POCOSINS: AN ECOLOGICAL PERSPECTIVE

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Abstract: Pocosins and associated wetlands (PAAWS) of the North Carolina Plain are among the least studied ecosystems in the U.S. The purpose of this overview is to (1) classify pocosins and give their geographical location, (2) provide information on their geological origin, and give an ecological analysis of these ecosystems, and (3) analyze development trends. Recent surveys have shown that pocosins occur on the southeastern coastal plain from Virginia to north Florida and once covered more than one million hectares in North Carolina. A broad definition of pocosins (*sensu lato*) would include all shrub and forested bogs, as well as Atlantic white cedar stands and some loblolly pine stands on flooded soils on the Coastal Plain. A stricter definition (*sensu stricto*) of pocosin for delineation purposes would only include the classic shrub-scrub (short pocosin) and pond-pine-dominated tall pocosin. Common synonyms for pocosin, including bay, bayland, bayhead, xeric shrub bog, and evergreen shrub bog, further confuse what is and is not classified as a pocosin. The advanced identification and delineation of pocosins from upland and other associated wetland types will require detailed field analyses following the stricter definition of pocosins. Over 51% of the forested palustrine wetlands in North Carolina have been disturbed, and approximately 33% of pocosins have been destroyed. The 1991 U.S. Fish and Wildlife Service data follow the general trends for pocosin loss reported by Richardson in 1981. The high rate of wetland modification, especially for pocosin-type palustrine wetlands, suggests that stricter wetland laws are needed if we are to follow the concept of "no net loss of wetlands."

Key Words: Palustrine, bays, swamp, development trends, geology, soils.

INTRODUCTION

Sixty-five percent of the nation's palustrine forested wetlands (pocosins, swamps, bays, bottomland hardwoods, and bogs) and 22% of the palustrine emergent wetlands (inland freshwater marshes) occur in the southeast (Hefner and Brown 1984). Unfortunately, few detailed studies have been completed on the pocosins and associated wetlands (PAAWS). The only recent detailed survey of pocosins was completed by Richardson (1981a, 1983) but only for the state of North Carolina. I utilized and updated the North Carolina data and compiled new data for

this review of pocosin ecosystems. For a more extensive analysis of pocosins and Carolina bays, the reader is referred to Richardson (1981a), Sharitz and Gibbons (1982), Savage (1982) and Ross (1987). The purpose of this overview is to (1) define, classify, and give the geographical location of pocosins, (2) provide information on their geological origin, and give an ecological analysis of these ecosystems, and (3) analyze trends in alteration and loss.

It is hoped that this introduction and the papers that follow will provide an updated analysis of the functions and values of pocosins as well as provide state and federal agencies and landowners with a better framework for the delineation of pocosins and associated wetlands.

DEFINITIONS AND CLASSIFICATION

Definitions

Pocosin is an ancient Algonquin Indian word meaning "swamp-on-a-hill" (Tooker 1899). It has over 20 different spellings and is often seen on old maps and records as poquosin, poquoson, percoason, pekoson, pocoson, and pocason. One of the earliest reported usages of the term pocosin to indicate low, marshy ground or swamp is by Lawson (1709):

"The swamp I now spokd of, is not a miry Bog, but you go down to it thro' a steep Bank, at the Foot of which begins this Valley.... The Land in this Percoarson, or Valley, being extraordinary rich, and the Runs of Water well stor'd with Fowl."

Tooker (1899) gave several names that he considered dialectical corruptions of the work "pocosin" and stated

"The application of the term, therefore, in its linguistic sense, was to indicate or to describe localities where water 'backed up' as in spring freshets, or in rainy seasons, which, by reason of such happenings, become necessarily more or less marshy or boggy."

In 1875, Kerr, a geologist, defined pocosins as "...flatwoods with no natural drainage ways, different from swamps in that they are not alluvial, occurring on divides between rivers and sounds and frequently elevated above streams of which they were the source" (Kerr 1875). Harper (1907) characterized a pocosin as an "...extensive, flat damp, sandy or peaty area usually remote from large streams, supporting a scattered growth of pine (mostly *Pinus serotina*, Michx.) and a very dense growth of shrubs, mostly evergreen, giving the whole a decided heath-like aspect...". The most holistic definitions of pocosin were proposed by Wells (1928), Woodwell (1958), and Kologiski (1977). They described pocosins as being primarily restricted to the southeastern coastal plain, occurring on broad shallow basins, drainage-basin heads, and broad flat uplands. These areas have long hydroperiods, temporary surface water, periodic burning, and soils of sandy humus, muck, or peat.

The ecological relationship among pocosins, Carolina bays, and bay forests or bay swamps is that these wetland types can contain similar shrub vegetation, trees, and fauna. However, different geological conditions are responsible for the development of these ecosystems. Specifically, Carolina bays are ovate shallow solution depressions or deflation basins of variable size (a few hectares up to several thousand) found primarily on the coastal plain of North Carolina, South Carolina, and Georgia (Sharitz and Gibbons 1982, Richardson and Gibbons 1992). These wetlands are mostly classsified as non-tidal palustrine wetland ecosystems; trees, shrubs, persistent emergents, emergent mosses, or lichens cover 30% or more of the area (Cowardin *et al.* 1979). The relationship among these wetland types, when shown on a Venn diagram, shows that all pocosins, bay forests, pond pine woodlands, and Atlantic white cedar ecosystems are Palustrine wetlands, either forested or scrub-shrub (Figure 1). Moreover, most Carolina bays can be classified as Palustrine wetlands, with some overlap of species found in pocosins. However, some of the Carolina bays would have too little plant cover (e.g., large proportion of open water) to be classified as palustrine and would be classified as lacustrine wetlands.

Classification

The Indians used the term pocosin to describe a variety of bog and swamp ecosystems rather than to delineate a single class of wetlands. For this reason, pocosin was used by Richardson *et al.* (1981) to cover a number of subclasses of wetlands found on the coastal plain of the southeastern United States. Specifically, the dominant subclasses from the 1954 classification of the United States Fish and Wildlife Service (USFWS) that were included under the term bog were pond pine wetlands and scrub/shrub wetlands, along with Atlantic white cedar stands, savannas, and loblolly pine stands on hydric soils. For a more complete classification of pocosin types, see Weakley and Schafale (1991).

In the 1956 national survey of wetlands types (Shaw and Fredine 1956), pocosins were classified as Type VIII (bogs) and given the lowest waterfowl rating nationwide. Kuchler (1964) classified this wetland type as follows: TITLE (pocosin, *Pinus-Ilex*); PHYSIOGNOMY — Low open forests of needleleaf evergreen trees and broadleaf evergreen low trees and shrubs and much moss; DOMINANTS — Gall berry (*Ilex glabra* L.) and Pond pine (*Pinus serotina*, Michx.); OTHER COMPONENTS — *Cyrilla racemiflora* L., *Gordonia lasianthus* L., *Magnolia virginiana* L., *Myrica cerifera* L., *Persea borbonia* L., *Smilax laurifolia* L., and *Sphagnum* spp.; OCCURRENCE — Coastal plains from Virginia to South Carolina.

In the new wetland classification system, pocosins are classified as palustrine systems; class: scrub-shrub (vegetation less than 6 meters high is referred to as short pocosin, see Figure 2) or forested (vegetation more than 6 meters high

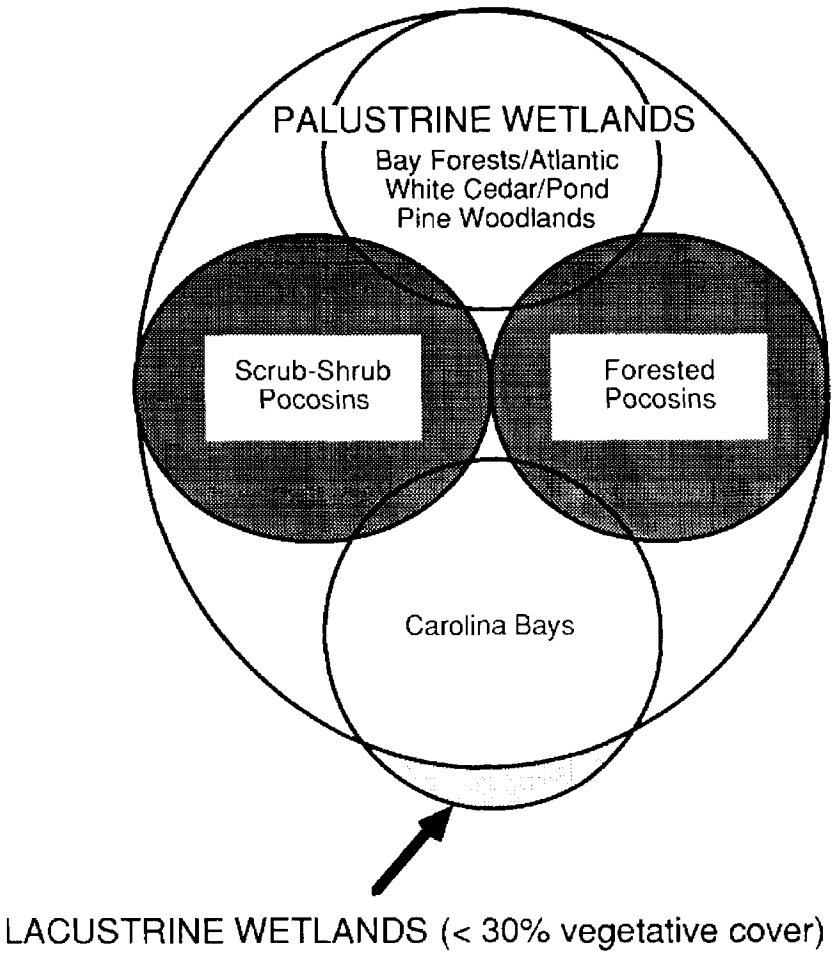

Figure 1. The relationship of pocosins, Carolina bays, bay forests, and swamp forests in the U.S. Fish and Wildlife Service wetland classification system.

is called tall pocosin, see Figure 2); subclass: broad-leaved evergreen; water regime: saturated or semipermanently, intermittently, or seasonally flooded; water chemistry: fresh-acid; soil: organic (Medisaprist) (Cowardin *et al.* 1979).

A broad definition of pocosins (sensu *lato*) utilized by Richardson resulted in the inclusion of all shrub and forested bogs, Atlantic white cedar stands, and some loblolly pine stands on flooded soils, as well as a number of other coastal freshwater

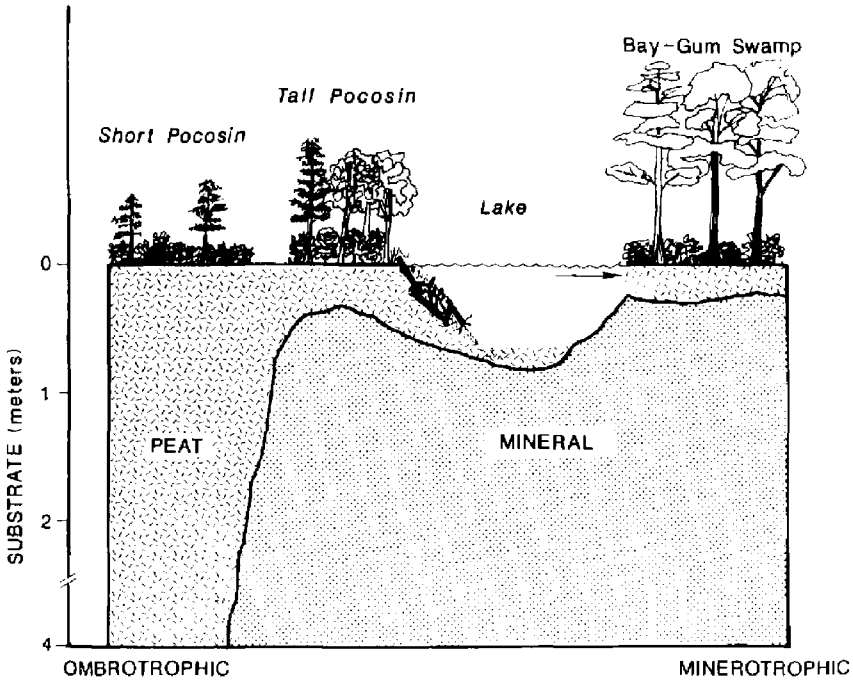

Figure 2. Profile view of the short and tall pocosin and bay gum forests on the North Carolina landscape.

wetlands. This inclusive definition of pocosin would thus incorporate most of the freshwater wetlands on the Carolina coastal plain. However, many have argued that a stricter definition of pocosin would be more useful, especially for delineation purposes. If defined *sensu stricto*, then the classification of pocosin would only include the classic shrub-scrub (short pocosin), and pond-pine-dominated tall pocosin. The exact breakdown by bog subclasses in the 1954 report was as follows: Pond-pine - 413,797 ha; scrub/shrub - 332,452 ha; savanna - 24,700; and loblolly pine - 391,000 ha. The total area of pocosins in North Carolina, using the stricter definition, would represent a 36% reduction in wetlands classified as pocosins by Richardson (1981a, 1983). His study was based on Wilson's 1962 report that 908,000 ha of pocosins existed in North Carolina as of approximately 1950.

In summary, savanna and loblolly pine stands would not be included as pocosins sensu *stricto*. Seventy percent of the nation's scrub-shrub and pond-pine pocosins are, however, found in North Carolina and they comprise more than 50% of North Carolina freshwater wetlands (Richardson *et al.* 1981).

Common synonyms for pocosin include bay, bayland, bayhead, xeric shrub bog, and evergreen shrub bog (Kologiski 1977), which further confuses what is meant by the term pocosin. From a vegetational point of view, there seems to be a consensus that pocosins and bays are usually covered in a dense tangle of evergreen and deciduous shrubs, and vines. However, differences in size and geologic origin exist between large pocosin tracts and Carolina bays.

Geographic Distribution of Pocosins

Recent surveys have shown that pocosins occur on the southeastern coastal plain from Virginia to north Florida and once covered more than one million hectares in North Carolina (Richardson 1981a, 1983). Pocosin vegetation has been found as far west as coastal Alabama. The exact distribution of pocosins along the coastal plain has not been mapped for most states, but their location as of 1950 in North Carolina is shown in Figure 3. This pocosin map was based on Wilson's 1962 report, which in turn utilized USFWS aerial surveys taken from 1939 to 1949 (USFWS 1954).

GEOLOGY

Geologic Origin and Soils

Pocosin tracts often cover hundreds of square kilometers and are found on flat, clay-based soils in shallow basins on divides between ancient rivers and sounds on the Atlantic coastal plain. Impeded runoff of fresh water (i.e., blocked drainage due to sediment build-up, rising sea levels, and peat formation) coupled with the milder climate since the Wisconsin Ice Age about 18,000 years ago, resulted in a shift from boreal forest species to present-day southern wetland forests and evergreen shrub bog communities (Whitehead 1972, 1981). A more detailed analysis of pocosin structure and function relevant to landscape scales is given by Brinson (1991).

Pocosin vegetation is found on mineral soil, sandy humus, organic muck, and peat (Histosols, Terric or Typic Medisaprist) (Barnes 1981, Gilliam and Skaggs 1981). A number of studies, including greenhouse bioassays (Woodwell 1958, Wilbur and Christensen 1983), fertilization of natural ecosystems (Simms 1985, Bridgham and Richardson 1992), and fertilization studies in managed ecosystems (Maki 1974, Ralston and Richter 1980) suggest that phosphorus is the proximal limiting nutrient in pocosin ecosystems. The ecosystem gradient from short pocosin to tall pocosin to bay forest represents a natural gradient of increasing P availability and decreasing soil N:P ratio (Table 1) (Walbridge 1991). Exchangeable P, peat depth, and bulk density also differ among pocosin sites. Exchange of hydrogen ions

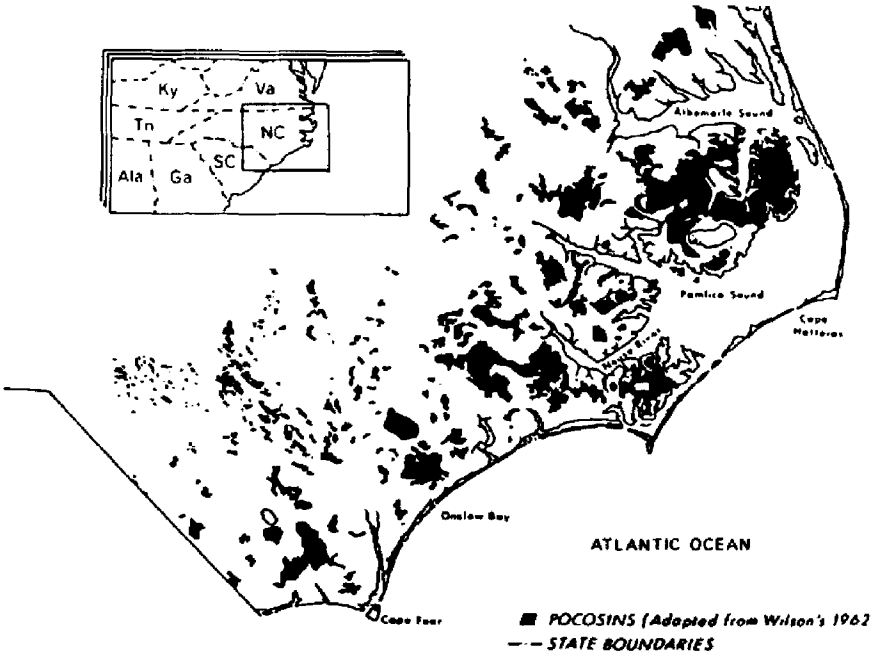

Figure 3. A map showing the distribution of pocosin wetlands and Carolina bays in North Carolina in the 1950s. Total area was estimated to be 908,000 hectares (Wilson 1962).

for cations results in low soil pH (pH < 4.0) (Dolman and Buol 1967), which, along with anaerobic conditions, preserves the organic constituents of the poorly drained peats (Maki 1974, Snyder 1978). These soils are saturated or shallowly flooded primarily during the cool seasons. On raised organic soils, precipitation is virtually the only external source of plant nutrients; the peat is thick enough to keep the underlying mineral soil out of contact with plant roots, and there is no external drainage of water into these bogs. These peatlands are referred to as oligotrophic (i.e., having water poor in nutrients).

Based on carbon-14 dating from the Dismal Swamp, the deposition of most organic clays and overlaying peat within this region began between 10,340 ± 130 and 8,135 ± 160 years before present (Daniel 1981). However, radiocarbon dates from much of the peat forest present today in the Dismal Swamp indicate ages under 3,500 years. This information, when coupled with the changes in pollen profiles (Whitehead 1972, 1981), the presence of charcoal at various depths

Table 1. Physical and chemical properties of pocosin soils in coastal North Carolina (Adapted from Walbridge 1991).

Stands and Peat Depth (cm)	Loss Ignition (%)	Soil pH	Bulk Density (g/cm^3)	Ca:Mg[3]	Exchangeable P (kg/ha)[1]	Total N (kg/ha)	Total P (kg/ha)	N:P
Natural Gradient[2]								
Short Pocosin >150	95.2a	3.9a	0.049a	0.61±0.02a	6.2±1.5a	1124±80a	19.6±0.2a	57.2±5.8a
Tall Pocosin 66-109	94.4a	3.7b	0.046a	0.72±0.07b	7.7±1.0a	950±29a	29.3±3.1a	32.9±3.3b
Bay Forest	76.2b	3.7ab	0.090b	1.14±0.15b	34.6±3.6b	2234±77b	118.3±4.2b	18.9±0.3c

Values with the same letter are not significantly different, (P=0.05).

[1]Mass per hectare is based on a depth of 15 cm.

[2]Ranges of two site means.

[3]From Bridgham and Richardson 1992.

(Dolman and Buol 1967), and the evidence of decreased rainfall (McComas *et al.* 1972, Whitehead 1981), indicates fluctuations in peat oxidation and accumulation rates and the occurrence of extensive fires in pocosin peatlands: thus, a dynamic peat-development history.

ECOLOGY

Tall Pocosins, Short Pocosins, and Bay Swamps: A General Comparison

Disturbance of wetlands began in the southeast as early as 1700 for timber and later for agriculture (Richardson 1981a). The pocosin communities of today are only a remnant of the vegetation of pre-settlement times (Lilly 1981). Most of the extensive stands of Atlantic white cedar, cypress, pine, and gum, etc. were harvested during the past 200 years. However, an interesting mosaic of wetland ecosystems still exists across the coastal-plain landscape. Distinct ecosystems, varying in vegetational composition and soil-nutrient status (Table 1), occur along a topographic gradient, even though local relief is generally 2 m or less. Topographic highs are occupied by nutrient-deficient short pocosins, which are ombrotrophic shrub bogs that occur over relatively deep peat accumulations (> 1m) (Figure 2, Richardson 1983). Tall pocosins and sometimes shallow dystrophic lakes border short pocosins. Tall pocosins occur over shallower peat (approximately 50 to 100 cm), have soils with higher nutrient content, and exhibit greater vegetation height and aboveground biomass than short pocosins (Wendel *et al.* 1962, Christensen *et al.* 1981). Relatively nutrient-rich gum swamps and bay forests occur along the southern margins of the lakes and along outflow stream drainages (Figure 2). Peat depths in gum swamps/bay-forest stands can range from approximately 50 cm to > 150 cm of organic matter, depending on the age of the stand, and the soil-mineral content is somewhat greater than in pocosins (Table 1). A detailed comparison of low and tall pocosin plant-community characteristics is given by Weakley and Schafale (1991).

A large store of organic matter exists in short and tall pocosins and gum swamps, with the top 30 cm containing 1,520, 860, and 1,010 MT of carbon, respectively (Bridgham 1991). Bridgham found highest gaseous carbon loss via CO_2 in gum swamps (90 mole CO_2 m^{-2} yr^{-1}), followed by tall pocosin (66 mole CO_2 m^{-2} yr^{-1}), and short pocosin (58 mole CO_2 m^{-2} yr^{-1}), thus supporting the peat storage trends. Methane loss was insignificant compared to carbon dioxide losses. Aboveground productivity averaged 710 Kg/ha/yr for short-pocosins and 2,820 and 4,310 Kg/ha/yr in tall-pocosins and gum swamps, respectively. Bridgham (1991) noted that belowground C storage is the most important storage process and that the importance of this increases in the most nutrient-deficient short pocosins.

In general, pocosins and bay-swamp forests share a number of species like *Magnolia virginiana* L., *Persea borbonia* L., *Gordonia lasianthus* L., *Cyrilla*

racemiflora L., and *Pinus serotina* Michx. Pocosin species shared with the pine flatwoods include *Ilex glabra* L., *Ilex coriacea* (Pursh), *Vaccinium corymbosum* L., *Aronia arbutifolia* L., and *Gaylussacia* spp. Synder (1980) compared the floristic similarity for the five major community types and found the highest community similarity between pocosin and the pine savanna. This was also the case in north Florida, where Monk (1968) found a fifty percent similarity in tree species between the flatwoods savanna and bayheads (pocosins).

The number of tree stems per hectare and the basal area are very much reduced in both pocosin types compared to adjacent swamp forest stands, while herb cover is lowest in the gum swamp/bay forest. Jones (1981), in a comparison study in South Carolina, also found a greater number of tree species, shrub species, and total woody species as well as greater basal area in bay forests than in pocosins. Species evenness is highest in the low pocosin type and decreases steadily as productivity increases (Woodwell 1958, Christensen 1979).

Succession and Stable Plant Communities in Pocosins

The two basic theories of pocosin succession are in sharp contrast with each other. In 1928, Wells proposed that the frequency and intensity of fire controls successional development. According to this theory, the pioneer stage is short pocosin, which succeeds to the bay forest climax within a few hundred years if disturbance is prevented. The second theory of pocosin succession (Otte 1981) assumes that nutrient levels are the controlling factor. The limiting soil nutrient is primarily phosphorus (Richardson 1983, Walbridge 1991). According to this hypothesis, the successional sequence is marsh —> swamp forest —> bay forest —> tall pocosin —> short pocosin. As mentioned earlier in the geologic section, pollen analysis supports Otte's proposed sequence in communities. This succession has taken place over the past 5,000 years as paludification (peat expansion over the landscape) has resulted in an extensive peat-covered landscape in part of the southeastern coast and an associated gradual rise in the water table. The importance of fire versus nutrients or hydroperiod in controlling pocosin succession, however, is not clear.

These factors are so interrelated that it is impossible to isolate one as the primary control (Otte 1981). In addition, the amount of peat accumulation also is a factor that controls plant community distribution, succession, and stability.

Christensen *et al.* (1988) in a detailed ordination analysis of coastal vegetation in the southeastern United States, found that soil-nutrient content was related to vegetational patterns. They found that pocosin sites on the landscape were those with low soil fertility and that with decreasing peat depth and less frequent inundation, they graded into flatwoods, which have saturated mineral soils (gleyed Aquults) (Figure 4a). They also found that all communities were highly correlated to time since the last fire and that all communities were negatively related to peat depth. This suggests that some index of nutrient status and the specific time since

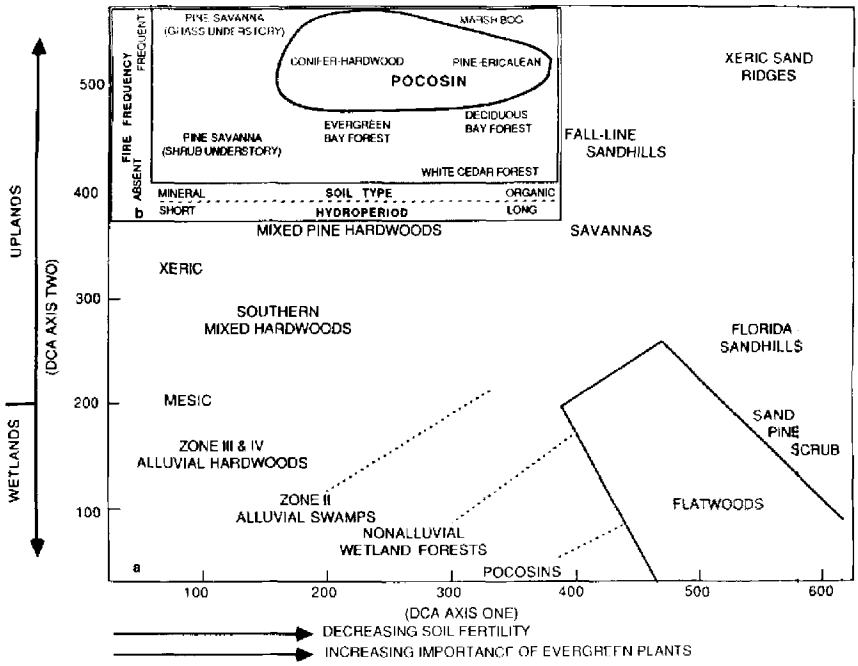

Figure 4a. An ordination analysis of the vegetation of the southeastern United States. Axis one of a Detrended Correspondence Analysis (DCA) shows a separation of communities by fertility. The importance of evergreens was also noted by Christensen (1988). DCA axis two separated uplands and wetlands primarily on depth of peat. Figure was adapted from Christensen (1988).
Figure 4b. Proposed relationships among wetland vegetation types, hydroperiod, and fire in pocosin habitats (based on Kologiski 1977).

last fire would greatly improve our understanding of succession and plant communities. Christensen also noted that detrended correspondence analysis (DCA axis 2) allowed pocosins to be distinguished by peat depth from nonalluvial white cedar swamp forests, which in turn grade into alluvial swamp forests (bayheads and cypress), and allowed alluvial swamps to be separated from the upland mesic forests (Figure 4a).

These correlations do not show cause and effect but do support the theory that nutrient-poor short pocosins on deeper peat are the climax community on the landscape once the peat depth reaches a thickness that prevents plant roots from reaching the mineral-rich substrate (i.e., the short pocosin will remain until a major

fire or other disturbance reduces the peat layer). The high water table in short pocosins for 6 to 12 months per year, in conjunction with the fact that these nutrient-poor raised bogs only receive nutrients from rainfall (ombrotrophic), also contributes to their dominance on many parts of the coastal landscape, especially in North Carolina today.

One interpretation of how these factors control the patterns of wetland comunities on the coastal plain is Kologiski's model (Kologiski 1977) of the relationship among vegetation types, hydroperiod, soil type, and fire for the Green Swamp area of North Carolina (See insert, Figure 4b). He noted that hydroperiod was probably the most important variable, for it controls the establishment and growth of plants and, to some extent, the severity of fire. In general, pocosins originally covered thousands of hectares on the coastal landscape, especially in Virginia and the Carolinas, in areas with deeper peat, longer hydroperiods (6 to 12 months), and fires occurring on a 20 to 50 year cycle (Christensen *et al.* 1988). Pine savannas (shrub understory) occur on mineral soils with short hydroperiods and very low fire frequency. Frequent fires (3 to 10 years) on mineral soils and short hydroperiod result in a pine savanna with a grass understory. Marsh bogs (terms from Kologiski) are believed to be the result of severe fires, which result in deeply burned peat areas and have a combination of marsh and bog species. The bay forest was divided into evergreen and deciduous types by Kologiski (1977) and were found on organic soils with moderate to long hydroperiods with a highly variable fire pattern of often > 50 years (Christensen *et al.* 1988).

If fires or development remove or alter the PAAWS soil or peat substrate or hydrology, endangered plants such as white wicky (*Kalmia cuneata* Michaux), arrowleaf shieldwort (*Peltandra sagittae-folia* Michaux), spring-flowering goldenrod (*Solidago verna* M.A. Curtis), and rough-leaf loosestrife (*Lysimachia asperulaefolia* Poiret) will face local extinction. Other plants that depend in part on pocosin-type habitat or adjacent coastal savanna are the threatened venus fly trap (*Dionaea muscipula* Ellis), dwarf fothergilla (*Fothergilla gardenii*), and sweet pitcher plant (*Sarracenia rubra* Walter) and the endangered white beakrush (*Rynchospora alba* L.) (Cooper *et al.* 1977).

Animal Communities

Few detailed studies have been completed on the fauna of PAAWS. Pocosins serve as habitat for the specialized swallowtail (*Papilio palamedes* L.) and the Hessel's hairstreak butterfly (*Mitoura hesseli* Hessel). They are important to the federally endangered pine barrens tree frog (*Hyla andersoni* Baird) (Wilbur 1981). The state endangered eastern diamondback rattlesnake (*Crotalus adamanteus* Beauvois) and American alligator (*Alligator mississippiensis* Daudin) are also found here. Pocosins are refuges for native big-game species, such as black bear (*Ursus americanus* Pallas) and white tailed deer (*Odocoileus virginianus*

Zimmermann), and smaller mammals, such as the bobcat (*Lynx refus* Schreber), marsh rabbit (*Sylvilagus floridanus* Allen), and gray squirrel (*Sciurus carolinensis* Gmelin) (Monschein 1981). The federally endangered red-cockaded woodpecker (*Dendrocopos borealis* Vieillot) inhabits mature pond pines in pocosins.

DEVELOPMENT TRENDS

Ownership Patterns in Pocosins

A detailed analysis of the conversion rate of pocosins reported for North Carolina is representative of all pocosins, for this state once contained nearly 70% of the nation's pocosins (Shaw and Fredine 1956). In 1980, it was estimated that major timber companies, large corporate farms, and state and federal ownership comprised 83% of the pocosin land in North Carolina (Figure 5a). The timber companies owned between 40 and 50% of all pocosin land. The only major shift in ownership patterns from the 1960s was that nearly 202,000 ha (500,000 acres) were transferred from corporate forestland to large-scale agriculture (Richardson *et al.* 1981). Small private landowners controlled about 12%, and only 5% of the pocosin land was under designated protection status (Figure 5a). In 1984, a 51,300 ha (127,000 acre) wetland area was donated to the USFWS by Prudential Life Insurance Company, and the Alligator River Wildlife Refuge was created. An additional 44,000 ha (108,910 acres) of pocosin land near the Alligator Refuge was purchased by the R.K. Mellon Foundation in 1989. By 1989, large corporate agriculture held only 14% of the pocosin land, and timber companies had also reduced their holdings (Figure 5b). Nearly 246,000 ha (608,910 acres) of pocosins and bay-type wetlands were under some form of protection in North Carolina (Weakley 1989, pers. comm.). This represents approximately 25% of the plaustrine wetland areas in North Carolina as described by Wilson in 1962.

Conversion of Pocosins to Developed Lands

Around 1950, pocosins covered 908,000 ha, nearly 16% of the entire land area of the forty-one coastal counties in North Carolina (Wilson 1962). Wilson's county maps were compared to 1979 Landsat imagery, 1980 field checks, and land-use field maps to obtain an estimate of the extent of conversion of pocosin land (note: a broad definiton of pocosin was used in this survey) from approximately 1940 to 1980 (Richardson *et al.* 1981). It was determined that 608,000 ha of natural or slightly altered pocosins remained by 1980. Of the pocosins identified as natural in Wilson's report, 299,000 ha are now totally developed (Figure 6). Totally developed is defined here as wetlands that have been drained and ditched, their natural vegetation removed, their soils prepared for agriculture, forestry or industry,

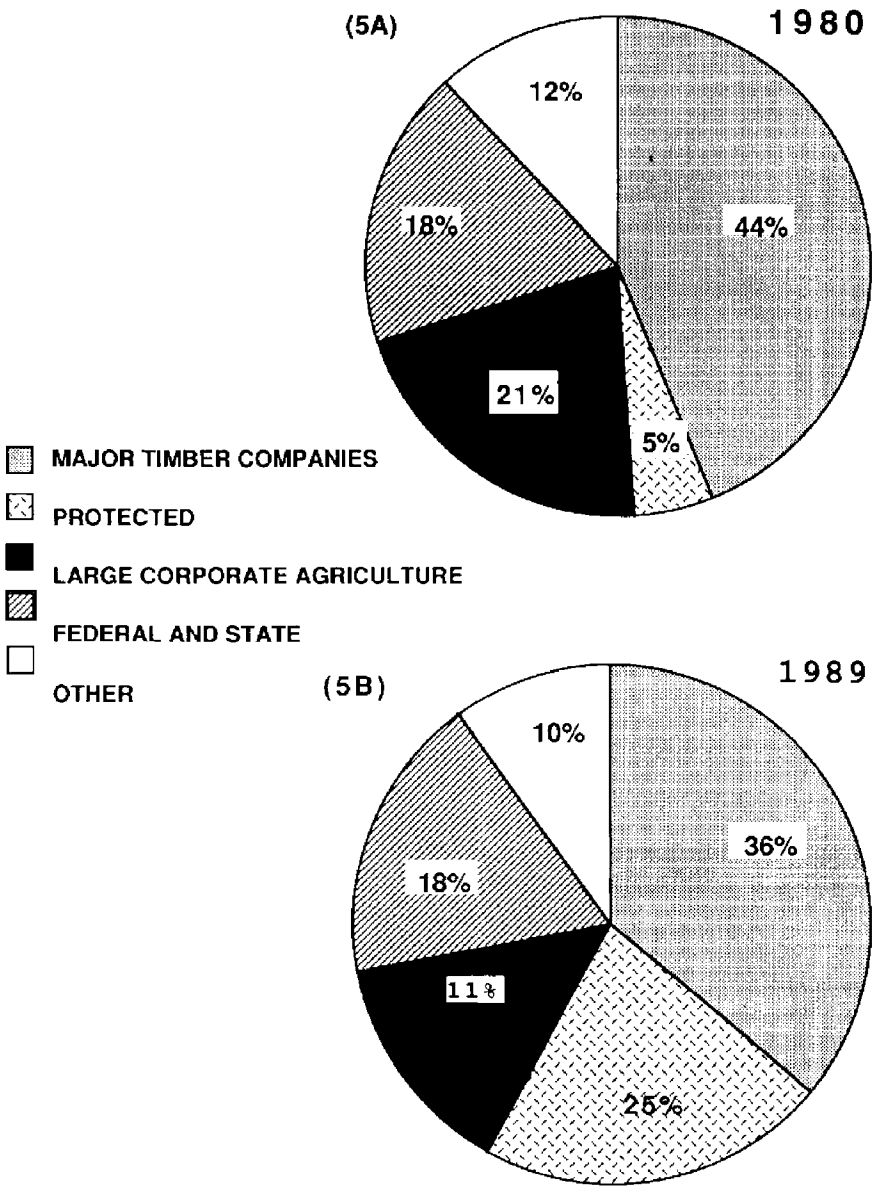

Figure 5a. Ownership patterns (by percent) of pocosins in North Carolina as of 1980. Calculation are based on tax office maps, industrial use maps, and state maps. Figure 5b. An estimate of ownership patterns (by percent) of pocosins in North Carolina as of 1989. Calculations of change are based on land sales.

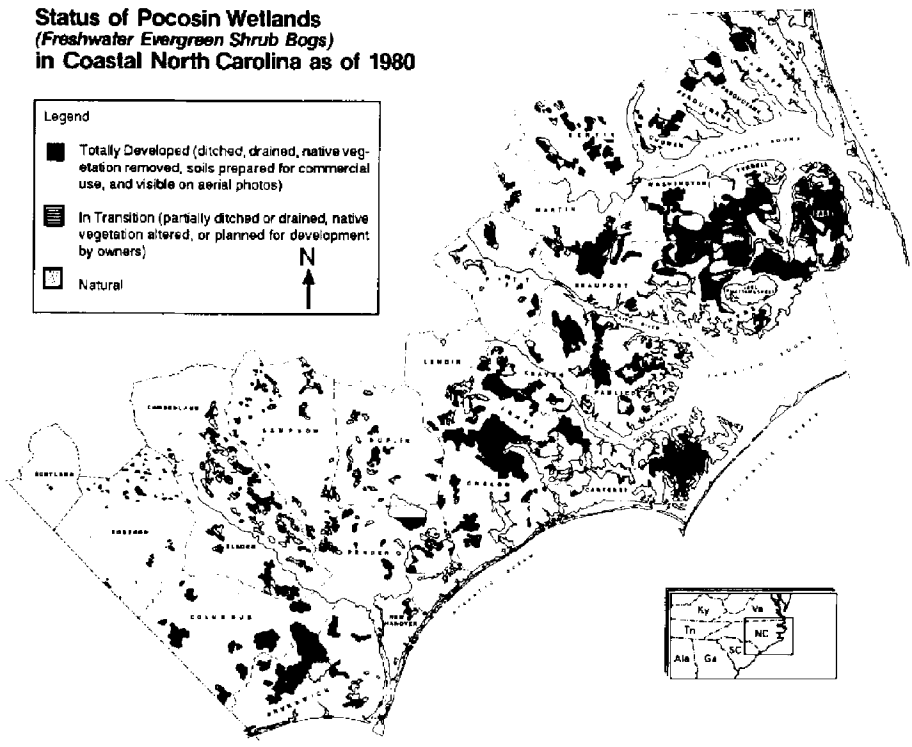

Figure 6. Status of pocosin wetlands in coastal North Carolina in 1980. Totally Developed (in black) denotes wetlands ditched and drained, with native vegetation removed and soils prepared for commercial use as visible on aerial photos. In Transition (cross hatched) denotes wetlands partially ditched or drained, native vegetation altered, or planned for development by owners. Natural (stippled) denotes undisturbed wetlands or areas set aside for protection (Richardson 1983).

etc., and that are clearly depicted on Landsat imagery or other photos. On a statewide basis, total conversion by 1980 represented nearly 33% of Wilson's reported acreage for pocosin land.

A second category, in-transition, was established to denote those pocosin areas that were either partially altered (drained, cleared, or cut), planned for development by their owners (personal communication with owners), and/or disturbed to the point where native vegetation and ecosystem processes (e.g., hydrologic flux) were changed. Thirty-six percent of the original 907,933 ha (i.e., 327,000 ha) of pocosin area may be classified as in-transition. Only 31%, or 281,000

ha, still existed in its natural state as of 1980. The acreage for pocosin that has had no drainage or human disturbance is, however, considerably less than 281,000 ha. For example, closer analysis of the largest expanse of pocosin in the Albermarle-Pamlico region of North Carolina reveals that portions of the area had undergone intensive lumbering and extensive drainage as early as the 18th century (Richardson *et al.* 1981).

A recently completed 1990 wetland development survey for all wetland types in the North Carolina Coastal Plain (Cashin 1990) revealed that significant development has taken place on all wetland types. Cashin found that 51% of all wetlands had been converted by 1980. Non-tidal wetlands experienced a higher loss (53%) than tidal wetlands(12%). Palustrine forested wetlands experienced the greatest percentage of conversion of any wetland type. An estimated 41% of the forested wetlands surveyed had been developed between 1950 and 1980. In addition, nearly a third of the total wetland loss (16% out of 51%) occurred between 1950 and 1980. Forestry was responsible for 53% of the wetland alteration and agriculture 42% of the wetland loss (Cashin *et al.* 1992). The impacts of forestry operations on PAAWS are discussed by Campbell and Hughes (1991).

Development Effects

The term "alteration" was used for the conversion of pocosin to pine plantation, since it is argued by the forest industry that loblolly pine plantations still maintain wetland status and some functions. It is true, however, that these systems no longer function as native pocosin ecosystems. The use of PAAWS for agriculture, forestry, or peat mining requires removal of native vegetation, placement of drainage ditches, burning of debris, scraping, surface preparation, and road building. Ditching by itself, however, does not result in total loss of pocosin vegetation, especially on deep peat, unless it is followed by soil surface alterations and continual water removal.

Preliminary estimates of carbon export (Richardson 1983) indicate that a major shift will take place in gaseous carbon flux if drainage occurs on peat soils. Fluvial organic carbon outputs are also three times higher from organic pocosin lands than from adjacent mineral soils. The additional effects of drainage on fluvial carbon losses are unknown. On a regional basis, the outputs, in addition to carbon from drained and developed pocosins, are fresh water and nutrients, with bacteria, trace metals, and pesticides being found only at specific sites (Richardson 1983). Drainage and development may at times increase the total outflow of water from pocosins, but more often, dramatic increases occur only in peak flows. This means that periodically, and quite possibly at a different season than normal, downstream systems will receive not ony increased volumes of fresh water but also increased dissolved nutrients and suspended materials. The effects of this input on downstream ecosystems such as estuaries have been noted by Barber *et al.* (1979) and

Street and McClees (1981). They suggest that reduced shellfish production is a direct consequence of lower salinity levels in estuaries where canals feed fresh water directly into primary nursery areas. Of special concern to regional eutrophication problems is the magnitude of total phosphorus (P) losses due to pocosin conversion. For example, natural pine stands on mineral soil and pocosin wetlands on organic soil lose 0.2 and 0.3 kg/ha/yr of P, respectively (Richardson 1983). When the organic soil pocosins in the region were converted to pasture and agriculture, the P losses increased to 6.1 and 8.5 kg/ha/yr, respectively. The effects of this increase on regional water quality are unknown, but indications of serious potential eutrophication problems have been estimated (Richardson 1981b, 1983). For a complete review of water quality of PAAWS, see Walbridge and Richardson (1991).

Additional ecological concerns surrounding pocosin development include (1) loss of habitat for unique plants and animals, (2) loss of wildlife habitat for species such as black bear and deer, (3) an increase in subsidence and oxidation of peat due to drainage, (4) the intrusion of saltwater into regional water supplies because of freshwater removal, (5) an increase in trace-metal output in water from drained areas, (6) loss of biological diversity, and (7) loss of a biological gene pool that is from one of the least studied ecosystems in the United States.

CONCLUSIONS

Pocosins are expansive freshwater wetlands that are confined to the southeastern United States. They are associated with similarly vegetated wetland types on the coastal plain but are of different geologic origin and size than Carolina Bays. Our knowledge of their functional value on the landscape is still poor since almost no detailed research has been funded for these wetlands. We do know that their role in coastal water quality is essential and that they function as giant evaporation systems in the regional hydrologic cycle as well as carbon storage systems on the landscape (Skaggs *et al.* 1991, Richardson and Gibbons 1992). The advance identification and delineation (ADID, Humphries 1991) of pocosins from upland and other associated wetland types will require detailed field analyses following the stricter definition of pocosins. Recent development trend data follow the general trends for pocosin wetland loss and conversion reported earlier by Richardson (1981a, 1983). The high rate of wetland development,especially for pocosin-type palustrine wetlands, suggests that stricter wetland laws are needed if we are to follow the policy of "no net loss of wetlands." The placement of an additional 20% of the palustrine wetland areas under protection status during the past ten years bodes well for the future of coastal freshwater wetlands in North Carolina. Other states have not followed this trend.

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