this is recently planted loblolly or longleaf pine plantations in which management practices disturbed the soil. 5.8 %

The mapping units were identified on the basis of their appearance in the aerial photos and on field observations. The field observations include two flights over the area in a N.C. Forest Service plane in August 1976 and January 1977.

In some cases small areas of a vegetation type are mapped to emphasize cor-

* see in the pouched back-cover.

Table 3. Phytosociological Table

This table shows all the identified species found in one of the 79 relevés included in the community-type tables (SNYDER 1978). Each species has been assigned a constancy class for each community-type in which it occurs. There are five constancy classes based on equal increments of percent occurrence, or constancy: 5 = 100-81 %, 4 = 80-61 %, 3 = 60-41 %, 2 = 40-21 %, 1 = 20-1 %.

The differential species of the various community-types are given first, followed by the remaining species. An attempt was made to arrange the remaining species in groups with similar distributions. Species which only have a constancy class of 1 in one or two community-types are listed at the end. Nomenclature follows RADFORD et al. (1968). XER = Xeric Longleaf Pine-Oak, SAV = Longleaf Pine Savanna, POC = Pocosin, BOT = Bottomland Forest, LOB = Loblolly Pine-Hardwoods.

| Species | XER | SAV | POC | BOT | LOB |
|-----------------------------------|-----|-----|-----|-----|-----|
| <i>Cnidocolus stimulosa</i> | 5 | | | | |
| <i>Euphorbia ipocacuanhae</i> | 3 | | | | |
| <i>Tragia urens</i> | 3 | | | | |
| <i>Quercus laevis</i> | 2 | | | | |
| <i>Quercus margaretta</i> | 2 | | | | |
| <i>Scleria triglomerata</i> | 2 | | | | |
| <i>Tephrosia florida</i> | 2 | | | | |
| <i>Quercus falcata</i> | 2 | | | | 1 |
| <i>Sassafras albidum</i> | 2 | | | | 1 |
| <i>Quercus incana</i> | 5 | 1 | | | |
| <i>Aster tortifolius</i> | 5 | 1 | | | |
| <i>Aster linariifolius</i> | 5 | 2 | | | |
| <i>Heterotheca nervosa</i> | 5 | 4 | | | |
| <i>Pinus palustris</i> | 5 | 5 | | | |
| <i>Carphephorus bellidifolius</i> | 3 | 1 | | | |
| <i>Trilisa paniculata</i> | 1 | 2 | | | |
| <i>Aster squarrosus</i> | | 2 | | | |
| <i>Carphephorus tomentosus</i> | | 2 | | | |
| <i>Eupatorium leucolepis</i> | | 2 | | | |
| <i>Hypericum reductum</i> | | 2 | | | |
| <i>Lespedeza capitata</i> | | 2 | | | |
| <i>Polygala lutea</i> | | 2 | | | |
| <i>Iris verna</i> | | 3 | | | 1 |
| <i>Eupatorium rotundifolium</i> | | 2 | | | 1 |
| <i>Panicum tenue</i> | | 2 | | | 1 |
| <i>Solidago odora</i> | | 2 | | | 1 |
| <i>Eupatorium pilosum</i> | | 3 | 1 | | |
| <i>Rhexia alifanus</i> | | 3 | 1 | | |
| <i>Xyris caroliniana</i> | | 3 | 1 | | |
| <i>Pinus serotina</i> | | 3 | 5 | | |
| <i>Calamovilfa brevipilis</i> | | 2 | 1 | | |
| <i>Lysimachia loomisii</i> | | 2 | 1 | | |
| <i>Sarracenia purpurea</i> | | 1 | 2 | | |

Table 3 (continued)

| Species | XER | SAV | POC | BOT | LOB |
|---|-----|-----|-----|-----|-----|
| <i>Zenobia pulverulenta</i> | | | 4 | | |
| <i>Carex walteriana</i> | | | 2 | | |
| <i>Cassandra calyculata</i> | | | 2 | | |
| <i>Itea virginica</i> | | | 1 | 4 | |
| <i>Osmunda regalis</i> var. <i>spectabilis</i> | | | 1 | 4 | |
| <i>Woodwardia areolata</i> | | | 1 | 5 | |
| <i>Cornus stricta</i> | | | | 4 | |
| <i>Decumaria barbara</i> | | | | 4 | |
| <i>Fraxinus</i> sp. | | | | 4 | |
| <i>Saururus cernuus</i> | | | | 4 | |
| <i>Ulmus americana</i> | | | | 4 | |
| <i>Berchemia scandens</i> | | | | 3 | |
| <i>Dioscorea villosa</i> | | | | 2 | |
| <i>Habenaria clavellata</i> | | | | 2 | |
| <i>Mikania scandens</i> | | | | 2 | |
| <i>Panicum commutatum</i> | | | | 2 | |
| <i>Polygonum</i> sp. | | | | 2 | |
| <i>Smilax walteri</i> | | | | 2 | |
| <i>Thelypteris palustris</i> | | | | 2 | |
| <i>Vitis</i> sp. (other than <i>V. rotundifolia</i>) | | | | 2 | |
| <i>Carpinus caroliniana</i> | | | | 3 | 1 |
| <i>Euonymus americanus</i> | | | | 2 | 1 |
| <i>Quercus michauxii</i> | | | | 2 | 1 |
| <i>Smilax bona-nox</i> | | | | 2 | 1 |
| <i>Anisostichus capreolata</i> | | | | 2 | 2 |
| <i>Mitchella repens</i> | | | | 2 | 2 |
| <i>Cornus florida</i> | | | | 1 | 2 |
| <i>Uniola laxa</i> | | | | 1 | 3 |
| <i>Nyssa sylvatica</i> | | | | | 4 |
| <i>Prunus serotina</i> | | | | | 3 |
| <i>Quercus stellata</i> | | | | | 2 |
| <i>Persea borbonia</i> | 2 | 4 | 5 | 5 | 5 |
| <i>Myrica cerifera</i> | 4 | 5 | 1 | 4 | 5 |
| <i>Ilex glabra</i> | 1 | 5 | 5 | 2 | 5 |
| <i>Smilax glauca</i> | 1 | 3 | 1 | 2 | 5 |
| <i>Gelsemium sempervirens</i> | 1 | 2 | 1 | 2 | 5 |
| <i>Rhus radicans</i> | 1 | 1 | 1 | 4 | 3 |
| <i>Sorbus arbutifolia</i> | | 5 | 5 | 1 | 2 |
| <i>Magnolia virginiana</i> | | 3 | 5 | 3 | 3 |
| <i>Ilex coriacea</i> | | 2 | 4 | 2 | 2 |
| <i>Gordonia lasianthus</i> | | 1 | 4 | | 1 |
| <i>Smilax laurifolia</i> | | 2 | 5 | 3 | 1 |
| <i>Lyonia lucida</i> | | 2 | 5 | 3 | 2 |
| <i>Woodwardia virginica</i> | | 1 | 5 | 3 | 2 |
| <i>Sphagnum</i> | | 1 | 4 | 3 | |

Table 3 (continued)

| Species | XER | SAV | POC | BOT | LOB |
|--|-----|-----|-----|-----|-----|
| <i>Cyrilla racemiflora</i> | | 2 | 5 | 2 | 3 |
| <i>Myrica heterophylla</i> | | 3 | 5 | 2 | 4 |
| <i>Nyssa sylvatica</i> var. <i>biflora</i> | | 2 | 4 | 5 | 1 |
| <i>Acer rubrum</i> | | 3 | 2 | 5 | 5 |
| <i>Liquidambar styraciflua</i> | | 2 | 1 | 5 | 5 |
| <i>Ilex opaca</i> | | 1 | 1 | 5 | 5 |
| <i>Parthenocissus quinquefolia</i> | | 1 | 1 | 4 | 3 |
| <i>Clethra alnifolia</i> | | 1 | 2 | 3 | 2 |
| <i>Symplocos tinctoria</i> | | 2 | 1 | 1 | 4 |
| <i>Vaccinium atrococcum</i> | | 3 | 2 | 1 | 4 |
| <i>Arundinaria gigantea</i> | | 2 | 2 | 2 | 2 |
| <i>Osmunda cinnamomea</i> | | 1 | 1 | 2 | 1 |
| <i>Lyonia ligustrina</i> | | 1 | 1 | 1 | 1 |
| <i>Aristida stricta</i> | 5 | 5 | 1 | | 1 |
| <i>Andropogon scoparius</i> | 5 | 3 | 1 | | 1 |
| <i>Gaylussacia dumosa</i> | 3 | 4 | 2 | | 1 |
| <i>Vaccinium crassifolium</i> | 3 | 5 | 1 | | |
| <i>Pteridium aquilinum</i> | 3 | 4 | 1 | | 3 |
| <i>Gaylussacia frondosa</i> | 3 | 5 | 2 | | 5 |
| <i>Rhus copallina</i> | 1 | 2 | 1 | | 2 |
| <i>Lyonia mariana</i> | 1 | 2 | 1 | | 1 |
| <i>Vaccinium tenellum</i> | 4 | 5 | | | 3 |
| <i>Trilisa odoratissima</i> | 2 | 4 | | | 1 |
| <i>Panicum consanguineum</i> | 1 | 2 | | | 1 |
| <i>Vaccinium stamineum</i> | 3 | 1 | | | 1 |
| <i>Pinus taeda</i> | 2 | 1 | | 3 | 5 |
| <i>Hypericum hypericoides</i> | 1 | 1 | | 3 | 4 |
| <i>Quercus laurifolia</i> | 1 | 1 | | 3 | 3 |
| <i>Diospyros virginiana</i> | 1 | 1 | | 2 | 1 |
| <i>Quercus nigra</i> | | 1 | | 2 | 5 |
| <i>Vitis rotundifolia</i> | | 1 | | 3 | 3 |
| <i>Smilax rotundifolia</i> | | 1 | | 2 | 2 |
| <i>Leucothoe axillaris</i> | | | 1 | 3 | 3 |
| <i>Viburnum nudum</i> | | | 1 | 3 | 1 |
| <i>Leucothoe racemosa</i> | | | 1 | 1 | 1 |
| <i>Andropogon virginicus</i> | | 3 | 2 | | 1 |
| <i>Panicum dichotomum</i> | | 1 | 1 | | 1 |
| <i>Amphicarpum purshii</i> | | 1 | 1 | | 1 |

Table 3 (continued)

Species with a constancy value of one in two community-types.

- XER-SAV: *Desmodium tenuifolium*, *Fimbristylis spadicea*, *Lespedeza hirta*,
Panicum lancearium
XER-LOB: *Castanea pumila* var. *ashei*
SAV-POC: *Gaultheria procumbens*, *Kalmia angustifolia* var. *caroliniana*,
Lachnanthes caroliniana, *Polygala brevifolia*, *Rhynchospora wrightiana*,
Sabatia difformis, *Sarracenia flava*, *Scleria minor*, *Xyris ambigua*,
Zigadenus densus.
SAV-BOT: *Viola primulifolia*
SAV-LOB: *Aster dumosus*, *Habenaria ciliaris*, *Quercus virginiana*
POC-LOB: *Ilex cassine* var. *myrtifolia*
BOT-LOB: *Callicarpa americana*, *Campsis radicans*, *Polypodium polypodioides*,
Quercus phellos, *Smilax hispida*, *Smilax smallii*
-

Species with a constancy value of one in only one community-type.

- XER: *Asclepias humistrata*, *Bonamia patens* var. *angustifolia*, *Carduus repandus*,
Eupatorium album, *Galactia regularis*, *Hieracium gronovii*, *Liatris gra-*
minifolia, *Marshallia graminifolia*, *Rhus toxicodendron*
SAV: *Agalinis purpurea*, *Agalinis setacea*, *Aletris farinosa*, *Aristida virgata*,
Arnica acaulis, *Aster concolor*, *Aster paludosus*, *Aster solidagineus*,
Carduus virginianus, *Cassia nictitans*, *Centrosema virginianum*, *Chondro-*
phora nudata, *Drosera capillaris*, *Gentiana autumnalis*, *Heterotheca ma-*
riana, *Hypericum stans*, *Juncus dichotomus*, *Lespedeza angustifolia*, *Linum*
virginianum var. *floridanum*, *Lobelia nuttallii*, *Lycopodium alopecuroides*,
Panicum angustifolium, *Panicum portoricense*, *Panicum strigosum*, *Ptero-*
caulon pycnostachyum, *Pyxidantha barbulata*, *Rhynchospora ciliaris*,
Rhynchospora plumosa, *Rubus argutus*, *Rubus flagellaris*, *Scleria ciliata*,
Seymeria cassioides, *Sisyrinchium albidum*, *Solidago microcephala*, *Soli-*
dago sempervirens, *Solidago stricta*, *Spiranthes praecox*, *Stylosanthes*
biflora, *Tephrosia hispidula*, *Tephrosia spicata*, *Viola emarginata* var.
acutiloba
POC: *Drosera intermedia*, *Lysimachia asperulaefolia*, *Panicum ensifolium*, *Pel-*
tandra sagittaeifolia, *Pogonia ophioglossoides*, *Rhododendron atlanticum*,
Rhynchospora gracilentata, *Zigadenus glaberrimus*
BOT: *Arisaema triphyllum*, *Boehmeria cylindrica*, *Carex debilis*, *Carex lupulina*,
Carex crinita var. *mittchelliana*, *Centella asiatica*, *Crateagus* sp., *Dry-*
opteris ludoviciana, *Dulichium arundinaceum*, *Eupatorium dubium*, *Hyperic-*
um walteri, *Hypoxis hirsuta* var. *leptocarpa*, *Juncus coriaceus*, *Juniperus*
virginiana, *Ligustrum sinense*, *Lobelia cardinalis*, *Ludwigia repens*,
Phoradendron serotinum, *Pluchea foetida*, *Rhynchospora miliacea*, *Rhyncho-*
spora mixta, *Rosa palustris*, *Rubus betulifolius*, *Sabal minor*, *Salix ca-*
roliniana, *Salix nigra*, *Sanicula canadensis*, *Sparganium americanum*, *Taxo-*
dium distichum, *Ulmus alata*, *Viola affinis*
LOB: *Amelanchier canadensis*, *Aralia spinosa*, *Aster paternus*, *Chimaphila macu-*
lata, *Elephantopus nudatus*, *Galium pilosum*, *Isotria verticillata*, *Lirio-*
dendron tulipifera, *Oxydendrum arboreum*, *Panicum ciliatum*, *Panicum virga-*
tum, *Quercus alba*, *Quercus marilandica*, *Vaccinium corymbosum*.
-

respondence with certain landscape features, such as the Longleaf Pine Savannas on the rims of Carolina bays.

3.1.3. Community-type Descriptions

3.1.3.1. Xeric Longleaf Pine-Oak

Setting: The Xeric Longleaf Pine-Oak community-type is found on low ridges of deep sands belonging to the Kureb soil series. These areas are mapped as part of the Echaw-Kureb unit on the soils map. Kureb soils are excessively drained and form the most xeric, nutrient deficient habitat in the research area.

This community is the least extensive of the major plant communities as this soil is found in only a few locations - mostly along forest route 128 and one site southeast of the intersection of county roads 1124 and 1140. The area of this type is less than 0.5 % of the total area.

The Xeric Longleaf Pine-Oak community is usually bordered by Longleaf Pine Savanna on the less well-drained sandy soils, although it may grade rapidly into Pocosin if the slope drops down to very poorly drained Murville soils.

Physiognomy and dominants: The Xeric Longleaf Pine-Oak community has the overall aspect of an open woodland. The canopy is open to very open and is composed entirely of pine with a crown height of 10-20 m. Typically the pine species is longleaf pine, *Pinus palustris*, although two relevés include *Pinus taeda* in addition. The amount of tree-sized pine is quite low in some cases because of cutting.

The subcanopy is also open and is predominantly formed by oaks and young pine about 3-10 m tall. The oaks present include *Quercus incana*, *Q. laevis*, *Q. falcata*, and *Q. margaretta*. *Q. virginiana* is infrequently present but was not included in any relevés.

The shrub layer is very sparse, mostly young oaks (or sprouts), especially *Q. incana*, and pine. Occasionally *Gaylussacia dumosa*, *G. frondosa*, or *Myrica cerifera* are significant in terms of cover.

The herbaceous layer is dominated by wiregrass, *Aristida stricta*, although the clumps rarely have more than 25 % cover. The only other herbs of any importance are *Carphephorus bellidifolius* and *Pteridium aquilinum*. The herbs do not completely obscure the ground surface and the light sand is exposed, especially in areas recently burned where the *Aristida* and pine litter have been removed. In some of the driest stands where there are large patches of

exposed sand *Cladonia* and a moss species are found.

Diagnostic species: Among those species restricted in distribution to the Xeric Longleaf Pine-Oak community, the three which occur most frequently are all herbaceous members of the *Euphorbiaceae*: *Cnidoscolus stimulosus*, *Euphorbia ipecacuanhae*, and *Tragia urens*. *Quercus laevis*, *Q. margaretta*, *Scleria triglomerata*, and *Tephrosia florida* are also faithful to this community although they appear in less than a third of the relevés.

Species of high constancy in this community-type but shared to some degree with the Savanna community include the composites *Aster tortifolius*, *A. linariifolius*, and *Heterotheca nervosa*. *Andropogon scoparius* is another species of common occurrence in this community which is found to a lesser degree in the savanna and rarely elsewhere. The canopy dominant *P. palustris* and the grass *Aristida* are equally characteristic of the Xeric Longleaf Pine-Oak and Longleaf Pine Savanna communities but *Quercus incana* is only rarely found in the savanna.

Other descriptions: In his summary of the major vegetational features of the North Carolina coastal plain, WELLS (1928) refers this community to the *Quercus-Aristida* associates, or the xeric coarse sandridge and interridge community. In a subsequent paper (WELLS and SHUNK 1931) he gives a detailed description of five phases of this associates found in the sandhill region of North Carolina. The most xeric phase, his xeric pioneer stage, is not found within the research area but is represented nearby to the south in the Patsy Pond area of the National Forest. Here expanses of bare sand with clumps of *Cladonia* are found under the scattered *P. palustris*, *Q. laevis*, and *Q. incana*; and characteristic herbs such as *Stipulicida setacea* and *Polygonella polygama* are present. This phase is so dry that little or no *Aristida* grows there.

The Xeric Pine-Oak found in the research area corresponds most closely to the xeric and xero-mesic phases of WELLS and SHUNK (1931) where *Aristida* is important and *Q. incana* and *Q. margaretta* join the *Q. laevis*. WELLS orders the following sandhill oak species found in the study area from xeric to mesic: *Q. laevis*, *Q. incana*, *Q. marilandica*, *Q. margaretta*, *Q. stellata*, *Q. falcata*, and *Q. alba*. In the relatively few stands of the Xeric Pine-Oak community in the research area *Q. incana* is found throughout, *Q. laevis* in the most xeric

sites, and *Q. margaretta* and *Q. falcata* in the more mesic sites. *Quercus marilandica*, *Q. stellata*, and *Q. alba* are found only rarely in the Loblolly Pine-Hardwoods community.

The distribution of the Xeric Longleaf Pine-Oak community is from the southern coastal plain of North Carolina (less commonly in the northern coastal plain) to northern Florida and as far west as east Texas (WELLS and SHUNK 1931). This is essentially the native range of *Pinus palustris*.

LAESSLE (1942) has described the sandhill vegetation of north central Florida, dividing it into a *P. palustris*-*Q. laevis* association on drier sites and a *P. palustris*-*Q. incana* association on slightly more mesic sites. Floristically the two associations are quite similar although the wiregrass cover is thicker in the more mesic community. MONK (1968) refers to turkey oak (*Q. laevis*) and sand post oak (*Q. margaretta*) phases of the sandhill vegetation in northern Florida.

Fire: The Xeric Longleaf Pine-Oak community-type evolved under a selective force of frequent fire. Only the most unproductive sites with little litter accumulation escape fire for long periods of time. The longleaf pine sites in the National Forest are prescription burned about every 2-3 years if there is sufficient fuel present. If fire were to be excluded there would be increased importance of the oaks and a gradual shift to a more mesophytic hardwood community (WELLS and SHUNK 1931, MONK 1968, VENO 1976).

3.1.3.2. Longleaf Pine Savanna

Setting: Longleaf Pine Savanna is found on flats and areas of slightly rolling topography. Along forest route 128 it is found on the Leon soils of the Leon-Murville and Leon complex mapping units and the more mesic portions of the Echaw-Kureb units. These are the sandy ground-water podzols with the chocolate-colored Bh horizons. The water table is near or at the surface during rainy periods. My observations in the field did not settle the question of the perched water table but the hard Bh appears to retard water percolation somewhat. The neighboring community on the more xeric extreme is the Xeric Longleaf Pine-Oak and on the more hydric extreme, Pocosin. The Savanna frequently has fingers of Pocosin on Murville soils running through it.

The Savanna is also found on loamy soils mapped as Rains-Lynchburg or Goldsboro-Autryville and is here associated with Tall Pocosin and Bottomland

communities on adjoining more poorly drained areas. The Loblolly-Hardwood community is sometimes found in similar situations.

Physiognomy and dominants: The aspect of the Longleaf Pine Savanna actually varies from a treeless savanna to a woodland. The canopy of pine is generally 15-25 m tall but quite variable from dense to nonexistent. In some clearcut areas only seedlings and saplings are present. The most important tree is *Pinus palustris* but it may be accompanied by *P. serotina* in the wetter areas or by *P. taeda* elsewhere. The savanna really has no distinct subcanopy although pine regeneration is often present and occasionally *Liquidambar styraciflua* or *Magnolia virginiana* may extend above the shrub layer.

The shrub layer is rather low, mostly below one meter, and the amount of cover is variable. *Ilex glabra* is often the most important component although *Gaylussacia frondosa* is frequently a co-dominant. Other shrubs occasionally with significant cover include *Vaccinium tenellum*, *V. crassifolium* (quite low and sprawling, belonging more to the ground layer), *Magnolia virginiana*, *Lyonia lucida*, and the bamboo *Arundinaria gigantea*.

The amount of herb cover is to a certain extent inversely proportional to the amount of shrub cover and, as in the case of Xeric Pine-Oak community, the herbaceous stratum is dominated by the bunch grass *Aristida stricta*. In moist spots the grass *Calamovilfa brevipilis* may contribute noticeable cover. *Pteridium aquilinum* may form extensive colonies where it is the dominant herb and in depressions clumps of *Osmunda cinnamomea* are important. The Savanna is known for its rich floral displays in which many different species exhibit aspect dominance even though not important in terms of cover.

Diagnostic species: Relatively few species are found exclusively in the Savanna community, and these only have a constancy of about 25 %. Most are herbs and three of them are composites: *Eupatorium leucolepis*, *Carphephorus tomentosus*, and *Aster squarrosus*. The others are *Lespedeza capitata*, *Polygala lutea*, and *Hypericum reductum*.

Species of restricted distribution which are shared with one other community include *Pinus palustris* and *Heterotheca nervosa* which are quite common in both Savanna and the Xeric Pine-Oak. Other species of lower constancy are *Iris verna* which is also found less often in the Loblolly-Hardwoods community, and *Eupatorium pilosum*, *Rhexia alifanus*, and *Xyris caroliniana* which also rarely appear in Pocasin.

Species of nearly universal appearance include the stratum dominants *Pinus palustris*, *Ilex glabra*, and *A. stricta*. Shrubs of high constancy include the previously mentioned *Vaccinium tenellum*, *V. crassifolium*, and *Gaylussacia frondosa* along with *Myrica cerifera* and *Sorbus arbutifolia*. *Sorbus*, although usually present almost never contributes more than one percent cover.

Other species: As mentioned earlier, the Savannas have a reputation for large numbers of showy flowers which appear throughout the growing season. One group of such plants is the orchids which are represented by a number of species. A list of orchids observed blooming in the Savannas of the research area is given below. Another distinctive group of plants characteristic of the Savannas is the carnivorous plants, and those found in the area are also listed below.

Orchids:

Calopogon pallida
C. pulchellus
Cleistis divaricata
Habenaria blephariglottis
H. ciliaris
H. cristata
Pogonia ophioglossoides
Spiranthes praecox

Carnivorous Plants:

Dionaea muscipula
Drosera capillaris
D. intermedia
Pinguicula caerulea
P. pumila
Sarracenia flava
S. purpurea
Utricularia subulata

Two of the carnivorous plants deserve special mention. *Dionaea muscipula*, the Venus fly-trap, is an endemic to the Carolina coast whose habitat is the moist ecotonal areas between Longleaf Pine Savannas and Pocosin (ROBERTS and OOSTING 1958). *Dionaea* only appeared in one of the relevés, and this one was discarded for being heterogeneous because it included both Savanna and Pocosin. *Dionaea* is included here with the Savanna flora because it is part of the herb-dominated community, unable to tolerate shading by larger herbs and shrubs. *Pinguicula pumila* is notable because it represents a northward range extension from Pender County, the nearest location given in the Carolina Manual (RADFORD et al. 1968).

Asclepias pedicellata is a species present in the Savanna of the research area although not found in any relevés. It too represents a minor range extension in that the northernmost location listed in the Manual (RADFORD et al. 1968) is neighboring Onslow County.

Other descriptions: The Savanna community-type most closely approaches the hydric extreme of the sand ridge *Quercus-Aristida* associates described by WELLS

(WELLS and SHUNK 1931). He calls it the *Aristida* semi-bog phase, and it occurs on Leon soils. The Savanna is also closely allied to the upland grass-sedge bog, the *Ctenium*¹-*Panicum* associates (WELLS and SHUNK 1928). In a later paper WELLS (1946) simply refers to this community as the wiregrass (*Aristida stricta*) savanna.

The upland grass-sedge bog is considered to be the result of annual fire on a poorly drained sandy loam with a dark surface horizon. Few examples exist today but the lengthy lists of herbs present show it to be a floristically rich community. The bog is divided into two consocieties, the *Ctenium* consocieties or bog proper and the *Panicum* consocieties or transitional bog. The bog proper has longer periods of high water table (hydroperiod) than the surrounding transitional bog. *Aristida stricta* is not found in the grass-sedge bog but most of the *Ctenium*-*Panicum* associates can be found associated with *Aristida* elsewhere (WELLS and SHUNK 1931).

KOLOGISKI (1977) describes variation in pine savannas in the Green Swamp area of southern North Carolina. The main type he recognizes is the *P. palustris*/*Aristida stricta*-*Rhynchospora* type which may grade into a similar type dominated by *Pinus serotina* in wet ecotones bordering Pocosin. There are also *Pinus palustris*-dominated types with large amounts of *Gaylussacia frondosa* or *Ilex glabra*. Minor areas of the undergrowth may be dominated by *Arundinaria*, *Pteridium*, or *Osmunda cinnamomea*. Rather complete lists of species likely to be found in this community in North Carolina can be found in WELLS and SHUNK (1928) and KOLOGISKI (1977).

Farther south in Florida, the longleaf pine flatwoods described by LAESSLE (1942) are quite similar in composition and appearance although shrubby elements such as the palm *Serenoa repens* are more prominent.

Fire: The Longleaf Pine Savanna is a frequent-fire community-type. Various estimates of the fire cycle range from almost yearly (LAESSLE 1942), every 2-3 years (WAHLENBURG 1946), to upper limit of every 4-10 years (CHRISTENSEN 1977b). Since the fires are almost entirely man-caused the fire cycle is the result of a balance between fire prevention efforts and accidental or prescribed fires. In Croatan National Forest the prescribed burning program has

¹ Nomenclature has been changed to agree with RADFORD et al. (1968).

an approximate 2-3 year cycle for *Pinus palustris*-*Aristida stricta* stands. The frequent burning of Savanna maintains a herbaceous understory while a decreased fire frequency allows more shrubby growth. With complete elimination of fire some type of mixed hardwood forest would develop (HEYWARD 1939, MONK 1968, WELLS and SHUNK 1931). The composition of such a forest would be the product of species present before elimination of fire and the available seed sources. In the study area a community similar to the Loblolly Pine-Hardwoods would develop.

3.1.3.3. *Pocosin*

Introduction: The most extensive type of vegetation found in the study area (nearly 70 %) is found in wet areas where there is an accumulation of organic matter. The soils on which it is found range from mineral soils with black surface layers to true histosols with peat more than one meter deep. Pocosin is a shrub-dominated type of vegetation generally associated with *Pinus serotina*.

On a floristic basis the Pocosin community is distinguished from the other major plant communities by the presence of *Zenobia pulverulenta* which occurs in no other community and *Gordonia lasianthus* which only rarely is found elsewhere. Not all relevés included in the Pocosin table (Table 4) have one or both of these species but the unit is held together by a large number of species of high constancy. *Smilax laurifolia* is present everywhere in Pocosin and the following additional plants have constancy greater than 80 %: *Pinus serotina*, *Cyrilla racemiflora*, *Lyonia lucida*, *Persea borbonia*, *Ilex glabra*, *Myrica heterophylla*, *Magnolia virginiana*, *Sorbus arbutifolia*, and *Woodwardia virginica*.

The Pocosin community can be divided into three subunits based on species distributions (see Table 4) and physiognomy. Each of the three subunits will be discussed separately.

Short Pocosin: Short Pocosin is found extensively in two different settings: on the Murville and Wasda soils in the Newport Barrier region of sandy sediments and in the deep organics (histosols) of the raised bog in the Backbarrier Flat region (Dare and some Ponzer soils). These are extremely waterlogged situations in which the soils are wet most of the year.

This subunit is the most distinctive type of Pocosin vegetation. Short Pocosin

usually has a dense shrub layer 1-2 m tall which is dominated by the ever-green shrubs *Cyrilla racemiflora* (really tardily deciduous), *Lyonia lucida*, and *Ilex coriacea*. Some of these species may have cover in excess of 25 %. The shrub *Zenobia* is characteristic of Short Pocosin and usually has cover between 5 and 25 %. The ubiquitous *Ilex glabra* often has significant cover. *Gaylussacia frondosa* infrequently is present with cover of 25 % or more. Occasionally species which can reach tree proportions are found as significant members of the shrub layer. These include *Pinus serotina*, *Magnolia virginiana*, *Gordonia lasianthus*, *Nyssa sylvatica* var. *biflora*, and *Persea borbonia*. A few other small shrubs can have cover greater than 5 %, such as *Myrica heterophylla*, *Gaylussacia dumosa*, and *Sorbus arbutifolia* which is usually present but seldom of much cover.

Also contributing to the denseness of the shrub layer is the spiny vine *Smilax laurifolia* known commonly as bamboo or more appropriately as blaspHEME vine. The density of the shrubs coupled with liberal amounts of *Smilax* often makes this vegetation difficult to negotiate.

Above the shrubs, *Pinus serotina* may extend as very scattered individuals with cover always less than 25 %. The heights of the pines are usually less than 12 m and the trees appear stunted with gnarled crowns. Another species commonly visible a few meters above the shrubs is *Gordonia*; less frequently *Nyssa* and *Magnolia* are emergents.

Throughout the Short Pocosin cushions of *Sphagnum* are present, although they usually cover an area of only a few percent. The large fern *Woodwardia virginica* is also found scattered throughout.

In the shortest and most open pocosin vegetation *Carex walteriana* may share dominance with the shrub species - often with cover over 25 %. Strongly associated with the *Carex* is the small shrub *Cassandra* (*Chamaedaphne*) *calyculata* which rarely has much cover. The *Carex-Cassandra* extreme of Short Pocosin tends to have a number of herbaceous species present that otherwise are shaded out by the dense woody growth. These species include *Sarracenia purpurea*, *S. flava*, *Rhynchospora wrightiana*, *Andropogon virginicus*, and a few other species also found in wet Savannas. *Gaylussacia dumosa* is another small shrub which is found often in the open type of Short Pocosin.

A few spots of open water are visible in the histosol area of the Lakes Pocosin. These watery depressions are probably the result of deep burns of the peat

during a wild fire. Observations while flying over the area indicate that *Sarracenia flava* forms dense stands around the edges of these depressions where it is seen as a bright yellow band.

Cassandra (*Chamaedaphne*) and *Sarracenia purpurea* are two species found in the more familiar northern bogs which serve to emphasize the bog aspect of Pocosins.

Two species rare in North Carolina that are found in the Short Pocosin of the study area are *Peltandra sagittaeifolia* and *Lysimachia asperulaefolia*. *P. sagittaeifolia* is near the northern end of its range and *L. asperulaefolia* has a very spotty distribution in the Carolinas.

The remaining two subunits of the Pocosin type differ from Short Pocosin in general by taller growth; the lack of *Zenobia*, *Carex walteriana*, and *Cassandra*; and shift in dominance of the remaining species. Two species common in the Loblolly-Hardwoods type, *Liquidambar* and *Smilax glauca*, are floristic elements which help to distinguish the Tall and Bay Pocosin from the Short Pocosin but there are no species in either of these larger statured Pocosin subunits which are not found in other communities.

A separate investigation of Pocosin phytosociology was conducted in a 100 ha area of shrub bog on histosol southwest of Great Lake (SNYDER 1977). This site is part of the Lakes Pocosin complex that is found in the northern part of the study area; the only natural boundary separating the two sites is the hardwood forest along the drainage out of Great Lake. In the Great Lake site *Ilex coriacea* and *Myrica heterophylla* are differential species for Tall Pocosin and are not found in Short Pocosin. In the study area *I. coriacea* is found frequently in both Short and Tall Pocosin. A possible explanation for this difference in distribution is that *I. coriacea* can grow in Tall Pocosin sites and also in Short Pocosin sites if they have shallow organic horizons. The site near Great Lake is confined to deep organic soils but in the study area only one relevé (No. 93, Table 4) was a Short Pocosin on deep organics.

Tall Pocosin: The Tall Pocosin is best developed in the very poorly drained loamy mineral soils such as the Pantego and Torhunta series and some poorly drained Rains soils which border the raised bog system in the northern portion of the research area. It is also found on some areas of Ponzer soils and Bayboro soils.

In the Tall Pocosin subunit the shrub layer reaches 3-4 m and is dominated by *Cyrilla* which may have cover greater than 50 %. Usually *Ilex glabra* is present with cover less than 25 % but it tends to be shorter than *Cyrilla*. *Acer rubrum*, *Liquidambar*, and *Nyssa sylvatica* var. *biflora* may form a significant part of the shrub layer. As mentioned earlier, *Zenobia* is generally not found in Tall Pocosin. It is included in one relevé of the Tall Pocosin subunit but was only present along an old plowline which passed through the relevé. Normally *Zenobia* is excluded from Tall Pocosin by its shorter stature and shade intolerance.

Cyrilla may form an almost closed subcanopy above the other shrubs at about 6 m but there is no real distinction between the shrub layer and the subcanopy. *Nyssa* or *Pinus serotina* may be present as scattered individuals above the general shrub layer to 8 m.

In addition to the more vigorous growth of shrubs the Tall Pocosin is characterized by the better growth of the *Pinus serotina*. The pine forms a canopy of 25-75 % cover with heights from 8 to 18 m. The *P. serotina* in Tall Pocosin has better formed crowns and often has the monotonous appearance of a loblolly pine plantation. The broadleafed species *Acer*, *Nyssa*, and *Liquidambar* may also be found in the canopy. The pond cypress, *Taxodium ascendens*, was not encountered in any of the Pocosin relevés but observations from the air indicate that it can have significant cover in certain areas of Tall Pocosin.

The characteristic herbs of Tall Pocosin are *Woodwardia virginica* and to a lesser extent *Sphagnum*. In general fewer herbs are present due to the deeper shade.

Bay Pocosin: The Bay Pocosin subunit is the least extensive of the three subunits and is generally found on very poorly drained and highly organic Johnston-Muckalee or Murville soils at the heads of streams.

In the Bay Pocosin the dominance shifts to *Persea borbonia*, the red bay, and *Pinus serotina* is usually reduced in amount or absent altogether. The height of the canopy is usually 10-12 m but in more mature Bay forest as found in releve 94 the canopy is close to 20 m. A few other deciduous trees can be found in the canopy with the evergreen *Persea*: *Acer*, *Nyssa*, and *Liquidambar*.

In the subcanopy along with *Persea* and the other canopy species there may be

Magnolia and *Gordonia*, the sweet and loblolly bays respectively. Approximately the same shrubs as in the Tall Pocosin are present in the Bay Pocosin with *Lyonia*, *Ilex coriacea*, and *Cyrilla* being the most important.

Herbs are even less frequent here than elsewhere in Pocosin but *Woodwardia virginica* is still present.

Terminology: I have chosen to use the name "Pocosin" for the shrubby bog vegetation. The term "pocosin" is an indigenous Algonquin name (Delaware "pakwesen" or Cree "pakwas" according to WOODWELL 1956) although it has been abundantly bastardized by European colonists (KOLOGISKI 1977). Usage of the term is largely restricted to eastern North Carolina according to HARPER (1907), although in a review of the term KOLOGISKI (1977) found it used in Virginia as well as the Carolinas.

The term "pocosin" is also used in reference to the boggy habitat found in a number of physiographic situations (after WELLS and BOYCE 1953, WOODWELL 1956): Carolina bays, broad upland flats such as Lakes Pocosin and Holly Shelter, depressions between sand ridges, and poorly drained heads of streams. To a certain extent all of these are found in the study area. By some authors (e.g. MAKI 1974) the term "pocosin" is restricted to the shrub bogs found on broad upland flats but here the term is used in the wider sense.

In addition to "shrub-bog", a commonly used synonym for Pocosin is "bay" or "bayland" (WELLS 1928, 1946, KOLOGISKI 1977). In this paper the terms are not used synonymously. The term "bayhead" is frequently used further south to denote a vegetation dominated by broadleafed, usually evergreen, trees growing in wet acid soils (LAESSLE 1942, MONK 1966b). Three species with common names of "bay" - *Persea*, *Magnolia*, and *Gordonia* - are often important components of bayheads. BUELL (1946) and KOLOGISKI (1977) in North Carolina have called a broadleafed forest on peat a bay forest, and it is in this sense that "Bay" is used here.

Bay Pocosin is considered to be a part of the Pocosin community because it is related floristically and successionaly to the other Pocosin subunits. The trees which can form the Bay forest - *Persea*, *Magnolia*, *Gordonia*, *Acer*, *Nyssa* - are found as part of the general shrub layer elsewhere in Pocosin, and there are not any species which distinguish it floristically; and although it can be considered a forest type it still possesses a dense shrub undergrowth.

The Short and Tall Pocosin subunits correspond in general to the low and high pocosin of local forestry usage (WENDEL et al. 1952). Referring to Tall and Short Pocosin eliminates some ambiguity in the local terms - "low" Pocosin is usually found in a topographically higher position than "high" Pocosin in the large raised bogs.

Other descriptions: WELLS (1928) in his summary of coastal plain vegetation calls Pocosin the *Ilex-Myrica-Cyrilla* associates. He states that it is the most indefinite of the major communities and that it grades into other communities, especially the swamp forest.

BUELL (1946) described the vegetation in Jerome Bog, a Carolina bay in southern North Carolina. His low shrub community is similar in composition and appearance to the more open type of Short Pocosin described here, and his pocosin pine (*Pinus serotina*) forest corresponds to a Tall Pocosin community. The tall shrub community he describes is intermediate between the denser type of Short Pocosin and Tall Pocosin. The only species listed for Jerome Bog that are not found in the Pocosin of the study area are *Ilex laevigata* and *Amelanchier canadensis*. The bay forest community described by BUELL is analogous to the Bay Pocosin of the study area but is dominated by *Acer rubrum* and *Magnolia virginiana*. An Atlantic white cedar (*Chamaecyparis thyoides*) forest is also present in Jerome Bog. *Chamaecyparis* is an element of the Pocosin bog system that is missing from the study area. It is quite uncommon in Croatan National Forest, and I have only seen a small area of it along the northern border of Catfish Lake.

A few detailed phytosociological studies of Pocosin in the Carolinas have been done. WELLS (1946) examined the large Holly Shelter Bay (Pocosin) in nearby Pender County. His data describe a community indistinguishable from the Short Pocosin of the study area.

The Green Swamp in Brunswick County is another of the large pocosin areas of the North Carolina coastal plain and KOLOGISKI (1977) has recently reported on the phytosociology of the area. He describes 6 major vegetation types within the bog system. His pine-ericalean pocosin type corresponds largely to the Short Pocosin of this study, although he considers the open areas dominated by *Carex walteriana* to be a separate type. His conifer hardwood pocosin is equivalent to the Tall Pocosin of this study, and his evergreen and decid-

uous forests are essentially Bay Pocosin with different dominant species. The *Chamaecyparis* bog is well represented in the Green Swamp.

WOODWELL (1956) surveyed the Pocosin vegetation in North and South Carolina and delineated three associations based on dominance in the shrub layer. He found that there was geographic segregation with *Cyrilla* the most important shrub in the northern part of the range, *Lyonia* in the southern part of the range, and *Zenobia* a successional stage which overlapped the ranges of the other two. His *Zenobia* association clearly falls within the Short Pocosin type. The *Lyonia* association would apparently be considered Tall Pocosin as described here, and the stands included in the *Cyrilla* association would represent both Short and Tall Pocosin communities.

Pocosin vegetation is apparently best developed within the range of *Zenobia* which is endemic to the coastal plain of the Carolinas and southeast Virginia. However, similar plant communities are found both to the north and south along the coast. KEARNY (1901) describes a similar type of vegetation in the Dismal Swamp region of southeastern Virginia which however lacks *Cyrilla*, *Zenobia*, and *Pinus serotina*. In north central Florida *P. serotina* is found in poorly drained flatwoods on acid sandy soil with a thin, hard organic surface layer (LAESSLE 1942). The shrub layer is predominantly *Lyonia lucida* but lesser amounts of *Ilex glabra*, *Kalmia hirsuta*, *Serenoa repens*, and *Lyonia ferruginea* are present. Shrubby pocosin-type vegetation is also found associated with *Pinus elliottii*, the slash pine, rather than *P. serotina*. The marginal thicket type of *P. elliottii* flatwoods in the more highly organic soils is similar in physiognomy to Pocosin (LAESSLE 1942).

The bayheads of north central Florida (LAESSLE 1942, MONK 1966b) are composed almost entirely of species found in the Pocosin in North Carolina, except for relic *P. elliottii* whose range reaches only to the southern coastal plain of South Carolina (RADFORD et al. 1968).

Fire: Fires occur sporadically in Pocosins and are much more intense than the grass fires common in *Aristida* areas. During extensive dry periods the peat substrate as well as the litter and vegetation can burn (WELLS 1946, MAKI 1974). Estimates of fire frequency range from less than every 15-20 years (WOODWELL 1958) to every 15-30 years (CHRISTENSEN 1977b). WELLS suggested prescribed burning of Pocosin on 4-6 year cycle to maintain a medium density for wildlife habitat (WELLS 1946).

Most of the Pocosin vegetation in the study area burned in 1955 but since then only relatively small areas have experienced fire. Occasionally fires started in Savanna areas move into Pocosin, but under normal prescribed burning conditions fires do not penetrate more than a meter to two into Pocosin before going out. Difficulty in containing fires in Pocosin during dry seasons is one of the main reasons for extreme precaution necessary in prescribed burning.

Frequent burns which do not burn deeply into the peat favor *Zenobia* over *Cyrilla* due to the ability of *Zenobia* to sprout quickly and spread rapidly by rhizomes. However, deeper burns of the peat may eliminate the shallow-rooted *Zenobia* and the root-sprouting *Cyrilla* will become dominant. Deep burns of peat may also be responsible for the absence of *Pinus serotina* and *Gordonia* from an area (WELLS 1946).

In drier areas, frequent fires may lead to increased amounts of *Arundinaria* (HUGHES 1966, WELLS 1946). In wet spots of bare peat exposed by burning *Carex* and *Sphagnum* often become prominent, while in less wet spots *Andropogon* may be the colonizer (WELLS 1946). Under annual fire, the Pocosin on mineral soil is converted to grass-sedge bog (WELLS 1928, WELLS and SHUNK 1928).

With the elimination of fire the successional trend appears to be toward the Bay Pocosin (BUELL 1946, WELLS 1946, WOODWELL 1956). The tree species which make up the Bay Pocosin are present throughout the Pocosin community and relief from fire would permit them to overtop the dense shrub layer.

3.1.3.4. *Bottomland Forest*

Setting: Bottomland Forest is found on the floodplains and adjoining lower slopes of the larger streams - the Northwest and Southwest Prongs of the Newport River and their tributaries. The soils are mapped as the mucky or sandy loams of the Johnston-Muckalee soils. This habitat is wet most of the year and is subject to flooding several times a year.

Physiognomy and dominants: The Bottomland Forest is the only major community in the study area dominated by deciduous, broadleaved trees; it also has the most diverse canopy composition in which dominance is shared by several species.

The canopy of the Bottomland Forest is generally closed with heights of 15 to 20 m although it can reach in excess of 30 m. The most important tree in

terms of cover is *Nyssa sylvatica* var. *biflora*, and it is frequently codominant with one or more of the following: *Pinus taeda*, *Liquidambar*, *Acer rubrum*, and *Fraxinus* spp. (*Fraxinus* is represented by *F. pennsylvanica* but there are likely other species involved). A number of other species may on occasion contribute significantly: *Taxodium distichum*, *Quercus michauxii*, *Q. nigra*, *Q. laurifolia*, and *Ulmus americana*.

The subcanopy in general reaches heights of 10 to 15 m but grades into the canopy. Canopy species are often found in the subcanopy; *Acer* is most frequently an important species. *Persea* and *Carpinus* are two important species which reach only subcanopy size as do the less important *Ilex opaca*, *Cyrilla*, and *Cornus florida*.

The shrub layer is usually very open and this makes movement through Bottomland much easier than through other wetland vegetation. However, *Leucothoe axillaris* often forms large patches and can have cover of over 50%. *Itea virginica* is occasionally present with significant cover and seedlings of *Persea* may be present in sufficient numbers to have greater than 5% cover.

A distinguishing characteristic of the Bottomland Forest which creates a tropical impression in presence of large numbers of lianas: *Berchemia scandens*, *Decumaria barbara*, *Vitis rotundifolia* and other *Vitis* spp., *Parthenocissus quinquefolia*, *Smilax* spp., and *Rhus radicans*.

The cover of the herbaceous layer tends to vary inversely with the amount of flooding. In most cases the conspicuous herbs are ferns, including *Woodwardia areolata*, *W. virginica*, *Osmunda regalis* var. *spectabilis*, and *O. cinnamomea*. In the drier areas *Dryopteris ludoviciana* is found. The dominant herb in the wettest locations is the forb *Saururus cernuus*. Patches of *Sphagnum* are also present where flooding is not too vigorous.

Diagnostic species: There are several species of moderate occurrence which are found only on the Bottomland community. These include the lianas *Decumaria* and *Berchemia*, the herb *Saururus*, and shrub *Cornus stricta*. The trees *Ulmus americana* and *Fraxinus* are also found nowhere else. Species less frequently encountered yet restricted to Bottomland Forest include *Dioscorea villosa*, *Mikania scandens*, *Habenaria clavellata*, and *Panicum commutatum*.

Species common in the Bottomland and only rarely seen elsewhere are *Woodwardia*

areolata, *Osmunda regalis* var. *spectabilis*, *Itea virginica*, and *Carpinus caroliniana*. Other species diagnostic by virtue of their high constancy are *Liquidambar*, *Persea*, *Nyssa*, *Acer*, and *Ilex opaca*.

One relevé (No. 95) included in the Bottomland table (SNYDER 1978, appendix A.4) represents vegetation approaching Bay Pocosin. It has an uncharacteristically low number of species but the presence of *Decumaria* and *Woodwardia areolata* indicate that its affinities are with the Bottomland Forest.

Other species: A large number of sedges are found here although they are not significant in terms of cover: *Carex debilis*, *C. lupulina*, *C. mitchelliana*, *Dulichium arundinaceum*, *Rhynchospora mixta*, *R. miliacea*, and at least an additional 8 species which could not be identified due to lack of fertile material. The palm *Sabal minor* was found in one relevé (No. 60) which is probably infrequently flooded.

Other descriptions: The Bottomland Forest belongs to the *Nyssa-Taxodium* subassociates of the *Nyssa-Taxodium-Chamaecyparis* associates of WELLS (1928). The *Chamaecyparis* subassociates of his swamp forest community-type would be here included in the Pocosin community-type since it is part of the bog system.

In a review of southern swamps, PENFOUND (1952) recognizes deep swamps and shallow swamps. The Bottomland Forest in the study area does not fit well into his classification. *Nyssa* and *Taxodium* of the deep swamp type are present in the research area but the Bottomland Forest is not flooded for extended periods of time. *Taxodium* is not very common in the research area but this may be due to selective cutting in the past. In terms of flooding regime the Bottomland Forest is more like the shallow fresh-water swamp. Genera such as *Fraxinus*, *Ulmus*, *Quercus*, and *Liquidambar* which indicate a transition to a more mesic forest are listed by PENFOUND (1952) as being present in shallow swamps.

The black gum swamp over sapric organic material in the Dismal Swamp as described by KEARNY (1901) is floristically very similar to the Bottomland Forest except that *Nyssa aquatica* is found there instead of *Nyssa sylvatica* var. *biflora* in the research area. A number of herbs are found in common with the Bottomland Forest and the presence of numerous lianas such as *Berchemia*, *Decumaria*, and *Vitis* is said to be characteristic.

In north central Florida mixed hardwood swamps are quite similar in tree

species composition although the addition of the subtropical element *Sabal palmetto* makes it distinctive (MONK 1966b).

Fire: Fire in the Bottomland Forest is an unlikely occurrence and there is almost no discussion of it in the literature (GARREN 1943). Ground fires are unlikely because of insufficient fuel. A crown fire would either eliminate the canopy trees or kill them back so that seedlings or sprout regeneration would be necessary to replace them. Certain understory trees and shrubs might benefit temporarily from increased light availability. According to WELLS (1928) the Bottomland Forest changes into Pocosin under aggradation and fire, a situation not likely to occur in the near future.

3.1.3.5. *Loblolly Pine-Hardwoods*

Setting: The Loblolly Pine-Hardwoods community-type is generally found on well drained (Goldsboro-Autryville) to poorly drained (Rains-Lynchburg) loamy soils bordering streams where it merges on the slopes with the Bottomland community. This community and the Longleaf Pine Savanna can both be found on these loamy soils but it appears that the Loblolly Pine-Hardwoods community is found more often on the soils with the higher clay content. The Loblolly Pine-Hardwoods is also found on the poorly drained, clayey Leaf soil in the research area. Much of the Loblolly Pine-Hardwoods borders on farmland on the side away from the Bottomland but it may be found grading into Tall Pocosin or Savanna depending on whether it is a wetter or drier situation.

Physiognomy and dominants: The Loblolly Pine-Hardwoods community is strictly a pine-dominated forest community at present but has a well-developed hardwood understory. The canopy is about 15-25 m tall, is fairly closed in most cases, and is composed almost entirely of *Pinus taeda*, loblolly pine. Only rarely are hardwoods found in the canopy.

The subcanopy beneath the pines reaches 5-10 m or more and is quite conspicuous although not dense. The leading constituents are *Liquidambar*, *Nyssa sylvatica* var. *sylvatica*, *Symplocos tinctoria*, *Quercus nigra*, *Q. stellata*, and *Q. falcata*.

The understory shrub layer is usually under 3 m tall but grades from low shrubs 0.5 m tall up to the subcanopy depending largely on the burning history. Saplings of *Liquidambar* are commonly important as is the shrub *Ilex glabra*.

A number of other shrubs can have cover greater than 5 %: *Leucothoe axillaris*, *L. racemosa*, *Myrica cerifera*, *Ilex coriacea*, *Gaylussacia frondosa*, *Clethra alnifolia*, *Lyonia lucida*, and *Magnolia virginiana*.

Lianas and sprawlers may add significant cover anywhere from the shrub layer to the canopy. Most often this is *Vitis rotundifolia* but *Gelsemium sempervirens*, *Smilax rotundifolia*, or *Rhus radicans* occasionally do so.

Herbaceous cover is generally very sparse but occasionally a few species have cover greater than 1 %. These are the ferns *Pteridium*, *Osmunda cinnamomea*, and *Woodwardia virginica*.

Diagnostic species: This community-type is poor in terms of good indicators restricted to Loblolly Pine-Hardwood. In this category only *Nyssa sylvatica* var. *sylvatica*, and *Prunus serotina* are of moderate constancy, and *Prunus* is usually found only as small saplings or seedlings. The grass *Uniola laxa* has moderate constancy in this community and only rarely occurs elsewhere in Bottomland Forest.

Although lacking in good "character" species this community has a number of species of high constancy which help to define it. Species found in all the Loblolly Pine-Hardwood relevés include *Pinus taeda*, *Liquidambar*, *Ilex glabra*, *Persea*, *Gaylussacia frondosa*, *Gelsemium sempervirens*, and *Smilax glauca*.

Other species with constancy greater than 80 % are *Quercus nigra*, *Acer rubrum*, *Ilex opaca*, and *Myrica cerifera*.

Other descriptions: It should be mentioned first that *Pinus taeda* is more prevalent on the North Carolina coastal plain today than it was historically. According to W.W. ASHE (1915) loblolly pine did not form extensive forests except in the extreme northeastern section of the state. The wide ecological tolerance of the tree and its extensive use as a plantation tree have made it the most common tree of the coastal plain.

WELLS (1928) lumps the upland forest communities (other than sand ridge vegetation) into a *Quercus-Carya-Pinus* associates. The *Pinus* consocieties can be dominated by either *P. taeda* or *P. palustris* and can be found on virtually any upland site. The understory of the Loblolly Pine-Hardwoods community-type contains some elements of the *Quercus* consocieties - *Liquidambar*, *Nyssa sylvatica*, *Quercus nigra* - and this is to be expected if the *Pinus* consocieties represents a successional stage preceding hardwood forest.

Although it is a widespread community there is relatively little literature on the composition of coastal plain loblolly pine forests. The hardwood forests which represent a later successional stage are mentioned in the discussion on fire.

Fire: *Pinus taeda* is an economically important tree and one of the main problems in its silviculture is suppressing the hardwood species which appear under the pine canopy. Prescribed burning is used to kill back such usurpers as *Liquidambar*, *Acer*, *Nyssa sylvatica*, and *Myrica cerifera* (LOTTI et al. 1960). In the study area most of the Loblolly Pine-Hardwoods is burned every 10 years or less, although some wetter sites have apparently been unburned for much longer periods.

As a seedling and sapling *P. taeda* is easily killed by even a light ground fire; however, once the tree reaches 3-4 m in height ground fires have little effect (LANGDON 1971). The *P. taeda* in the research area most likely became established during a period free from fires after clearcutting or a severe crown fire.

The trend is from pine-dominated forest toward dominance by hardwood species in the absence of fire. According to QUARTERMAN and KEEVER (1962) the climax vegetation of upland sites on the southeastern coastal plain is the southern mixed hardwoods community. Many of the characteristic tree species of this climax community are found in the understory of the Loblolly Pine-Hardwoods community, the most notable exceptions being *Fagus grandifolia*, *Magnolia grandiflora*, and *Carya* spp. In Florida the mesic hammocks (LAESSLE 1942) or southern mixed hardwoods (MONK 1965) show strong affinities with the Loblolly Pine-Hardwoods of the research area.

3.1.3.6. Other communities

Natural ponds: Several small ponds are found in the Longleaf Pine Savanna community south of road 1140. These ponds are in depressions probably formed during the deposition of the sandy sediments. The vegetation that is found in and around these ponds is distinctive but covers such small areas that it is not a mappable entity.

The vegetation is of note primarily for the occurrence of *Litsea aestivalis*, a lauraceous shrub with a center of distribution far to the south. The woody

vegetation in and around several for these depressions was examined but the herbaceous flora in the pond margins was flooded during the field season and no attempt was made to study the aquatics.

Commonly the following trees were found on the slopes around the ponds:

| | |
|---------------------------|--|
| <i>Pinus taeda</i> | <i>Q. virginiana</i> |
| <i>Quercus laurifolia</i> | <i>Nyssa sylvatica</i> var. <i>biflora</i> |
| <i>Q. nigra</i> | <i>Liquidambar styraciflua</i> |

The following shrubs were present:

| | |
|---|-----------------------------|
| <i>Cyrilla racemiflora</i> | |
| <i>Ilex cassine</i> var. <i>myrtifolia</i> | |
| <i>Litsea aestivalis</i> | |
| (the above were found on the bottom of the slopes or in standing water) | |
| <i>Ilex glabra</i> | <i>Myrica cerifera</i> |
| <i>I. opaca</i> | <i>Persea borbonia</i> |
| <i>Leucothoe racemosa</i> | <i>Vaccinium atrococcum</i> |
| <i>Lyonia lucida</i> | <i>V. corymbosum</i> |
| <i>L. mariana</i> | |

Around the margin of one of the larger ponds *Andropogon virginicus*, *Panicum* sp., *Cyperus* sp., and *Rhynchospora* sp. were seen. In the pond were *Nuphar luteum* ssp. *macrophyllum*, *Sphagnum* sp., and *Utricularia* sp. The ponds vary in size and degree of permanency and would undoubtedly yield a number of interesting species if studied carefully.

Disturbed habitats: Only two examples of communities of disturbed habitats will be mentioned. The first is the wet roadside or drainage ditch community. This community is quite prominent because wet ditches are very common in this area of poorly drained soils and because roadsides are visible while riding in an automobile.

Deep ditches filled with slowly moving water may be covered by *Utricularia purpurea* and shallow sandy ditches may be lined with different carnivorous plants and species of the moist Savannas. The diversity of the ditches appears to equal or exceed the diversity of the adjacent pinelands in terms of species per m².

Apparently many of the Savanna plants are better colonizers than *Aristida* and can flourish in disturbed habitats. The densest stand of *Dionaea* I have seen was in an area where a plow had scraped the top 15 cm of soil off a section of Savanna several square meters in area. The removal of *Aristida* may not

only lessen competition for light, water, and nutrients but may also remove the source of allelopathic inhibitors (CHRISTENSEN 1977b).

The other type of community in disturbed habitats is the young pine plantation. Here preplanting management practices such as disking and bedding not only disturb the soil surface, but they also introduce a high degree of microtopographic relief. A pattern of parallel rows in which the soil level is alternately raised and lowered creates a wide range of moisture conditions in a small area. The rich herbaceous flora of this habitat has been studied at a number of sites within the research area by WILSON (1978). The species richness of the disturbed communities greatly exceeds the richness of the undisturbed communities that they replace.

3.1.4. Floristics

3.1.4.1. Species diversity

The most basic concept of diversity is species richness, which can be measured as number of species per unit area (PEET 1974, WHITTAKER 1972). Table 5 compares the diversity of the five community-types in terms of species richness in 200 m² quadrats.

The community with the lowest total species diversity is the Xeric Pine-Oak. The mean number of 20 species per relevé is actually an overestimate due to the inclusion of a relevé (No. 83) which has an uncharacteristically high number of species. Without that relevé the mean number of species per relevé drops to 16.5. The low diversity of this community is possibly due to the extreme unfavorableness, low water and nutrient availability, which demands special adaptations on the part of the plants.

The highest species diversity is found in the Bottomland Forest and Longleaf Pine Savanna which both average over 32 species per relevé. Bottomland Forest is slightly more diverse, especially if a relevé transitional to Bay Pocosin is not included in the computations (Table 5). Bottomland Forest diversity is largely due to woody species whereas the Savanna richness is due to herbaceous species. The diversity of the Savanna is likely to be the most underestimated because of seasonal appearance of many of the herbs and the difficulty in distinguishing different species of sterile graminoids.

The herbaceous diversity of the Savannas is maintained by periodic disturbance

Table 5. Total species diversity of the major plant communities of the study area.

| | XER | SAV | POC | BOT | LOB |
|-----------------------------------|-----------------------------|------|------|-----------------------------|------|
| Number of relevés | 7 | 19 | 28 | 14 | 11 |
| Number of species | 56 | 152 | 80 | 116 | 100 |
| Average number of species/relevé | 19.6 (16.5) ¹ | 32.5 | 20.2 | 32.7 (34.1) ² | 30.4 |
| Largest number of species/relevé | 38 (25) ¹ | 46 | 32 | 50 | 42 |
| Smallest number of species/relevé | 10 | 24 | 11 | 15 (23) ² | 22 |

¹ Value discounting atypical relevé 83 given in parentheses.

² Value discounting atypical relevé 95 given in parentheses.

in the form of fire. If growth were allowed to become too thick, many of the smaller plants (e.g. *Dionaea*) would be eliminated. Fire might be likened to an "herbivore" which maintains diversity in a grassland (HARPER 1969). Fire may also increase diversity by removing allelopathic compounds produced by the dominant herb, *Aristida stricta* (CHRISTENSEN 1977b).

The Loblolly Pine-Hardwoods has a slightly lower level of diversity. The canopy is fairly dense pine, and this would be expected to suppress species diversity somewhat (WHITTAKER 1972, GLENN-LEWIN 1977). If this community were to remain undisturbed there would probably be a trend of increasing diversity along with hardwood dominance (QUARTERMAN and KEEVER 1962).

The Pocosin is a rather low diversity community-type except for the shrub layer. The total number of species (80) is much larger than the 40 species found in a different Pocosin site on histosols southwest of Great Lake (SNYDER 1977). This is due to the wider range of soil types found in the study area and to the interdigitation of Pocosin with other vegetation types, particularly Longleaf Pine Savanna, which allows more frequent colonization. The diversity of Pocosin is most likely limited by the unfavorableness of the habitat - low pH, waterlogging, and low nutrients. The trend of diversity with succession would probably be toward an even lower level as found in mature Bay Pocosin where dense shade eliminates most herbs and many intolerant shrubs.

There is little data on the total species diversity in plant communities of the southeastern coastal plain which can be directly compared to the communities of the study area. However, the data of MONK (1968) on tree species diversity of communities in north central Florida permit comparison of diversity of at least one component of the plant communities. In Table 6 the tree species richness of the five community-types in the study area is given along with the data from five similar communities in Florida. In this table a "tree" is any woody species capable of reaching 10 cm diameter breast height. The data from Florida represents species per stand rather than per sample plot and this may account for part of the consistently higher values found there.

The pattern of tree species diversity is the same in the study area as in north central Florida. The highest value is in the Pine-Hardwoods (southern mixed hardwoods) followed by Bottomland (mixed hardwood swamp). The Xeric Pine-Oak (sandhills) is the lowest in diversity and the Pocosin (bayheads) and Savanna (flatwoods) are both somewhat higher. This close correspondence of diversity patterns in tree species suggests that the communities in Florida are similar ecologically as well as floristically to those of the research area.

Table 6. Tree species diversity of the major plant communities of the study area and similar communities found in north central Florida (data of MONK 1968).

| | XER | SAV | POC | BOT | LOB |
|---------------------------------------|---------------------------|-----|-----|-----------------------------|------|
| STUDY AREA: Number of relevés | 7 | 19 | 28 | 14 | 11 |
| Number of tree species | 12 | 17 | 11 | 25 | 29 |
| Average number of tree species/relevé | 4.9 (3.8) ¹ | 5.9 | 6.0 | 10.4 (10.6) ² | 12.1 |
| FLORIDA: Number of stands | 16 | 32 | 9 | 24 | 60 |
| Number of tree species | 26 | 42 | 27 | 30 | 71 |
| Average number of tree species/stand | 8 | 10 | 10 | 14 | 20 |

¹ Value discounting atypical relevé 83 given in parentheses.

² Value discounting atypical relevé 95 given in parentheses.

Although the Loblolly Pine-Hardwoods community shows the highest tree species diversity as defined above, it does not have the highest diversity in terms of trees actually in the canopy. Most of the tree species in the Pine-Hardwoods are saplings or subcanopy individuals at present.

3.1.4.2. *Community similarity*

The overall floristic similarity of the five major community-types was computed using the coefficient of community (CC) which is based only on species presence (WHITTAKER 1972). The index is

$$\frac{2w}{A + B} \times 100$$

where w is the number of species in common and A and B are the number of species in the two sets being compared.

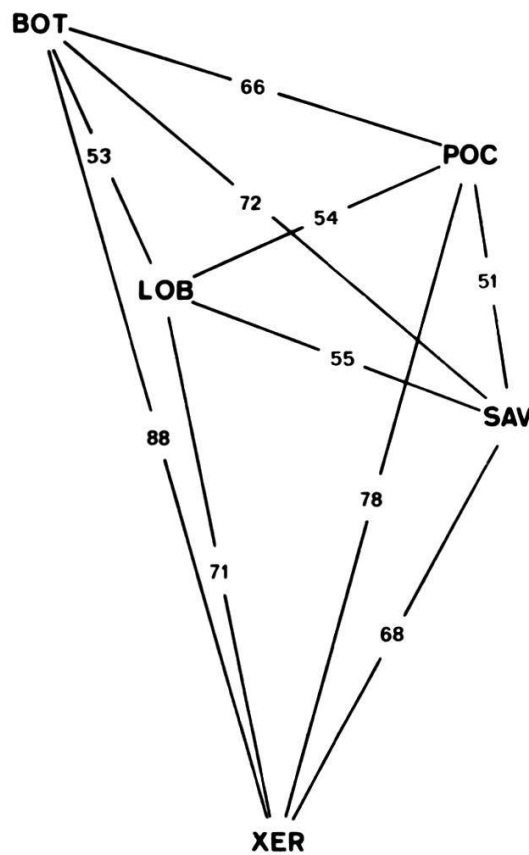


Figure 6. Graphic representation of the floristic similarity of the five major community-types. The closer two communities appear the greater their similarity. The numbers shown actually express dissimilarity (100 - coefficient of community) so that longer lines represent larger values. (XER = Xeric Longleaf Pine-Oak, SAV = Longleaf Pine Savanna, POC = Pocosin, BOT = Bottomland Forest, LOB = Loblolly Pine-Hardwoods).

The similarity relationships of the five community-types are shown graphically in Figure 6. The highest CC is between the Pocosin and Savanna types (49) but the Loblolly Pine-Hardwoods type has the greatest mean CC with the other four types. The Loblolly Pine-Hardwoods type is intermediate in terms of most important habitat factors and therefore might be expected to share many species with the other types. It is better defined by species of high constancy which also occur in other types than it is by species restricted to it alone.

The pair showing the lowest CC is the Xeric Pine-Oak and the Bottomland. This is expected because they occupy opposite extremes of the important habitat gradients. The Xeric Pine-Oak shows the lowest mean CC (24) because it is a dry habitat found surrounded by wet ones.

If floristic similarity is calculated with species weighted by their constancy class values there are some minor changes in the similarity relationships. The percent similarity (WHITTAKER 1972) of the Bottomland and Loblolly-Hardwoods is the highest (48) followed by Pocosin and Savanna (43) and Loblolly-Hardwoods with Savanna (42). Loblolly and Pocosin show a similarity of 39 % and the other comparisons show the same relations as with the unweighted index.

MONK (1968) calculated the percent similarity of various communities in north central Florida based on tree species only and weighted for presence. Of the communities with analogs in the research area, the pair with the highest similarity was the flatwoods (Savanna) and bayheads (Pocosin) with a similarity of 50 %. The lowest was the sandhills (Xeric Pine-Oak) and mixed swamp (Bottomland) with 7 % similarity. Thus, patterns of similarity are not too different in other areas with similar communities.

3.2. Soils

3.2.1. Results

The results of the laboratory analysis of the relevé soil samples are given in Figure 7. The values for individual relevés can be found in SNYDER (1978). The complete profile descriptions including lab results are given in Tables 7 - 11. No profile was done in Bottomland because of the difficulty in extracting samples so the data from the 0-20 cm sample of a representative relevé (No. 27) is given for comparison. Cation exchange capacity and percentage

Table 7. Soil Profile - Xeric Longleaf Pine-Oak

Series: Kureb

Location: near relevé 74, north of forest route 128

| Depth (cm) | Color (moist) | Texture | Density (g/cc) | O.M. % | pH | |
|---------------|---------------------------|---------|-------------------|-----------|-----|-------|
| | | | | | wet | dried |
| 0- 15 | dark gray (10 YR 4/1)* | sand | 1.32 | 1.52 | 3.7 | 4.0 |
| 15- 57 | light gray (10 YR 7/1) | sand | 1.48 | 0.0 | 4.1 | 4.7 |
| 57- 74 | brown (10 YR 4/3)** | sand | 1.21 | 1.03 | 4.4 | 4.6 |
| 74-126 | light red (2.5 YR 6/6) | sand | 1.35 | 0.0 | 4.8 | 4.6 |
| 126-150 | brown (10 YR 4/3)*** | sand | 1.33 | 0.19 | 4.8 | 4.7 |

| Depth (cm) | Acidity (me/100g) | Cations (me/100g) | | | CEC (me/100g) | % Base sat. | Mn (mg/100g) | P (mg/100g) |
|---------------|----------------------|-------------------|------|------|------------------|----------------|-----------------|----------------|
| | | K | Ca | Mg | | | | |
| 0- 15 | 2.61 | 0.01 | 0.19 | 0.06 | 2.86 | 9.1 | 0.05 | 0.15 |
| 15- 57 | 0.30 | 0.01 | 0.13 | 0.01 | 0.45 | 33.3 | 0.03 | 0.0 |
| 57- 74 | 1.69 | 0.02 | 0.12 | 0.01 | 1.84 | 8.2 | 0.03 | 0.08 |
| 75-126 | 0.36 | 0.01 | 0.11 | 0.01 | 0.49 | 26.5 | 0.07 | 0.07 |
| 126-150 | 0.51 | 0.01 | 0.07 | 0.01 | 0.60 | 15.0 | 0.06 | 0.30 |

* "salt and pepper" appearance

** dark brown (7.5 YR 3/2) - common, coarse, prominent concretions
 strong brown (7.5 YR 5/8) - common, coarse, prominent concretions

*** dark brown (7.5 YR 4/4) - common, coarse, distinct mottles
 black (5 YR 2.5/1) - few, coarse, distinct mottles

base saturation are only given in the profile descriptions for comparative purposes.

The results of the analysis performed by the state lab were reported on the basis of volume of dried and sieved soil but are presented here on a weight basis by using the reported bulk density to make the conversion. This is the most common way to report soil nutrient content although not as meaningful as nutrients per unit volume of undisturbed soil. I felt that since I had no measure of the true bulk density of the undisturbed soils it would be better to use a weight basis rather than on units based on a somewhat ambiguous volume of dried and sieved soils. The bulk density of the dried soil is strongly correlated with the bulk density of the undisturbed soil but there is no way of knowing to what degree the dried and sieved soils differ from

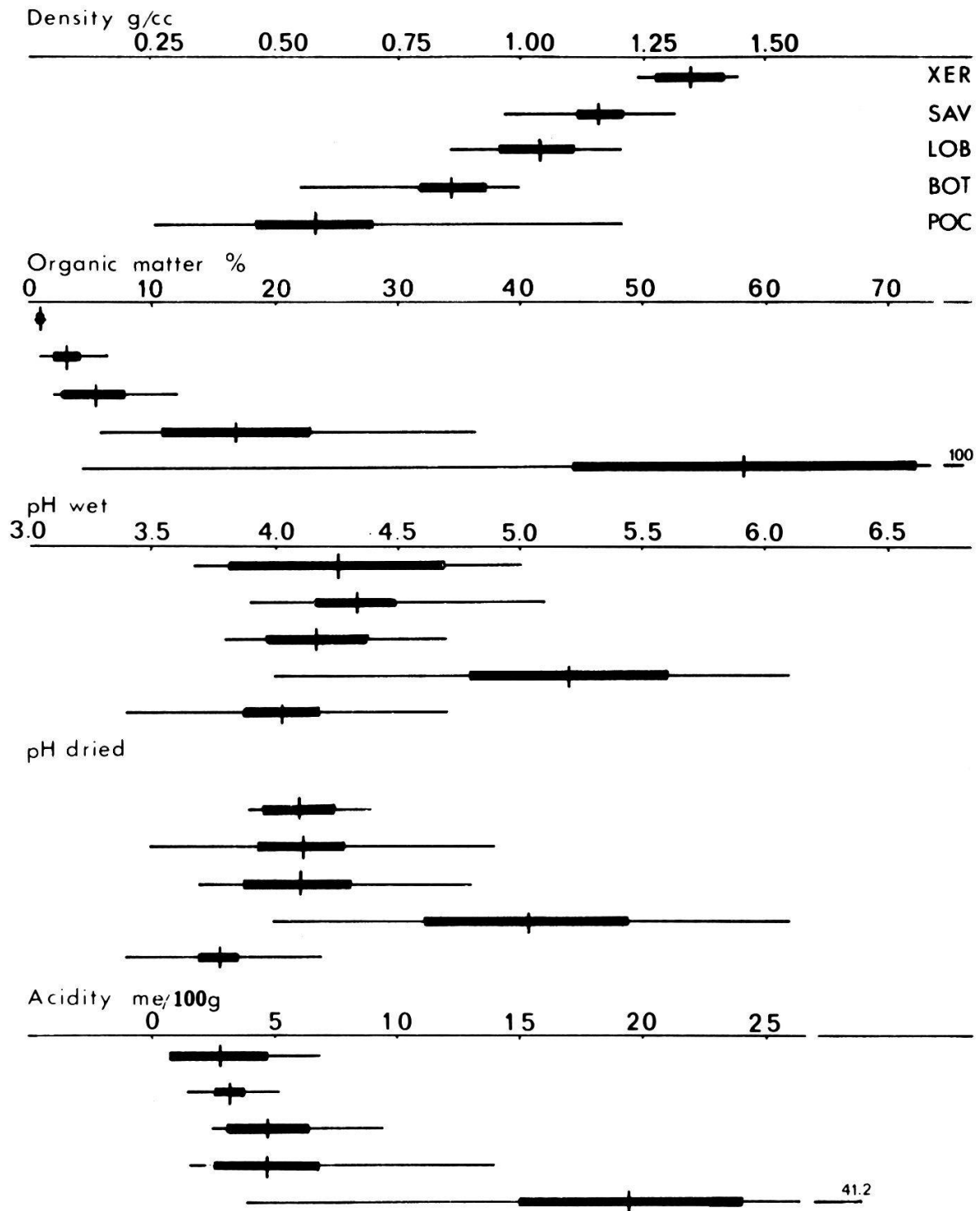


Figure 7. (part 1; part 2 see opposite side)
 Results of analysis of relevé soil samples summarized by community types. Data for individual relevés is given in SNYDER (1978). Vertical line is the mean, bar is the 95% confidence interval, and horizon line is the range. (XER = Xeric Longleaf Pine-Oak, SAV = Longleaf Pine Savanna, POC = Pocosin, BOT = Bottomland Forest, LOB = Loblolly Pine-Hardwoods).

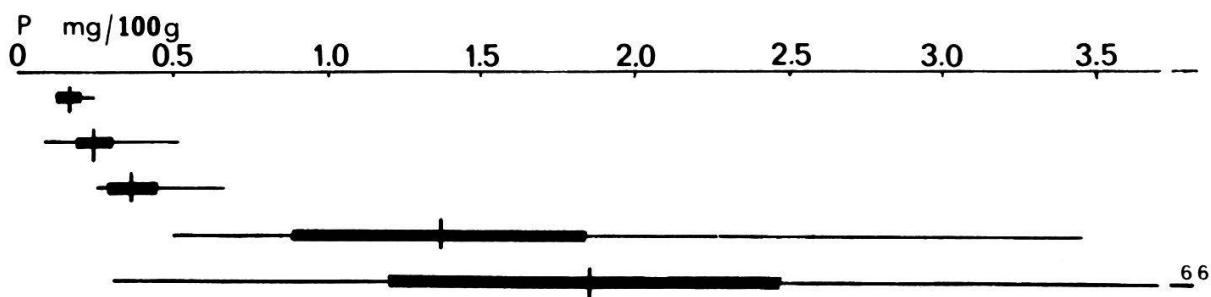
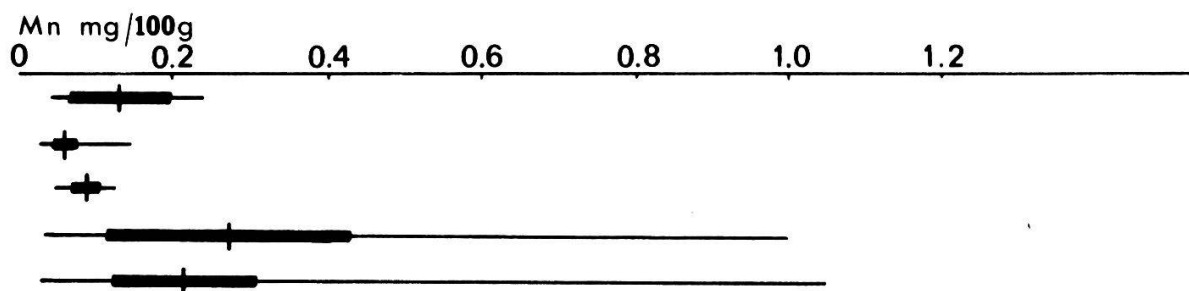
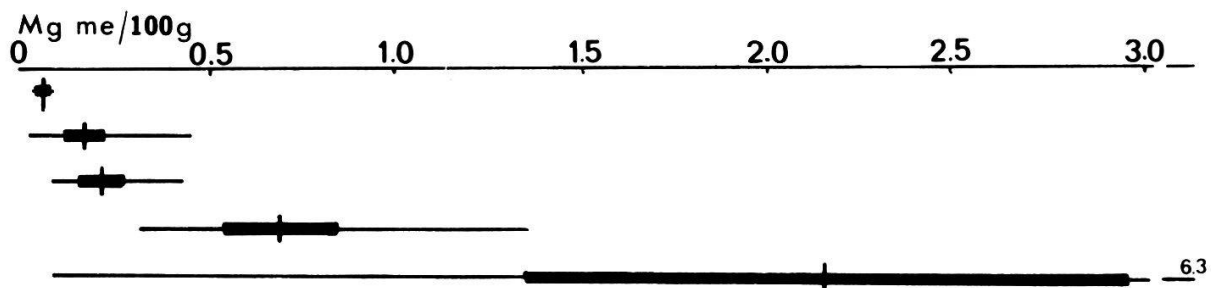
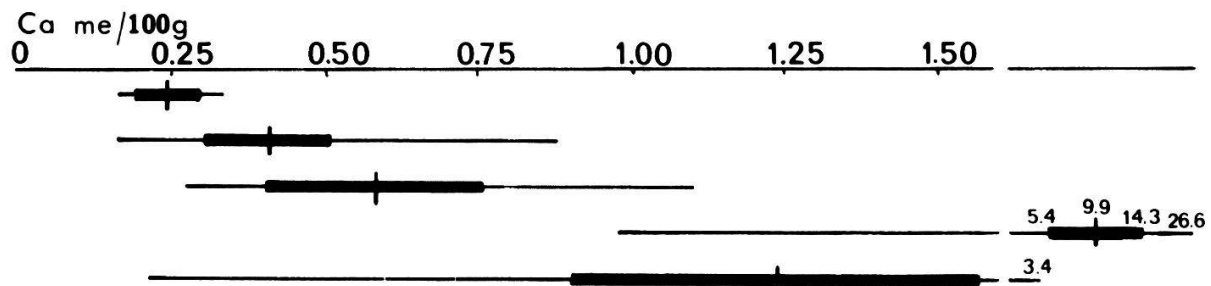
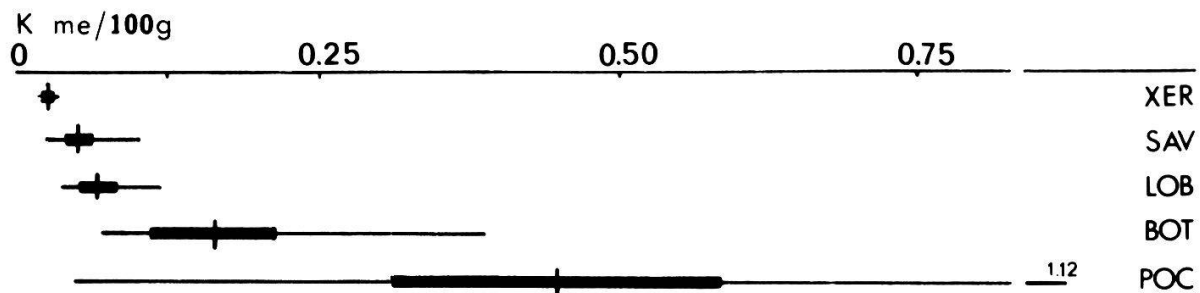


Table 8. Soil Profile - Longleaf Pine Savanna
 Series: Leon
 Location: near Relevé 80, southeast of junction of 1124 and 1140

| Depth (cm) | Color (moist) | Texture | Density (g/cc) | O.M. % | pH | |
|---------------|--|---------|-------------------|-----------|-----|-------|
| | | | | | wet | dried |
| 0- 8 | gray (10 YR 6/1) | sand | 1.22 | 1.64 | - | 4.1 |
| 8- 40 | light gray (10 YR 7/1) | sand | 1.46 | 0.0 | - | 5.0 |
| 40- 50 | dark brown (10 YR 3/3) to dark grayish brown (10 YR 4/2) | sand | 1.16 | 1.83 | - | 4.9 |
| 50-110 | light gray (10 YR 7/2) | sand | 1.33 | 0.0 | - | 4.6 |
| 110+ | brown (10 YR 4/3) | sand | - | - | - | - |

| Depth (cm) | Acidity (me/100g) | Cations (me/100g) | | | CEC (me/100g) | % Base sat. | Mn (mg/100g) | P (mg/100g) |
|---------------|----------------------|-------------------|------|------|------------------|----------------|-----------------|----------------|
| | | K | Ca | Mg | | | | |
| 0- 8 | 2.92 | 0.03 | 0.33 | 0.12 | 3.40 | 14.1 | 0.03 | 0.08 |
| 8- 40 | 0.33 | 0.01 | 0.17 | 0.01 | 0.52 | 36.5 | 0.0 | 0.0 |
| 40- 50 | 1.97 | 0.01 | 0.26 | 0.01 | 2.25 | 12.4 | 0.02 | 0.09 |
| 50-110 | 0.75 | 0.01 | 0.19 | 0.01 | 0.96 | 21.9 | 0.02 | 0.0 |

undisturbed soils. It must therefore be appreciated that the 100 g of organic soil refers to a much larger soil volume than 100 g of sandy or loamy mineral soil.

3.2.2. Discussion

A few observations on methods of soil analysis should be noted. It is apparently true that drying and rewetting soils lowers the pH, although I do not have statistical proof that this is the case with the soils of the research area. I measured the pH of 10 soil samples before and after drying and the mean drop in pH was .115 units. A paired t-test (SNEDECOR and COCHRAN 1967) showed the difference to be non-significant at the 95 % level. Perhaps a larger sample size would have made the small difference statistically real. The data from 100 soil samples measured by me before drying and by the state lab after drying showed a mean drop in pH of .233 with a 99 % confidence

Table 9. Soil Profile - Pocosin

Series: Murville

Location: near Relevé 39, north of forest route 128

| Depth (cm) | Color (moist) | Texture | Density (g/cc) | O.M. % | pH | | | |
|---------------|------------------------------------|-------------------|-------------------|-----------|------------------|----------------|-----------------|----------------|
| | | | | | wet | dried | | |
| 0- 11 | black (5 YR 2.5/1) | mucky sand | 0.82 | 30.64 | 3.9 | 3.9 | | |
| 11- 37 | black (2.5 YR N2.5/0) | sand | 1.01 | 20.17 | 3.9 | 3.8 | | |
| 37- 58 | dark gray (10 YR 4/1)* | sand | 1.23 | 7.22 | 4.0 | 4.0 | | |
| 58-150 | very dusky red (2.5 YR 2.5/2) | sand | 1.17 | 6.20 | 3.7 | 4.0 | | |
| 150+ | dark reddish brown (5YR 3/3) | sand | 1.37 | 2.37 | 3.5 | 4.0 | | |
| | | | | | | | | |
| Depth (cm) | Acidity (me/100g) | Cations (me/100g) | | | CEC (me/100g) | % Base sat. | Mn (mg/100g) | P (mg/100g) |
| | | K | Ca | Mg | | | | |
| 0- 11 | 10.24 | 0.28 | 1.10 | 1.21 | 12.83 | 25.3 | 0.24 | 0.73 |
| 11- 37 | 8.91 | 0.06 | 0.20 | 0.60 | 9.77 | 8.8 | 0.06 | 0.30 |
| 37- 58 | 5.63 | 0.02 | 0.16 | 0.21 | 6.02 | 6.5 | 0.03 | 0.08 |
| 58-150 | 2.91 | 0.02 | 0.13 | 0.11 | 3.17 | 10.6 | 0.05 | 0.09 |
| 150+ | 3.59 | 0.01 | 0.15 | 0.07 | 3.82 | 6.0 | 0.03 | 1.75 |

* many uncoated sand grains

interval of .116 to .350. It is likely that some of the difference is an artifact of the methodology or equipment used in the two laboratories and therefore the drop in pH cannot be attributed to the drying and rewetting. DOLMAN and BUOL (1967) found a mean drop in pH of 0.6 units after drying and rewetting coastal plain organic soils.

The percent organic matter as reported by the state lab is based on an assumed soil density of 1.25 g/cc which is quite uncommon for soils of the research area (Fig. 7). Therefore a correction was made by multiplying the reported organic matter percentage by 1.25 divided by reported bulk density. This lead in a few cases to soils having a calculated organic matter content greater than 100 %. In these instances the organic matter was set to 100. The wet chemical method employed by the state lab is adapted to normal agricultural soils and therefore might be expected to have some difficulties with organic soils. However, organic matter as estimated by loss on ignition

Table 10. Surface Soil - Bottomland Forest

Series: Johnston-Muckalee (?)

Location: Relevé 27, along S.W. Prong Newport River, west of 1124

| Depth (cm) | Color (moist) | Texture | Density (g/cc) | O.M. % | pH | | | |
|---------------|----------------------|-------------------|-------------------|-----------|------------------|----------------|-----------------|----------------|
| | | | | | wet | dried | | |
| 0-20 | dark brown | loam | 0.86 | 12.06 | 5.4 | 5.3 | | |
| | | | | | | | | |
| Depth (cm) | Acidity (me/100g) | Cations (me/100g) | | | CEC (me/100g) | % Base sat. | Mn (mg/100g) | P (mg/100g) |
| | | K | Ca | Mg | | | | |
| 0-20 | 3.07 | 0.20 | 12.18 | 0.60 | 16.05 | 80.9 | 0.12 | 1.16 |

Table 11. Soil Profile - Loblolly Pine-Hardwoods

Series: Leaf (?)

Location: near Relevé 29, north of forest route 128, about 1.6 km west of 1124

| Depth (cm) | Color (moist) | Texture | Density (g/cc) | O.M. % | pH | | | |
|---------------|--|-------------------|-------------------|-----------|------------------|----------------|-----------------|----------------|
| | | | | | wet | dried | | |
| 0-17 | dark gray (10 YR 4/1) | loam | 1.11 | 2.48 | - | 4.9 | | |
| 17-30 | grayish brown (10 YR 5/2) | loam | - | - | - | - | | |
| 30-50+ | light brownish gray (10 YR 6/2 with 10 % 10 YR 6/6) | clay loam | 1.10 | 0.23 | - | 4.8 | | |
| | | | | | | | | |
| Depth (cm) | Acidity (me/100g) | Cations (me/100g) | | | CEC (me/100g) | % Base sat. | Mn (mg/100g) | P (mg/100g) |
| | | K | Ca | Mg | | | | |
| 0-17 | 2.7 | 0.04 | 1.03 | 0.18 | 3.95 | 31.6 | 0.04 | 0.09 |
| 30-50+ | 2.84 | 0.05 | 0.86 | 0.11 | 3.86 | 26.4 | 0.05 | 0.09 |

agreed rather closely with the soil testing lab's results in a number of Pocosin soils from a nearby location in Croatan National Forest (SNYDER 1977). The wet combustion method tended to overestimate compared to the loss-on-ignition (mean difference 2.32 %, N = 15) but a paired t-test showed it not significantly different from zero at the 95 % level.

The surface soils (0-20 cm) collected at the releve sites show a wide range of organic matter content. The Xeric Longleaf Pine-Oak soils had about 1 % or less while some Pocosin soils were almost pure organic material. The

density of the dried and sieved soils showed an inverse relationship to the percent organic matter. Based on 120 samples from the research area the correlation coefficient (SNEDECOR and COCHRAN 1967) was $r = -.87$ with $p < .00001$. Density increased in the order Pocosin < Bottomland < Loblolly-Hardwoods < Savanna < Xeric Pine-Oak. There is no overlap in 95 % confidence intervals although ranges do overlap. Percentage organic matter shows the opposite relationship except that the confidence intervals of the Savanna and Loblolly-Hardwoods soils overlap.

The reaction of the soils is always acid with values as low as pH 3.4 found in the organic Pocosin soils. Most of the soils have pH values between 3.5 and 4.5 except the Bottomland Forest soils which average about 5.0. Values as high as 6.1 were found in the alluvial Bottomland soil. The higher pH probably is largely due to higher calcium concentrations derived from outcropping of calcareous strata of the Yorktown formation.

The extractable nutrients are in general found in quantities related to the organic matter content of the soil. The nutrient concentrations of the soils of the various communities can be rated as follows:

| | |
|-------|--|
| K, Mg | XER < SAV \leq LOB < BOT < POC |
| P | XER \leq SAV \leq LOB < BOT \leq POC |
| Ca | XER < SAV \leq LOB < POC < BOT |
| Mn | SAV < LOB \leq XER \leq POC < BOT |

where \leq indicates a greater mean value but an overlap in 95 % confidence interval. The only major exception to the extractable nutrient content paralleling organic matter content is the very high relative values of calcium in Bottomland soils which are probably responsible for the higher pH of the soils as previously mentioned. Manganese shows an unusual pattern with rather high values in the otherwise depauperate Xeric Pine-Oak soils.

A certain degree of caution must be used in interpretation of nutrient concentration data which are reported on a weight basis. The wide range in densities means that concentrations do not refer to equal soil volumes. To at least partially account for differences in true soil density, the soils of the five community-types were compared on the basis of nutrients per unit volume of dried and sieved soil. The relationship for K and Mg remained unchanged except that the Pocosin soils were no longer significantly higher than the

Bottomland soils. P remained the same except that the mean value for Bottomland became higher than the mean of the Pocosin soils. The relationship for Ca changes to $XER \leq SAV \leq POC \leq LOB < BOT$ and here the important difference to note is the decreased value of Pocosin soils when soil density is considered. Mn also shows a relative drop in the value of Pocosin soils:

$SAV \leq LOB \leq POC \leq XER \leq BOT$.

By compensating somewhat for the low density of the Pocosin soils it can be seen that nutrient concentrations are not as high as the data given on a weight basis suggest. In fact, the densities of the Pocosin soils in the field are probably even lower than those of dried and sieved soils because the soils shrink a great deal on drying.

The cation exchange capacity (CEC) of soils low in clay is largely due to the organic matter fraction (ETHERINGTON 1975) and in these largely cation unsaturated soils this is reflected in the correlation between buffer acidity and organic content (Tables 7 - 11, Fig. 7). The Bottomland soils show a relatively low exchange acidity because more of their exchange sites are occupied by basic cations (especially Ca) and also because the pH at which acidity was measured is closer to actual field pH of the soil. The other soils have considerably lower pH so that their acidity was more grossly overestimated by measurement at pH 6.6.

The pH of the soil affects the availability of most nutrients and this must be considered when evaluating relative nutrient status of soils. As the pH of the soil decreases below pH 5 the availability of Ca, Mg, K and P is decreased (LARCHER 1975). Therefore in terms of available nutrients the Bottomland Forest ranks highest because of high concentrations and the most favorable pH. The Xeric Pine-Oak has the lowest due to low concentrations and poor exchange capacity. Longleaf Pine Savanna and Loblolly Pine-Hardwoods are intermediate in terms of available nutrients although the Loblolly community tends to have slightly higher concentrations. The Pocosin soils probably rank near or slightly above the Xeric Pine-Oak in terms of available nutrients in spite of higher concentrations because of the unfavorable pH and frequently waterlogged conditions.

The low soil pH has other important indirect effects on plant nutrition. Under low pH there is reduced microbial activity, especially bacteria (ETHERINGTON 1975). This results in slowed mineralization of organic matter which means a

delayed release of organically bound nutrients and possibly peat formation. Low pH affects the bacteria involved in the nitrogen cycle as well. The reduced action of nitrifying bacteria leads to accumulation of ammonia rather than nitrate (LARCHER 1975). Nitrogen fixation is probably impaired by the low soil pH. JURGENSEN and DAVEY (1968) found in the Croatan National Forest that nitrogen fixing blue-green algae were absent from soils with pH less than 5.4. However, they did find nitrogen fixing algae in Bottomland areas where the pH was 5.4 or higher. WOODWELL (1958) has suggested that the low pH of Pocosin soils may exclude certain mycorrhizal fungi.

Coastal plain soils are generally infertile and the excessively drained soils of sand ridges are notoriously so (WELLS and SHUNK 1931). Nitrogen has been found to be the most deficient element in soils of sand ridges (WELLS and SHUNK 1931) and savannas (CHRISTENSEN 1977a). Pocosin soils have been found deficient in N, P, and Ca for oats and in N and P for the growth of *Pinus serotina* seedlings (WOODWELL 1958). Based on field experiments MAKI (1974) feels that Ca and P are limiting *P. serotina* growth in pocosins. Most of the macronutrients are probably in suboptimal concentrations in most coastal plain soils.

3.3. Ecology

3.3.1. Fire Ecology

Fire is one of the major factors influencing vegetation of the southeastern coastal plain (WELLS 1928, GARREN 1943, KOMAREK 1974). Before the presence of man in the southeast, fires were caused by lightning strikes. But the arrival of Indians about 20,000 years ago drastically increased the frequency of fires, particularly in the winter when lightning was unlikely (KOMAREK 1974).

European settlers in many places continued the Indian practice of frequent burning of pine woods. This had no great effect on the vegetation but once large-scale harvesting of pine began the practice of annual burning prevented the reestablishment of pine. This led to efforts on the part of foresters to eliminate fire. Long periods without fire allowed the accumulation of large amounts of fuel which made wildfires more destructive when they did occur. Today, however, prescribed burning is standard practice in the silviculture of longleaf and loblolly pine, and it is the most common type of fire in the southeast.

The details of the fire history of the study area are available only for relatively recent prescription burns performed by the Forest Service. The last major wildfire occurred in 1955, and it burned almost half the National Forest including the research area (R. MILLS, pers. comm.). Of course the intensity of the fire varied from place to place and some areas were probably little affected. Since that time the only significant burning to take place has been prescribed fires for fuel reduction and hardwood suppression in *Pinus taeda* and *P. palustris* stands.

In terms on fire frequency in recent times, the community-types can be ordered as follows: The Longleaf Pine Savanna and Xeric Longleaf Pine-Oak are both high frequency types, although the former probably burns more often because of faster fuel accumulation. The Loblolly Pine-Hardwoods is prescription burned every few years but the pine was probably established during a fire-free period following some form of disturbance such as logging or crown fire. Pocosin burns less frequently, and the three subunits can be ranked Short, Tall, and Bay in decreasing order. The Bottomland Forest is rarely burned.

Fire is a selective force, and it is to be expected that plant species growing in regions that are frequently burned should be able to cope with it. Many species exhibit fire adaptations that allow them to tolerate fire or even require it to complete their life cycles.

Pinus palustris seedlings grow for several years without stem elongation in the so-called grass stage during which time they can tolerate light grass fires. After several years the stem rapidly elongates; the terminal bud quickly grows above the reach of ground fires; and the trunk develops a thick, resistant bark. *P. serotina* saplings are susceptible to fire but are able to sprout from the base if killed back. Larger *P. serotina* can recover from the killing back of their branches by epicormic sprouting from the bole. *P. taeda* shows the least adaptation to fire, being killed when young, but it is resistant to ground fires when older.

The xeric oaks have thick bark which can withstand light fires, but they can also sprout prolifically if the aboveground portions should succumb. Virtually all Savanna and Pocosin herbs and shrubs have the underground resources to recover after a fire kills back the shoot. One is amazed at the rapid regreening of a Savanna or Pocosin after a fire.

Aristida stricta normally does not flower unless it is burned (PARROTT 1967). It is also a species that would seem to support the hypothesis that plant communities dependent on fire have been selected for increased flammability (MUTCH 1970). The wiregrass (*A. stricta*) fuel type is perhaps the most flammable in North Carolina (WELLS and SHUNK 1931, WENDEL et al. 1962). The loose "pine straw" or fallen needles from *P. palustris* also insure fuel for fires.

In addition to more or less direct effects on vegetation, fire has an influence on the soil and the cycling of nutrients. In terms of the total ecosystem pool of a given mineral nutrient, fires can either cause no change or result in net losses. In the case of nitrogen it is conceivable that increased N fixation could be stimulated by burning. Fires also can increase the rate of nutrient cycling in an ecosystem by speeding the rate of mineralization of organic matter.

After a prescribed burn in coastal plain pine forest the levels of soluble cations in the remaining litter are greatly increased (LEWIS 1974). The basic cations found in the ash are generally credited with increasing the soil pH after burning (AHLGREN and AHLGREN 1960). In a 20 year study of annual and periodic burning in coastal plain pine forest the amount of extractable Ca and Mg in the soils was increased by burning but K was unchanged (WELLS 1971). The pH of the 0-5 cm layer of soil showed an increase from 4.2 to 4.6.

Significant amounts of cations are released to the atmosphere as fine particulate matter during a fire and cations may also be lost to runoff or the groundwater (LEWIS 1974). Losses to the ground water would be especially likely in deep sandy soils of low cation exchange capacity such as Kureb series. Repeated fire prevents the accumulation of organic matter and limits the nutrient (and water) storing capacity of the soil. The rapid regrowth from sprouts following fire is probably an efficient mechanism for preventing large losses of newly available nutrients.

Phosphorus is not made more soluble directly by burning (LEWIS 1974) but may be found at slightly higher levels after a period of prescribed burns (WELLS 1971). It may be that a more favorable soil environment for microbes results in more rapid mineralization.

Organic matter in the litter is decreased with increasing frequency of burn-

ing but the amount of organic material in the mineral soil is increased (WELLS 1971). The increase in soil organic matter is probably due to both increased root production and the penetration of small particles from the litter layer. Total N shows approximately the same pattern as organic matter. The total amount of N in the soil plus litter is unchanged by 20 years of prescribed burning. Large amounts of N are lost to the atmosphere during a prescribed fire - from 12 kg/ha (LEWIS 1974) to 110 kg/ha (WELLS 1971) - and there is no increase in soluble nitrate or nitrite in the litter immediately after the fire (LEWIS 1974). Laboratory studies have shown that most N is lost as N_2 gas (DEBELL and RALSTON 1970, LEWIS 1975) but small amounts of N as nitrite, nitrate, and ammonia were recovered from a simulated burn (LEWIS 1975).

Increased nitrogen fixation must be at least part of the explanation for maintained levels of N in spite of large losses during burning. Anaerobic, non-symbiotic bacteria have been indicated as important nitrogen fixers (JORGENSEN and WELLS 1971). Blue-green algae are unlikely to contribute in most soils due to low pH (JURGENSEN and DAVEY 1968) but symbiotic systems may be important, particularly where burning increases the leguminous content of the herb layer.

Fire in Pocosin systems has not received as much study as it has in economically important vegetation types. One important difference is that the soil of Pocosin is combustible and in times of drought the fire may burn down through the peat until it reaches mineral soil or the water table. MAKI (1974) reports the burning of 30-60 cm of peat in a Pocosin wildfire. It is unlikely that large amounts of cations are lost from Pocosin soils after a shallow burn because of the large unsaturated exchange complex. If the root mat of the shrubs is not burned the rapid regrowth probably takes up most of the released nutrients.

3.3.2. *Water and Hydrology*

Water is another factor of profound influence on the vegetation found in the coastal plain (WELLS 1928). Habitats range from deep sands of low water-holding capacity to various types of waterlogged bogs and swamps. Therefore plants must often face conditions of too much water or too little water.

WELLS (WELLS 1928, WELLS and SHUNK 1928) uses the term "hydroperiod" to refer

to the length of time that water is at or near the soil surface. Moisture gradients or changes in hydroperiods are responsible for much of the vegetation pattern in the coastal plain. WELLS described a moisture gradient in the sandhill vegetation (WELLS and SHUNK 1931) and certainly the Xeric Pine-Oak - Savanna - Pocosin vegetation complex in the research area is largely controlled by water relations. Of course it is impossible to completely separate moisture from fire and nutritional factors.

The five community-types can be roughly ordered along a moisture gradient in which the Xeric Pine-Oak occupies one extreme. At the other extreme are the Pocosin and Bottomland Forest. The Bottomland habitat experiences the highest water levels and is the last to dry out during drought periods due to its topographic position. However, water movement and nutrient properties are probably more important than hydroperiod per se in separating Pocosin and Bottomland. The Loblolly Pine-Hardwoods and Savanna are intermediate in hydroperiod, and my observations indicate that they overlap in this factor and that they must be separated on some other habitat factor. The higher clay content in the Loblolly-Hardwood soils may serve to ameliorate water stress during dry periods when sandy soils in the Savanna are depleted of water.

At the xeric extreme many of the plants show adaptations to drought, such as heavy tap roots (e.g. *Euphorbia ipecacuanhae*) or revolute leaves (e.g. *Aristida stricta*). Pine needles are considered to show a number of attributes for water conservation. The leaves of *Quercus leavis* show a thick epidermis and compact mesophyll, characteristics considered to be adaptations to a xeric environment.

Most of the vegetation, however, must tolerate periods of high water tables and saturated rooting zones. Plants in the Bottomland Forest rarely experience drought conditions but WELLS considers alternating periods of waterlogging and drought to be a strong selective force in Pocosin and Savanna (WELLS and SHUNK 1931, WELLS 1946) and only species capable of tolerating both conditions can survive.

Waterlogging has a number of effects on plant nutrition. Anaerobic conditions develop as microbial and root respiration deplete oxygen; at the same time carbon dioxide concentrations increase. Decreased microbial activity under anaerobic conditions leads to accumulation of organic matter (at some point

called peat) and higher C/N ratios. This may lead to decreased availability of N for higher plants as it will be quickly taken up by microorganisms (WOODWELL 1958). Under anaerobic conditions ammonia is the main nitrogenous decomposition product (ETHERINGTON 1975) so plants must be able to utilize ammonia. *N. P. serotina* apparently requires ammonia nitrogen (WOODWELL 1958). Denitrification and nonsymbiotic nitrogen fixation are processes associated with anaerobic conditions. The lower redox potentials of waterlogged soils increase the availability of manganese and iron to the extent that they may become toxic to plants that have no mechanism to exclude them (ETHERINGTON 1975).

Wetland plants commonly show structural adaptations such as large amounts of aerenchyma tissue which permit the diffusion of oxygen to the roots. The well-known "knees" of *Taxodium* have often been suggested to aid in aeration of roots but experimental evidence seems to refute this (KRAMER et al. 1952).

Bog plants often exhibit structural characteristics associated with dry habitats. This led SCHIMPER (1903) to suggest that bogs are "physiologically" dry even though the plants are standing in water. Some factor inhibits the ability of roots to absorb water and therefore the leaves must reduce transpiration. WELLS refers to the "xeric" grass-sedge and shrub bogs (WELLS 1928). CAUGHEY (1945) showed that transpiration rates of Pocosin shrubs were comparable to those of mesophytic upland species and suggested that the xeromorphism was due to a nutrient deficiency. However, the flooding of the Pocosin shrubs did drastically reduce their transpiration rates.

It has been suggested that reduced transpiration by plants in waterlogged soils is an adaptation to reduce the rate of water uptake by roots so that soluble toxins (Mn and Fe) can be oxidized and rendered harmless at the root surface (ETHERINGTON 1975). This leads to the rather odd conclusion that the xeromorphism may be of greatest benefit when conditions are wet. The reduced uptake of water during waterlogging also results in reduced uptake of nutrient ions which may further aggravate the nutrient-poor conditions already present.

Related to xeromorphism, and in Pocosin shrubs virtually synonymous with it, is sclerophylly. Essentially all the evergreen shrubs in the research area have tough, sclerophyllous leaves and many of the deciduous species do also. Sclerophylly and evergreenness have been shown to be related to low nutrient

status. Low levels of phosphorus have been associated with the occurrence of sclerophyllous vegetation or increased degrees of sclerophylly (LOVELESS 1962). In Florida, MONK (1966a) found evergreenness more common on dry, sterile sites than on more mesic, fertile sites. In the study area, the only vegetation type to have a significant deciduous component in the canopy is the Bottomland Forest which is on the moist, fertile extreme of habitats.

Evergreenness may be of advantage by returning nutrients to the soil continually throughout the year by means of leaching and leaf fall and the slower decomposition rate of litter (MONK 1966a, THOMAS and GRIGAL 1976). In vegetation where the sudden release of nutrients by fire commonly occurs it does not seem that slow, continual release of nutrients would be of much selective advantage. Perhaps sclerophylly has adaptive value mainly as a deterrent to herbivores.

The pattern of bog vegetation - Short, Tall, and Bay Pocosin - is determined by many factors including fire, depth of peat, hydroperiod, and nutrient availability. Short Pocosin is found in the center of the bog over the deepest accumulations of peat and therefore on the highest part of the landscape under ombrotrophic conditions. Tall Pocosin is found along the bog margin where organic deposits are thinner or between Short Pocosin and Bay Pocosin. Bay Pocosin is found at the heads of streams draining the bog. Although soil nutrient concentrations do not appear to vary significantly among the three subtypes it is likely that centrifugal patterns of water movement are responsible for improving the nutrient availability toward the margins of the bog and along drainage ways. In standing water such as found in the center of a raised bog the zone around individual roots may become depleted of nutrients whereas roots with water moving past them (even if slowly) are constantly brought into contact with new nutrients (INGRAM 1967).

In a study of Minnesota peatlands, HEINSELMAN (1963) declared that circulation of bog waters is the primary factor controlling *Picea mariana* sites. It is likely that the same is true for *Pinus serotina* and its associated vegetation. His study could serve as a model for an investigation of large Pocosin such as the one found in Croatan National Forest.

Summary and Conclusions

There are five major plant community-types found in the study area in Croatan National Forest. These community types are defined by floristic composition in terms of diagnostic species with restricted distributions or frequent occurrence in the community-type. The five communities are:

1. Xeric Longleaf Pine-Oak
2. Longleaf Pine Savanna
3. Pocosin
4. Bottomland Forest
5. Loblolly Pine-Hardwoods

The diagnostic species (the differential species and species with a constancy class of five) for each type are shown in Table 3.

The areal extent of the community-types is shown in the vegetation map (Fig. 5). Comparison of the vegetation map with the maps of the surface geology and soils (Fig. 3 and Fig. 4 respectively) shows that there are definite correlations between the distribution of plant communities and the geology and soils. In the Newport Barrier region, which corresponds to the Newport Sand facies of the Flanner Beach formation, a wide range of soil types supports vegetation ranging from Xeric Pine-Oak to Bottomland Forest and Pocosin. In the Newport Backbarrier Flat region, or the Beard Creek Facies, histosols support a large expanse of shrub bog known as Lakes Pocosin.

Xeric Longleaf Pine-Oak is largely restricted to the deep, excessively drained sands of the Kureb soil and Longleaf Pine Savanna is found on the sandy ground-water podzols of the Leon series, as well as some of the better drained loamy soils. The very poorly drained upland soils with the black surface horizons generally support Pocosin and the histosols of the Dare and Ponzer series always do so. Bottomland Forest grows in the mucky soils along the major drainage-ways, generally mapped as Johnston-Muckalee soils. The Loblolly Pine-Hardwoods are found in loamy to clayey soils such as the Goldboro-Autryville and Leaf soils.

There are three habitat factors of major importance in determining the vegetation pattern seen in the study area and in the southeastern coastal plain in general. These are availability of nutrients, water relations, and fire. The diagram showing the floristic similarity of the community-types (Fig. 6) can be regarded as an informal ordination of the communities. In Figure 8 the ordination is related to gradients of the three primary environmental factors. Even though the habitat factors are not independent of one another it can be seen that each one influences the distribution of the communities.

The Xeric Longleaf Pine-Oak and the Bottomland Forest community-types are found at opposite extremes of the three environmental gradients and show the lowest floristic similarity of any pair of communities. The Xeric Pine-Oak habitat is the driest and most nutrient-deficient, and the vegetation is burned frequently, although possibly not as often as the Longleaf Pine Savanna. The Bottomland Forest shares the hydric extreme with Pocosin and rarely experiences fire. Nutrient availability is highest in the Bottomland Forest based on levels of extractable nutrients and relatively high pH. The Loblolly Pine-Hardwoods is found at an intermediate position on all three gradients and shows the highest mean floristic similarity with the other community-types.

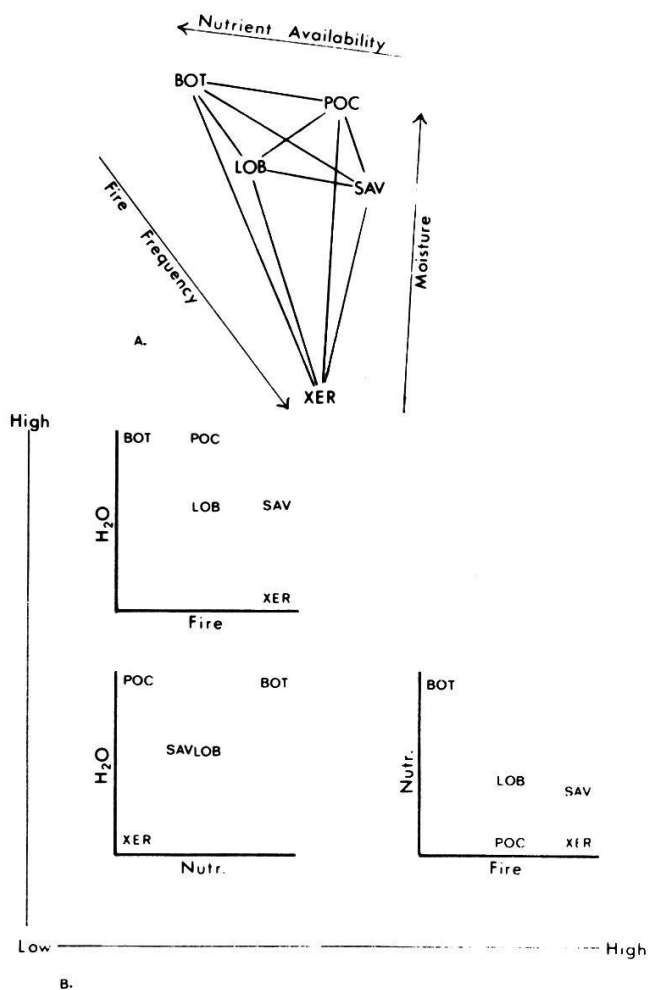


Figure 8. Relationships of community-types to environmental gradients. a) Informal ordination of the five major plant community-types (based on floristic similarity as in Fig. 6) related to important environmental gradients. Some relationships are not shown properly due to the projection in two dimensions. SAV is actually in an intermediate position on the nutrient gradient and XER is found no higher, and possibly lower, than SAV on the fire gradient. b) The actual position of the communities on the environmental gradients. (XER = Xeric Longleaf Pine-Oak, SAV = Longleaf Pine Savanna, POC = Pocosin, BOT = Bottomland Forest, LOB = Loblolly Pine-Hardwoods.)

Abb. 8. Beziehungen zwischen den Vegetationstypen und den Standortsgradienten. a. Ordination der fünf Hauptvegetationstypen (hinsichtlich der floristischen Ähnlichkeit wie in Abb. 6) in bezug auf die wichtigen Standortsfaktoren. Verschiedene Beziehungen können nicht genau aufgezeigt werden, weil die Darstellung nur zwei Dimensionen hat. Die *Pinus palustris*-Savanne (SAV) nimmt eigentlich eine mittlere Stellung auf dem Nährstoff-Gradienten ein und der *Pinus palustris*-*Quercus*-Trockenwald (XER) ist auf keinen Fall höher, wahrscheinlich aber tiefer auf dem Feuer-Gradienten als die Savanne. b. Stellung der Vegetationseinheiten auf den Standortsfaktoren-Gradienten. (XER = *Pinus palustris*-*Quercus*-Trockenwald, SAV = *Pinus palustris*-Savanne, POC = Pocosin-Vegetation, BOT = Auenwald, LOB = *Pinus taeda*-Hartholzwald.)

In terms of the three environmental gradients, the Savanna differs strongly from the Pine-Hardwoods only in having fires with high frequency. The Pocosin community is found at the hydric extreme of the moisture gradient but differs from the Bottomland Forest by being extremely poor in nutrient availability and by burning with moderate frequency.

The Pocosin community-type (Table 4) shows a range of variation from Short Pocosin with the lowest growth of shrubs and poor growth of *Pinus serotina*, through the Tall Pocosin with better growth, to Bay Pocosin which is dominated by hardwood tree species, including *Persea borbonia*. The hydrology of the Pocosin was not studied but it may prove that patterns of water movement are more important than fire or soils in the differentiation of shrub-bog vegetation.

The plant communities of the research area are representative of much of the vegetation of the North Carolina coastal plain and are similar in composition and structure to communities found from southeastern Virginia to northern Florida. The floristic relations of the community-types in the research area in terms of diversity and similarity of composition are comparable to those found in north central Florida. The affinity of vegetation of the research area to more southern regions is also evidenced by the presence of a number of species with southern distributions which are uncommon in North Carolina; including *Asclepias pedicellata*, *Litsea aestivalis*, *Peltandra sagittaeifolia*, and *Pinguicula pumila*.

Zusammenfassung

Analyse der Vegetation der Küstenebene in Croatan National Forest.

Es werden 5 Hauptvegetationstypen im Untersuchungsgebiet des Croatan National Forest unterschieden. Diese Vegetationstypen sind durch die Kombination von typischen Arten gekennzeichnet, die auf diese Vegetationen beschränkt sind oder sehr häufig darin vorkommen. Die 5 Vegetationseinheiten sind:

1. *Pinus palustris*-*Quercus*-Trockenwald
2. *Pinus palustris*-Savanne
3. Pocosin-Vegetation
4. Auenwald
5. *Pinus taeda*-Hartholzwald

Die typischen Arten für jede Vegetationseinheit (Differential-Arten und Arten mit einer Stetigkeit von 5) sind in der Tabelle 3 zusammengestellt.

Die Verbreitung der Vegetationseinheiten ist auf der Vegetationskarte (Abb.5) zu sehen. Ein Vergleich der Vegetationskarte mit der geologischen und der Bodenkarte (Abb. 3 und 4) zeigt, dass zwischen Vegetationsverbreitung und Geologie und Boden eindeutige Beziehungen vorhanden sind. In der Newport Barrier-Gegend, welche der Newport Sand-Fazies der Flanner Beach-Formation entspricht, tragen eine weite Spanne von verschiedenen Bodentypen Vegetationen, die von der Föhren-Eichen-Trockenwald- bis zum Auenwald und zur Pocosin-Vegetation reichen. In der Newport Backbarrier-Ebene oder in der Beard Creek-Fazies wachsen weite Strauchsümpfe, die als Lakes-Pocosin bezeichnet werden.

Der *Pinus palustris*-*Quercus*-Trockenwald ist grösstenteils auf die tiefgründigen, übermässig durchlässigen Sande des Kureb-Bodens beschränkt. Die *Pinus*

palustris-Savanne dagegen findet man über den sandigen Grundwasser-Podsolen der Leon-Serien und auf etwas besser drainierten lehmigen Böden. Die wenig durchlässigen Böden der höheren Lagen mit schwarzem Oberflächenhorizont zeigen im allgemeinen Pocosin-Vegetation, während über den Histosolen der Dare- und Ponzer-Serien immer Pocosin-Vegetation anzutreffen ist. Auenwälder wachsen längs der Hauptentwässerungsrinnen auf vernässten Böden, die allgemein als Johnston-Muckalee-Böden bezeichnet werden. Der *Pinus taeda*-Hartholzwald ist über lehmigen bis tonigen Böden zu finden, z.B. über Goldsboro-Autryville und über Leaf-Böden.

Drei wichtige Standortsfaktoren bestimmen die Vegetationsverteilung im Untersuchungsgebiet und in der Küstenebene der Südoststaaten ganz allgemein: Nährstoffzugänglichkeit, Wasserverhältnisse und Feuer. Das Diagramm der floristischen Aehnlichkeit der Vegetationstypen (Abb. 6) gibt eine ungefähre Ordination der Vegetationseinheiten. Aus Abbildung 8 ist die Ordination der Gradienten der 3 wichtigsten Standortsfaktoren ersichtlich. Auch wenn die Standortsfaktoren nicht voneinander unabhängig sind, kann doch erkannt werden, dass jeder Faktor die Verbreitung der Gesellschaften beeinflusst.

Der *Pinus palustris*-*Quercus*-Trockenwald und der Auenwald bilden die beiden Extreme in bezug auf die drei Standortsfaktoren und zeigen die geringste floristische Aehnlichkeit aller Vegetationseinheiten-Paare. Der Standort des *Pinus palustris*-*Quercus*-Trockenwaldes ist am trockensten und nährstoffärmsten; die Vegetation wird oft abgebrannt, wenn auch wahrscheinlich nicht so oft wie die *Pinus palustris*-Savanne. Der Auenwald zeigt ähnliche Bodenvernässung wie der Pocosin und wird nur selten vom Feuer heimgesucht. Die Nährstoffzugänglichkeit ist im Auenwald am höchsten, gemessen an der Menge der Nährstoffe und am relativ hohen pH. Der *Pinus taeda*-Hartholzwald zeigt eine mittlere Stellung für alle drei Gradienten und die höchste mittlere floristische Aehnlichkeit mit allen anderen Vegetationstypen. In bezug auf die drei Standortgradienten unterscheidet sich die Savanne einzig durch die häufigeren Brände vom *Pinus taeda*-Hartholzwald. Die Pocosin-Vegetation befindet sich am feuchten Ende des Feuchtigkeitsgradienten, unterscheidet sich aber vom Auenwald durch die hohe Nährstoffarmut und die gelegentlichen Feuer.

Die Pocosin-Vegetation (Tab. 4) zeigt eine weite Variation vom Short-Pocosin mit niedrigem Strauchwuchs und schlecht wachsenden *Pinus serotina*-Bäumen über den Tall-Pocosin mit besserem Wachstum bis zum Bay-Pocosin, der von Hartholzbäumen dominiert wird, darunter *Persea borbonia*. Die Hydrologie der Pocosin-Vegetation wurde nicht untersucht. Es ist aber gut möglich, dass Veränderungen im Wassergehalt des Bodens wichtiger sind für das Zustandekommen von Strauchsumpf-Vegetation als Feuer oder Bodenart.

Die Pflanzengesellschaften des untersuchten Gebietes sind charakteristisch für den grössten Teil der Vegetation der North Carolina-Küstenebene und in ihrer Zusammensetzung und Struktur ähnlich wie die Gesellschaften, die zwischen Südost-Virginia und Nord-Florida auftreten. Die floristischen Beziehungen der Vegetationstypen im Untersuchungsgebiet sind hinsichtlich Artenvielfalt und Aehnlichkeit der Zusammensetzung vergleichbar mit jenen aus dem nördlichen Zentral-Florida. Die Aehnlichkeit des Vegetationsgebietes mit südlicheren Gegenden wird auch durch eine Reihe von Arten südlicher Verbreitung betont, die sonst in North Carolina selten sind: z.B. *Asclepias pedicellata*, *Litsea aestivalis*, *Peltandra sagittaeifolia* und *Pinguicula pumila*.

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Figure 5. Vegetation map showing the major vascular plant communities as described in Tables 3 and 4 and the text. Mapping was done on the basis of field observations and aerial photography. The base map was an uncorrected photomosaic constructed from 1971 black and white aerial photographs at a scale of 1:15,840.

