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THE ECOLOGY OF SOUTHEASTERN SHRUB BOGS (POCOSINS) AND CAROLINA BAYS: A Community Profile

Fish and Wildlife Service

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THE ECOLOGY OF SOUTHEASTERN SHRUB BOGS (POCOSINS) AND CAROLINA BAYS: A COMMUNITY PROFILE

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PREFACE

This report is one of a series of U. S. Fish and Wildlife Service Community Profiles synthesizing the available literature for selected critical ecosystems into comprehensive and definitive reference sources. The objective of this particular account is to review the information available on the shrub bog communities, primarily pocosins but also including many Carolina bays, of the mid-Atlantic Coastal Plain. Both of these ecosystems are included under the same community profile because they frequently exhibit similar vegetational characteristics, have overlapping geographical ranges, and usually have low nutrient, peaty soil conditions.

The combination of similar environmental conditions and the regional overlap of the two ecosystems results in their having similar species compositions. They are generally distinguishable, however, because of the distinctive morphology of Carolina bays (oval-shaped depressions with identifiable margins) and clearly different geologic origins, although disagreement exists about how both pocosins and Carolina bays were formed. Nonetheless, they share in being the major sites of shrub bog communities on the mid-Atlantic Coastal Plain.

These shrub bog communities are under severe environmental impact throughout the Southeast although the major threats vary in different areas. Most man-related environmental alterations have occurred because pocosins and Carolina bays can be drained and the land used for agricultural, forestry, or urban purposes and because they often have peaty soils, which may be commercially valuable. Because of previous and continuing efforts to use or alter these areas for commercial purposes, the amount of remaining natural habitat diminishes annually.

The shrub bog community of pocosin and Carolina bay ecosystems is one of the least-studied, most poorly understood of the natural wetlands in the Eastern United States, a fact that makes the rapid disappearance of these habitats due to the environmental alterations associated with land use and development of critical importance. This report will provide a synthesis of what is currently known about the geologic origins, hydrology, soil conditions, water quality, biota and general ecology of these ecosystems. A consideration of the community as a whole reveals major gaps in our knowledge of its structure and dynamics at all levels. The limited information already available clearly documents the close environmental tie between coastal pocosins and contiguous estuaries. A strong interaction between Carolina bays and mobile animals from surrounding terrestrial habitats can also be demonstrated. This community profile addresses information gaps which still exist about the significant environmental interactions between shrub bog communities and surrounding habitats.

The information in this community profile should be useful to all environmental planning groups, ecosystem managers, and concerned laymen in the Atlantic Coastal Plain, as well as to students and professional wetland ecologists. The quantitative presentations in figures, tables, and text will permit easy access to detailed information about specific qualities and characteristics of the habitats. Thus, the document should be valuable for report writing, planning environmental assessment studies, preliminary determinations of potential impacts of land management, or general information for formal courses on the topic of natural wetlands. Such information on environmental impact, rate of habitat loss, and gaps in our knowledge about these systems should interest all ecologists, environmental planners, and environmentally aware citizens. An extensive, thorough and current bibliography is provided for anyone wishing to pursue particular topics in depth.

The authors accept full responsibility for all statements, interpretations, citations of other investigators, and original data presented.

Any questions or comments about or requests for this publication may be directed to:

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A number of reviewers, including A. N. Ash, C. B. McDonald, and L. J. Otte (East Carolina University), C. J. Richardson and N. L. Christensen (Duke University), E. C. Pendleton and J. M. Hefner (U. S. Fish and Wildlife Service), C. A. Gresham (Clemson University) and J. F. Schalles (Creighton University), provided useful comments on an early draft. Members of the National Coastal Ecosystems Team (NCET) staff, especially W. M. Kitchens and E. C. Pendleton, were extremely helpful in offering guidance and suggestions. G. Farris, S. Lauritzen, and E. Krebs of NCET provided editorial, layout, and word-processing assistance, repectively; G. Golden assisted in drafting.

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INTRODUCTION

COMMUNITY PROFILE BACKGROUND AND OBJECTIVES: SHRUB BOGS OF THE ATLANTIC COASTAL PLAIN

The recognition and appreciation that natural wetlands are a valuable, non-renewable resource that can provide critical or essential habitat for natural vegetation and wildlife, including non-game and endangered species, are becoming widespread among government, academic, and even commercial organizations. This concern has led to establishment of Federal and State regulations (for example Executive Order 11990, Protection of Wetlands) to protect these natural systems and their associated flora and fauna.

Understandably, initial attention by most interested groups focused on large bodies of permanent water such as estuaries, major lake systems, and rivers or streams which supported obvious game or commercial enterprises. When industrial, agricultural, or urban impacts on these large aquatic areas affected commercial and sports fisheries interests or the hunting of waterfowl, environmental concerns quickly became an issue. Resolution of the complex of environmental, legal, ethical, and other issues surrounding the best approaches of preserving, managing, or utilizing natural wetlands is not likely to be attained in the near future. It is agreed, however, that our basic knowledge of the structure and function of most natural systems is woefully inadequate for us to make prudent decisions about the optimal management (or non-management) approach. Far too little is known about the life histories of most plants and animals inhabiting aquatic areas. Biological surprises about even the most thoroughly studied species emerge monthly in professional journals (e.g., Echelle and Mosier 1981; Fairchild 1981), reinforcing the awareness that we know far too little about the ecology of most natural systems to be able to exercise reasonable judgment about how these systems should interface with our agro-industrial society.

Among the natural wetlands that are most poorly studied are two types restricted to the Atlantic Coastal Plain and abundant from southern Virginia to northern Florida. These wetland ecosystems--pocosins (Figure 1) and Carolina bays (Figure 2)--share a common feature of being systems of low-nutrient status that in most instances do not have permanent standing water, but are strongly influenced by the hydrologic regime. The vegetation of pocosins and of many extant Carolina bays is dominated by pines and broadleaved evergreen shrubs or low trees that are generally but not always growing on highly organic or peat soils.

Man's activities have imposed a variety of environmental modifications and ecological changes in pocosin and Carolina bay ecosystems. Subsequent to regional timber removal in the early development of the Southeast, pocosin ecosystems have generally been considered of low economic value for agriculture, although they have recently become recognized as a source of peat. In regions of excessively drained soils, Carolina bays have commonly been farmed because they are areas of higher soil moisture. Few studies, however, have been carried out to assess the regional importance of either ecosystem in terms of faunal and floral dependence and utilization. It is not known how critical a pocosin or a Carolina bay is to regional wildlife. For example, black bears are characteristically encountered in pocosins of eastern North Carolina, primarily because these ecosystems contain some of the few natural areas left in the region. Are present-day land management practices jeopardizing the future of certain plants and animals that rely on such natural habitats for feeding or breeding sites or other purposes?

The extent of man's alteration of these wetlands cannot be determined. During colonization, widespread timbering occurred throughout the Coastal Plain region. Although such logging was not exclusively in pocosins or Carolina bays, these habitats were not spared from considerable tree removal. Thus, major losses of Atlantic white cedar, cypress, and black gum probably occurred. As a result, the original vegetational characteristics of many localities are unknown today. The shrub bog community may be second-growth in some instances, following logging of the original forest species. In other areas, particularly in smaller Carolina bays, an original evergreen shrub vegetation may have been altered or removed by farming operations so that the shrub community is sparse or absent today.

Because of the peat soil feature characteristic of many pocosins, large expanses of pocosin vegetation may have been burned during dry periods in early historical and recent times. A major modern impact is the removal of peat for commercial purposes. The highly organic soil can be processed to produce methanol or sold as a mulching agent for horticultural operations or home use. Although at the present time peat has been mined only experimentally in the major pocosin areas of North Carolina, peat-methanol gasification operations are scheduled for future development. Thus, there is potential that thousands of acres of natural pocosin habitat could succumb to the commercial efforts of peat mining in the Carolinas.

Major changes have also occurred in the hydrologic regimes of many pocosins and Carolina bays, primarily because wet

Figure 1. Evergreen shrub bog pocosin in Dare County, NC. (Photograph by Charles B. McDonald, East Carolina University, Greenville, NC.)

Figure 2. Two aspects of a typical Carolina bay (Dry Bay, Savannah River Plant, SC), showing gradation in vegetation types from grasses (Panicum spp.), shrubs, and cypress (Taxodium spp.) to hardwoods and pines.

conditions interfere with most agricultural or commercial operations. Thus, drainage has perhaps been the most severe environmental alteration of these systems. Innumerable Carolina bays have been drained with single, long-axis ditches, which lower the surface waters and expose additional acres of land. Extensive drainage canal systems have been used in agriculturally converted pocosin areas, creating more rapid runoff following precipitation and lowering the subsurface water level in the immediate vicinity. The pocosin canals have caused measurable changes in water quality of surface runoff into adjacent estuaries in North Carolina (Kirby-Smith and Barber 1979; Pate and Jones 1980).

In spite of the variety of activities affecting these ecosystems, our understanding of their ecological structure and functioning, as well as of their ability to withstand perturbations, is limited. Our objectives are to define, characterize, and review the level of ecological knowledge about pocosin and Carolina bay ecosystems, with emphasis on the shrub bog communities that characterize the pocosins and are found in some Carolina bays. Such a review reveals certain major and critical gaps in what we know, or should know, about these ecosystems and suggests areas of research where efforts should be placed in future studies. The knowledge presently at hand, however, permits us to make some recommendations about current management and commercial practices within the context of how critical pocosin and Carolina bay ecosystems are to the natural flora and fauna.

CHAPTER 1

DESCRIPTION OF SHRUB BOGS OF THE ATLANTIC COASTAL PLAIN

1.1 DEFINITIONS OF SHRUB BOGS, POCOSINS, CAROLINA BAYS, AND SIMILAR ECOSYSTEMS

In this document, "shrub bog" is a general term referring to a specific successional vegetational stage of many coastal palustrine[1] wetlands that is dominated by broadleaved evergreen shrub vegetation. Shrub bogs of the Southeast occur in areas of poorly developed internal drainage that typically but not always have highly developed organic or peat soils. Pocosins and Carolina bays are types or subclasses of shrub bogs that exhibit these attributes and occur chiefly in the Carolinas and Georgia.

A variety of geological situations may have led to the development of pocosin ecosystems that contain such a vegetation type. Carolina bays, on the other hand, are further defined in terms of their characteristic geomorphometry and are a subclass of shrub bogs only in those cases where the characteristic shrub bog vegetation occurs. In addition to shrub bog floral and faunal communities, Carolina bays may also include other successional stages of wetland vegetation, or non-palustrine habitats such as open water or even upland plant and animal associations (as a result of extensive drainage or other alterations). The relation of pocosins and Carolina bays to each other, to shrub bogs, and to other palustrine wetlands is depicted in a broadly simplified manner in Figure 3. A discussion of other associated wetlands and their relation to the two focused on in this profile will be deferred until the chapter on succession.

[1]The palustrine system includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens (Cowardin et al. 1979).

Pocosins and Carolina bays may share roughly the same distribution patterns, soil types, floral and faunal species composition and other community attributes, but they differ in their geological formation and present geomorphometry. Carolina bay communities develop only within the unique elliptical depressions that characterize these systems. Pocosin communities develop in a variety of geologic situations (including Carolina bay depressions) in which water drainage is restricted.

In this profile, the terms "pocosin" and "Carolina bay" are used to indicate entire community entities. As adjectives, the terms "pocosin" and "shrub bog" can often be used interchangeably. The term "Carolina bay" may be synonymous when the

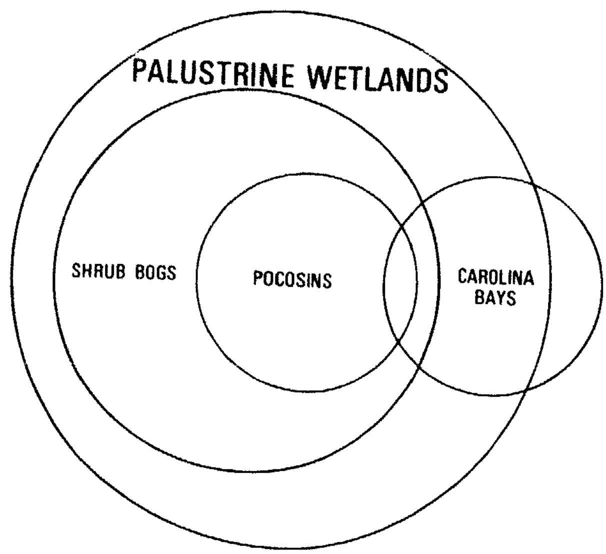

Figure 3. The relation of shrub bogs, pocosins, and Carolina bays to each other and to the general class of palustrine wetlands (E.C. Pendleton, U.S. Fish and Wildlife Service, Slidell, LA; pers. comm.).

vegetation and fauna are characteristic of a pocosin. When the discussion of Carolina bays is on attributes not in common with shrub bogs or pocosins, the meaning should be clear from the context of the narrative.

Pocosins

The pocosin ecosystems of the Southeast contain broadleaved evergreen shrub bogs. Such bogs typically occur in areas characterized by highly organic soils and long hydroperiods during which inundation may occur. A recent map of pocosin wetlands prepared by Richardson et al. (1982) shows that the largest areas of pocosin occur in the outer Coastal Plain of North Carolina (Figure 4). Although early settlers used the term to depict a variety of swamp vegetation types, early botanical accounts of these systems variously described them as marshy or boggy shrub areas or flatwoods with poor drainage where peaty soils support scattered pond pines and a dense growth of shrubs, mostly evergreen.

The Oxford English Dictionary (OED 1971) describes pocosin as a tract of low swampy ground, usually wooded, in the Southern United States, and reports that the word pocosin (also poquosin, poquoson, percoarson, perkoson, poccoson, and pocason) is derived from the Algonquin Indian word "poquosin." The OED provides various reports of the usage of the term pocosin to indicate low marshy ground or swamp, including:

"1875 W. C. Kerr Rep. of the Geol. Survey of N. Carolina I.15. There is a large aggregate of territory (between 3,000 and 4,000 square miles) mostly in the counties bordering on the seas and the sounds, known as Swamp Lands. They are locally designated as 'dismals' or 'pocosins' of which the great Dismal Swamp on the borders of North Carolina and Virginia is a good type..." and an earlier reference in which the term was used to mean swamp:

"1709 J. Lawson Hist. Carolina 26. The swamp I now spoke 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 place names that he considered dialectal corruptions of the word "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, became necessarily more or less marshy or boggy."

He mentions the name of a river in North Carolina that was called the Poquosen and points out the term "pocoson" was "frequently used by George Washington (1763), for example, 'Black mould taken out of the pocoson on the creek side....'"

In 1928, Wells provided a broad definition of what he considered the pocosin concept which included soil type, topography, hydrology, effects of burning, and vegetation composition. He described pocosins as occurring in broad shallow stream basins, drainage basin heads, or broad flat upland areas of the Coastal Plain that are characterized by long hydroperiods, temporary surface water, periodic burning, and soils of sandy humus, muck or peat. He noted that even though it occurs over large areas of the Coastal Plain, the pocosin ecosystem is poorly defined. The dominant vegetation is usually broadleaved evergreen shrubs or low trees (Figure 1), such as titi (*Cyrilla racemiflora*), red bay (*Persea borbonia*), sweet bay (*Magnolia virginiana*), loblolly bay (*Gordonia lasianthus*), bitter gallberry (*Ilex glabra*), zenobia (*Zenobia pulverulenta*), and wax myrtle (*Myrica cerifera*), overtopped by pond pine (*Pinus serotina*) and woven together with greenbrier (*Smilax* spp.). Definitions by more recent authors (Penfound 1952; Oosting 1956; Woodwell 1956; Kuchler 1964; Radford 1977) generally follow Wells' concept of pocosin.

According to the wetland classification system developed by the U. S. Fish and Wildlife Service (Cowardin et al. 1979), pocosins are classified as system: palustrine; class: scrub-shrub; subclass:

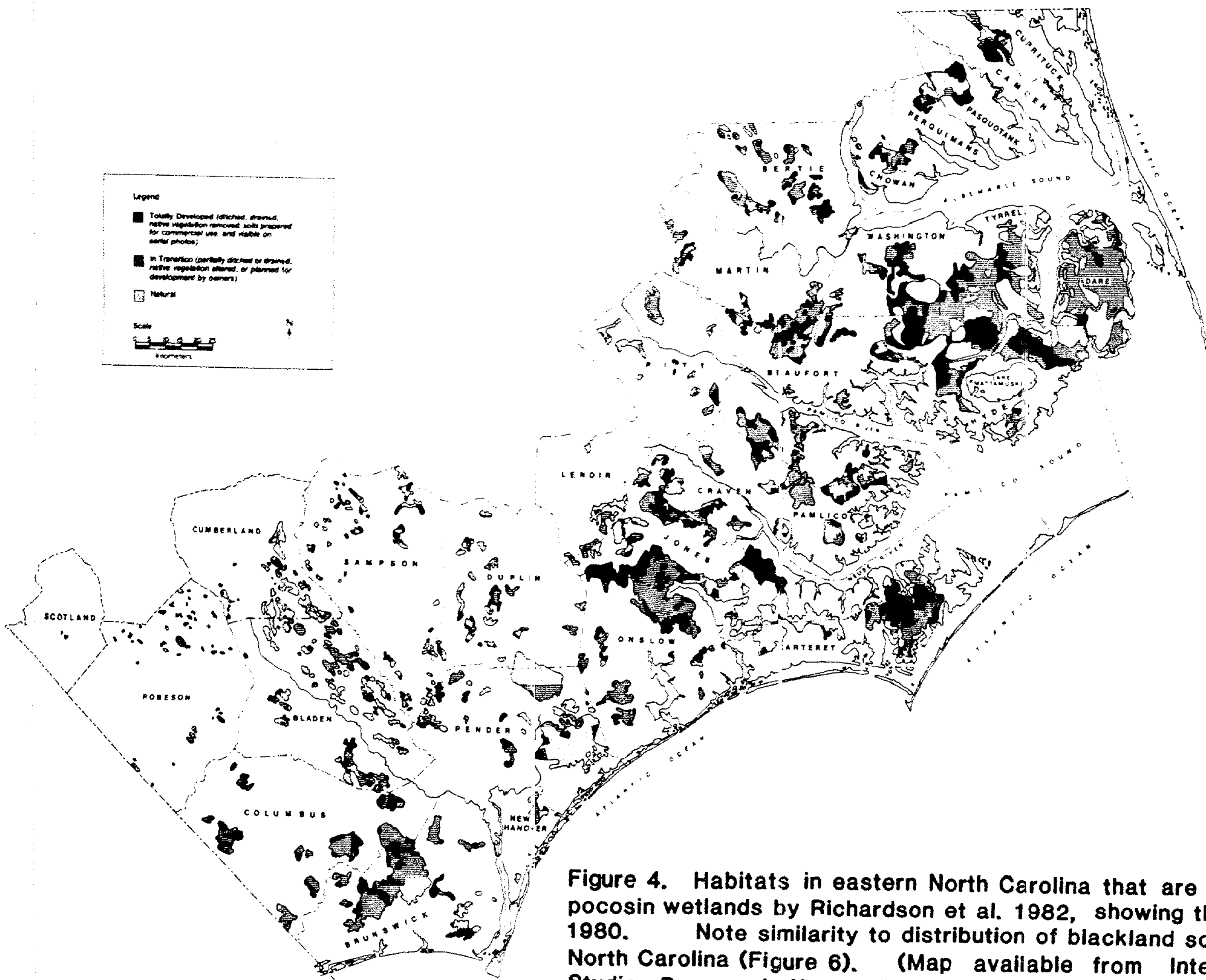

Figure 4. Habitats in eastern North Carolina that are identified as pocosin wetlands by Richardson et al. 1982, showing their status in 1980. Note similarity to distribution of blackland soils in eastern North Carolina (Figure 6). (Map available from Integrated Case Studies Program in Natural Resource Analysis, School of Forestry and Environmental Studies, Duke University, Durham, NC 27706.)

broadleaved evergreen; water regime: saturated; water chemistry: fresh-acid; and soil: medisaprist.[2]

The definition of pocosin is confounded by various terminologies that have arisen among different professions. For example, pine-dominated flatwoods occurring in areas with prolonged hydroperiods may be included in a forester's definition, whereas a hydrologist might consider only those shrub bogs occurring in broad, undrained interstream areas to be true pocosins. Because of the various definitions and the similarities between pocosin vegetation and other plant communities such as bay forests, some of the material in this review may be taken from or applied to Coastal Plain wetlands that are closely related to pocosins but do not fit the ecological definition in all aspects. Possible successional relationships among these various wetland communities are discussed in Chapter 3.

In summary, for the purposes of this community profile, pocosins are defined as freshwater wetland ecosystems characterized by broadleaved evergreen shrubs or low trees, commonly including pond pine, and commonly growing on highly organic soils that have developed in areas of poor drainage. Their present range of occurrence is the Atlantic Coastal Plain from southern Virginia to northern Florida.

Carolina Bays

Carolina bay ecosystems are formed in elliptical depressions which occur abundantly in a broad band across the Coastal Plain province of the Southeastern United States (Figure 5). Some bays are less than 50 m (162 ft) in length; an unusually large one (Lake Waccamaw in North Carolina) is more than 8 km (5 mi) long. These puzzling physiographic features of the landscape present a remarkable consistency of shape and degree of parallelism in compass orientation along their axes. Called "bays" by early European pioneers who observed the evergreen shrubs and bay trees typically growing on their margins (Figure 2), these ovate wetlands afford suitable habitat for a vast assortment of plants and animals.

Colloquial names such as "highland pond" or "wet weather lake" indicate the dependency of Carolina bay ecosystems upon rainfall and their lack of association with other lentic (still water) or lotic (flowing water) habitats. They characteristically have no tributary streams, are not spring-fed, and rely on direct precipitation and run-off to maintain water volume. Groundwater recharge has been suggested as an additional source in some situations (Schalles 1979). Evaporative water loss, a temperature-dependent phenomenon, reduces water volume and can result in the complete drying of shallow bays. Thus, many smaller Carolina bay depressions contain temporary aquatic habitats that may dry up seasonally or for longer intervals under local conditions of low precipitation or regional drought.

Because of extensive variability in size, depth, substrate conditions, and geographic location, Carolina bays do not have a single characteristic vegetation type. Many, including Jerome Bog (Buell 1946a) and Rockyhock Bay (Whitehead 1981) in North Carolina, contain evergreen shrub bogs or pocosins. Others contain lakes (Frey 1949), herbaceous marshes (Wharton 1978), or swamps (Porcher 1966). Still others, such as Ellenton Bay in South Carolina (Sharitz and Gibbons 1982) may have once supported forest or shrub communities, but have been severely modified by agricultural practices. Both the natural unaltered plant communities and the direction and rate of successional change in Carolina bays following disturbance are highly dependent upon environmental variables such as water level and fire. Therefore, a particular community type does not necessarily represent a particular stage of succession.

For more than 300 years, natural habitats in the region encompassing Carolina bays have been influenced by human alteration as a consequence of agriculture, forestry, industry, and other land management. These impacts, in addition to any burning by Indians (Wells and Boyce 1953b), have left unanswerable the

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[2]Medisaprist soils are well-decomposed organic soils (histosols) with an organic depth greater than 40 cm (16 inches).

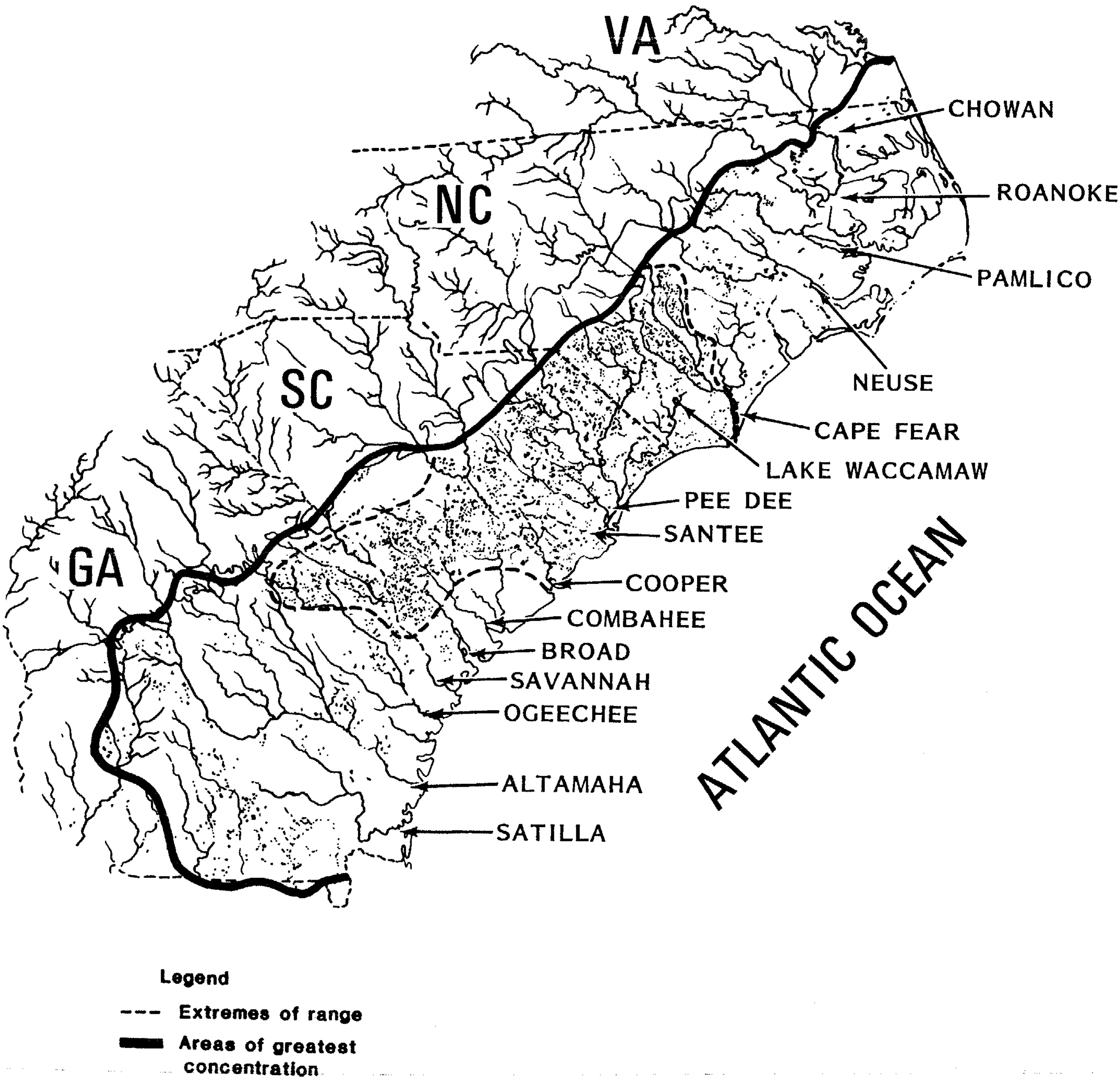


Figure 5. South Atlantic Coastal Plain showing distribution of Carolina bays larger than 246 m (800 ft) in length (based on Prouty 1952).

question of how extensively the evergreen shrub bog community type, the "pocosin," may have occurred within Carolina bay systems. Logging may have enhanced the conversion of forests to pocosin shrub communities in many of the larger bays, whereas other disturbances such as farming have reduced the extent of pocosin vegetation.

For purposes of this community profile, we define Carolina bays as elliptical depressions of the southeastern Coastal Plain which are consistently oriented in a northwest-southeast direction and many of which contain shrub bog communities. We may, however, use certain examples from the literature or from our own studies which include Carolina bays that at present do not meet every qualification of this plant community type, although they may have had all of the characteristics under earlier natural conditions.

Related and Superficially Similar Habitats

Not included in this report are a number of ecosystems in the Eastern United States containing plant associations that have certain characteristics in common with pocosin vegetation. Among these are the pine barrens of New Jersey, which are characterized by a stunted pine canopy overtopping a low shrub thicket, and bay forests of Florida, which are dominated by evergreen shrub and tree species. Large wooded wetlands on peaty substrates also include portions of the Florida Everglades and the Okefenokee Swamp in Georgia, which are generally not considered pocosins primarily because of differences in tree and shrub height and/or species dominance in the community. Most of these systems also do not occur within the mid-Atlantic Coastal Plain range of pocosins and Carolina bays and therefore are not under consideration in this report. Within this region, however, the shrub bog community as described above sometimes grades into other communities such as evergreen and deciduous bay forests, pine flatwoods and swamp forests, so that the boundaries may not be precisely delimited. Descriptions and data from these and other closely related plant communities, such as Atlantic white cedar bogs, pine savannas and bay forests of the mid-Atlantic Coastal Plain, will be presented as is appropriate to point out similarities and differences and to provide insight when available information on pocosins is limited.

1.2 GEOGRAPHIC DISTRIBUTION OF POCOSINS AND CAROLINA BAYS

Pocosins typically occur in the lower and middle Coastal Plain terraces of the mid-Atlantic States. A precise description of their distribution is hindered by the lack of agreement regarding the definitions and characteristics of these systems. In addition, many of the characteristic pocosin plant and animal species may be distributed in wetlands throughout the Eastern or Southeastern United States. For example, pond pine, the canopy dominant in many pocosins, occurs from New Jersey to Florida and Alabama (Kaufman et al. 1954; Woodwell 1958). In this report we will consider the geographic range of pocosin habitat to be in restricted areas of the Coastal Plain from southern Virginia to northern Florida and as far west as Alabama (Shaw and Fredine 1956; Wells and Whitford 1976).

It is estimated that pocosin ecosystems once covered more than 1.2 million ha (approximately 3 million acres) of the southeastern Coastal Plain. Today the largest evergreen shrub bog pocosins are on the outer Coastal Plain of North Carolina (Figure 4) where they are one of the major plant communities developed on the blackland soils (organic and dark-surfaced mineral soils) (Figure 6). Richardson et al. (1981), who examined the developmental status of North Carolina pocosins, reported that the six largest natural pocosin areas remaining in the State are in Dare and Pasquotank Counties in the northern part of the Coastal Plain; in Carteret, Craven, and Jones Counties in the central part of the region; and in Pender, Duplin, and Brunswick Counties in the southern portion. They estimated that in 1962, nearly 70% of all the existing pocosins (about 907,933 ha or 2,243,500 acres) occurred in North Carolina. They are rapidly being developed, and by 1979 only 31% of this ecosystem remained in its natural state (Richardson 1982). Nevertheless, they still comprise more than 50% of North Carolina's wetlands (Richardson et al. 1981). Some of the best examples of natural pocosin vegetation in North Carolina today are found in Angola Bay, Holly Shelter, portions of the Croatan National Forest, and portions of the Green Swamp.

Carolina bays are restricted to the southeastern Coastal Plain and lower Piedmont, and occur predominantly in the coastal areas of South Carolina and in southeastern North Carolina (Figure 5). Defining the exact boundaries of the distribution of Carolina bays is difficult because of the interpretive problem of whether certain small depressions are "true" bays or not. The area of highest density of these depressions extends between the Fall Line and the lower Coastal Plain from the Ogeechee River area in Georgia to the Cape Fear River region of North Carolina (Figure 5). Frey (1950) reported that in North Carolina, bays are more common on the middle Coastal Plain terraces than on either the lower or upper Coastal Plain. The same appears to be true in South Carolina on the basis of aerial photography.

The only appreciable cluster of Carolina bays recognized by Prouty (1952) as being above the Fall Line is in Jasper and Putnam Counties, Georgia. Wharton (1978) does not identify this cluster and shows bays in Glascock County, Georgia, as being closest to the Fall Line. Dense clusters on the western and southern extremities of the range occur in Brooks County, Georgia, west of the Okefenokee Swamp, with isolated examples extending almost to Alabama (Prouty 1952) and into northern Florida. Northern range limits are more obscure. A recent report by Bliley and Pettry (1979) identified more than 150 bays on the Eastern Shore of Virginia (southern extremity of the Delmarva Peninsula), and Melton (1938) stated that examples could be found in Maryland and Delaware. A small cluster of lakes southeast of Philadelphia was noted by Prouty (1952) in his original map, but their designation as true Carolina bays may not be appropriate. Clearly, the density of Carolina bays varies appreciably over their geographic range (Figure 7). About 400,000, or 80% of the total number estimated by Prouty

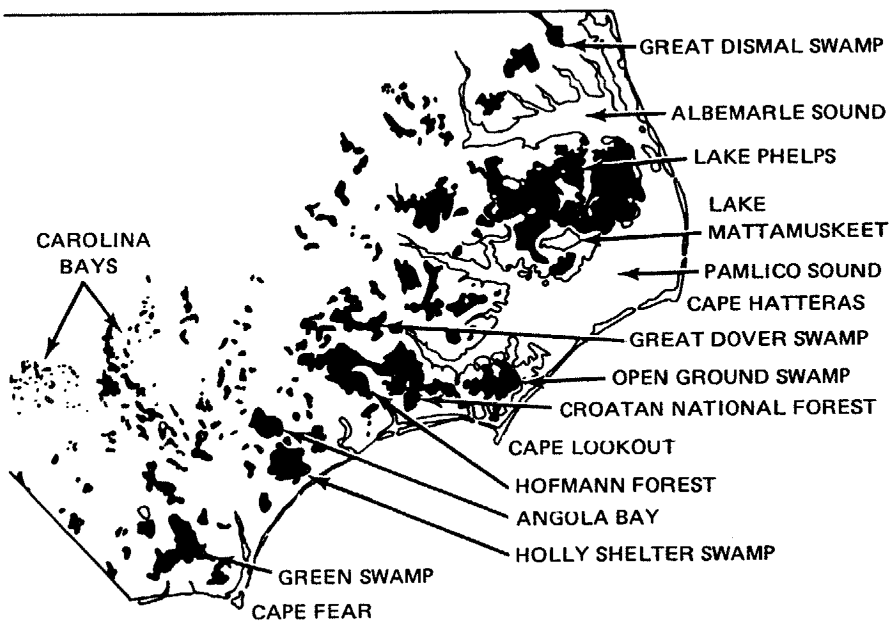
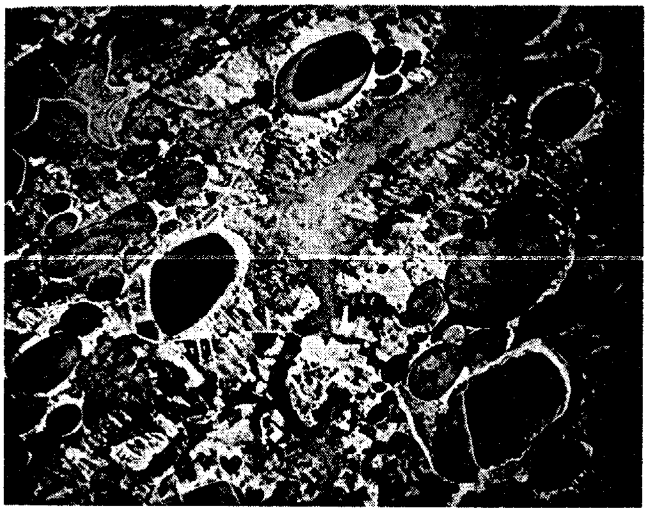
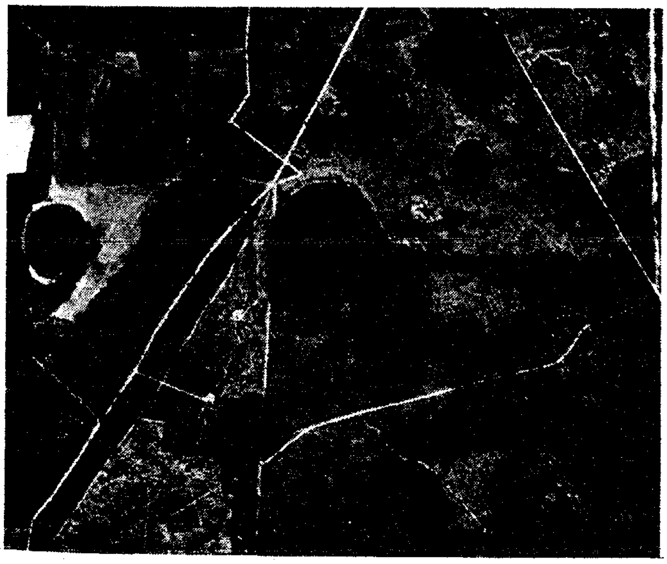


Figure 6. Distribution of blackland soils (organic soils and dark-surfaced mineral soils) in North Carolina (Lilly 1981b in Pocosin Wetlands: An Integrated Analysis of Coastal Plain Freshwater Bogs in North Carolina, ed. C. J. Richardson. Copyright 1981 by Hutchinson Ross Publ.Co., Stroudsburg, PA. Reprinted by permission of the publisher).

(1952), are found in the Carolinas (North Carolina Natural Heritage Program unpublished data, cited by Richardson 1982). It is difficult to estimate the total area covered by Carolina bays because they are non-contiguous in distribution, and many may have boundaries that are hard to recognize, may be obscured by farming or other land management or development practices, or may partly overlap each other. The geographic range of Carolina bays encompasses approximately 23,310 km^2 (9000 mi^2).



High density area, Bladen County, NC (Photograph by Charles E. Roe, North Carolina Natural Heritage Program.)



Low density area, Barnwell County, SC

Figure 7. Aerial comparison of two Carolina bay area densities.

Neither pocosins nor Carolina bays demonstrate clear gradients in geomorphology or in species composition throughout their range of occurrence, although certain regional differences may be recognizable. For example, directional orientation of Carolina bays may show a slight geographic variation (Johnson 1942a), as described in Chapter 2. The total acreage of land occupied by pocosin wetlands on the Coastal Plain decreases from north to south in accordance with changes in the topography and geology. Although organic soils supporting pocosin vegetation may develop under several geologic situations, flat interstream areas of the lower Coastal Plain terraces in North Carolina support the greatest expanse of pocosin vegetation. In South Carolina where pocosin ecosystems are more restricted in area, they occur chiefly in depressions associated with ridge and swale topography and in Carolina bays. Likewise, certain differences in the characteristic species may be recognizable in pocosin or Carolina bay communities throughout their range. Woodwell (1956) classed pocosins according to their dominant shrub species and reported a shift in species dominance along a north-south gradient and following fire (see Chapter 3). The North Carolina pocosin communities represent the northern range extensions for certain species, including loblolly bay. Similar geographic patterns of species distribution may have become obscured by disturbance from natural causes or from land management practices.

1.3 THEORIES OF GEOLOGIC ORIGIN

Pocosins

On the basis of the most thoroughly studied pocosin habitats--those in the Coastal Plain of North Carolina (Richardson 1981a)--these wetland communities began to develop following the Wisconsin Ice Age, about 15,000 years ago. Daniel (1981) described the geologic processes that led to the development of these areas. More than 75,000 years ago prior to the last expansion of the polar ice cap, the level of the Atlantic Ocean in the Southeast was 13 to 15 m (approximately 45 to 50 ft) higher than at present. During the Wisconsin Ice Age, however, the sea level dropped to as much as 120 m (about 400 ft) below its present level and exposed large areas of the Continental Shelf. Because sea levels during the Wisconsin Age were much lower than at present, fast-flowing rivers cut through the Coastal Plain terraces to the Atlantic Ocean.

During the next several thousand years as the ice receded, sea levels gradually rose (~ 30 cm/century, Milliman and Emery 1968) and brought about major changes in the hydrology of the Coastal Plain. One theory of pocosin formation relies on the assumption that during this period river flows were slowed and organic sediment loads were deposited in the interstream areas as the lotic (flowing) systems shifted to near-lentic (or slow-moving) aquatic systems (Daniel 1981). Aquatic plants began to grow in these shallow bodies of water, adding to the accumulation of sediments and the buildup of aquatic debris. Concomitant with the buildup in organic sediments and the climatic warming trend that accompanied the end of the Wisconsin Ice Age, the cooler-climate, boreal forest communities were gradually eliminated (Whitehead 1972) and replaced with hardwood forests, swamps, bogs, and marshes. In the nutrient-poor areas often associated with the buildup of deep peat, evergreen shrub forests became predominant.

It is assumed that wet habitats with a propensity for buildup of organic soils developed as a consequence of a shallow water table, large distance between streams (both resulting in slow runoff and subsequent accumulation of water), and rainfall that has exceeded evapotranspiration (Daniels et al. 1977). The accumulations of peat that would ultimately form the Coastal Plain pocosins generally began between 8,000 and 10,000 years before present (B. P.) (Daniel 1981). For example, radiocarbon dating of the earliest organic sediments in the Great Dismal Swamp of Virginia indicates that these peats were formed about 8,900 ± 160 years ago (Oaks and Coch 1973). However, a mantle of organic deposits in the Hofmann Forest of North Carolina may have begun as long ago as 220,000 years. Radiocarbon dates of sediment profiles from other sites (e.g., Chesapeake Bay, Harrison et al. 1965) generally indicate ages of 8,000 to 15,000 years B. P. Additional evidence gained by matching pollen profiles from pocosin peat with known floral succession patterns associated with the glacial retreat supports the assumption that the pocosin wetlands developed between 10,000 and 12,000 years ago (Otte 1981).

Otte (1981) challenged the theory of pocosin development in stream valleys and flat interstream areas as a consequence of blocked drainage associated with sea level rise. He pointed out that 10,000 to 12,000 years ago the sea level was approximately 25 m (81 ft) below the present level and many miles eastward of the present shoreline. He contended that the position of the sea at that time was so far removed from the sites of development of the blocked drainage systems that it is unlikely that sea level could have been the major controlling factor in the development of these wetlands. Furthermore, Otte noted that pocosins have developed in only a portion of the drainage systems on the Coastal Plain, not in all. This evidence also strongly suggests a non-sea-level cause of pocosin formation. If Otte's theory is correct, the origin of the drainage blockages that resulted in pocosin formation in certain stream systems is as yet unknown.

Four different types of geologic situations are considered to support pocosin communities in the southeastern Coastal Plain. These are (1) flat areas associated with blocked stream drainage on the lower terraces (Figure 8), (2) Carolina bays, (3) areas of ridge and swale topography between relict beaches and dune ridges (Woodwell 1956), and (4) springs and stream heads of the upper Coastal Plain area (Wells 1932; Christensen et al. 1981). In addition, this evergreen shrub bog association may develop, although not usually as extensively, in other areas such as along floodplains of streams (Daniel 1981). The major pocosin areas of the Carolinas and Virginia have formed in stream valleys or on broad interstream areas with restricted drainage.

Paludification (bog expansion caused by a gradual rising of the water table as peat accumulates) has proceeded for several thousand years in these broad interstream areas in which natural drainage is blocked (Daniel 1981; Richardson et al. 1981). Richardson (1982) described the process by which these pocosins may have developed from a primary mire system (formed in a basin or depression) through a secondary mire stage in which they expanded beyond the physical boundaries of the depression because the peat acted as a water reservoir (Figure 8). Many of the North Carolina pocosins are tertiary mire systems which have developed above the physical limits of the ground waters (Richardson et al. 1981) under conditions of rainfall in excess of evaporation for several thousand years. In these wetland systems, the peat continues to act as a reservoir holding water by capillarity above the level of the groundwater. Hydrologically, the pocosin has a perched water table elevated above that of the surrounding areas and receives water primarily from rainfall (Richardson et al. 1981). Water moves slowly out of these raised bogs into adjacent areas.

Carolina Bays

No theory on the origin of Carolina bay depressions is universally accepted by scientists or laymen. The earliest published theory (Toumey 1848) was that springs rising to the surface of a sandy plain formed circular lakes. Glenn (1895) suggested that the depressions were formed when coastal sandbars built up across the mouths of shallow embayments. Although the rounded contours of Carolina bays were noted in these early descriptive accounts, their abundance, elliptical shape, and parallel alignment were not recognized until aerial photographic surveys were made of the southeastern Coastal Plain in the 1930's.

Melton and Schriever (1933a,b) noted the uniform shape and consistent directional alignments of the depressions and proposed the captivating hypothesis that they are the result of an ancient meteor shower striking the earth at an oblique angle. Prouty (1952) supported this hypothesis with explanations that the shallowness and shape of such depressions could be accounted for by shock waves from a swarm of meteors crashing into sandy, uncompacted coastal plain soils. An argument that meteorite fragments have not been found associated with any Carolina bay depression (Johnson 1942b) was not considered as compelling negative evidence since a lack of fragments could be due to the low probability of finding pieces of an exploded meteorite (MacCarthy 1937; Prouty 1952) or due to a non-metallic meteor swarm (Sharitz and Gibbons 1982).

In rebuttal to this early extraterrestrial theory of origin, other theories followed which implicated wind and wave action (Cooke 1940, 1943a,b; Johnson 1944a, b; Odum 1952; Thom 1970; Whitehead 1973; Bliley and Pettry 1979; Kaczorowski 1977); dissolution of substrate minerals in solution pits (Smith 1931; Johnson 1942b); or a combination of factors (Johnson 1942b, 1944a,b; Whitehead 1981). More imaginative hypotheses regarding the origin of Carolina bays include the formation of pools by large schools of spawning fish (Grant 1945b), melting icebergs (Kelly and Dachille 1953), collision of the earth with anti-matter (Baxter and Atkins 1976), or launching sites for extraterrestrial spacecraft (see Justis 1974).

In support of the wind and wave action theory, perhaps the strongest challenge to the meteor theory, Kaczorowski (1977) compared the Carolina bays with modern analogues found in Alaska, Chile, and Texas. He proposed that oriented lakes develop in topographic depressions created by any one of several processes including those coastal, fluvial, aeolian, solutioning, glacial, or tectonic in nature. He argued that once these depressions are formed, orientation could be a function of wind regime, perhaps accompanied by wave action. He stated that no evidence existed to support a meteor origin for the initial Carolina bay depressions.

Much disagreement also exists regarding the age of Carolina bays, although they are generally accepted as being pre-Holocene by most authorities (Schalles 1979). Wells and Boyce (1953) estimated the age of Carolina bays as 250,000 years B.P. Other estimates range from 10,000 to 100,000 years B.P. From a study of pollen profiles, Whitehead (1973) suggested that the oldest sediments were formed about

100,000 years ago. He later stated that there were at least two time periods when bays were formed (Whitehead 1981). Some bays that occur on the lower Coastal Plain terraces are considered by Thom (1970) to be younger than those on the middle Coastal Plain, also an hypothesis requiring an explanation that allows for multitemporal formation.

In conclusion, authorities do not agree on the age (within the 10,000 to 250,000 year limits), concurrency of formation, or mechanism of formation of Carolina bays. Disagreement also still exists about whether one of the processes described by Kaczorowski (1977) or a meteor shower created the initial depressions.

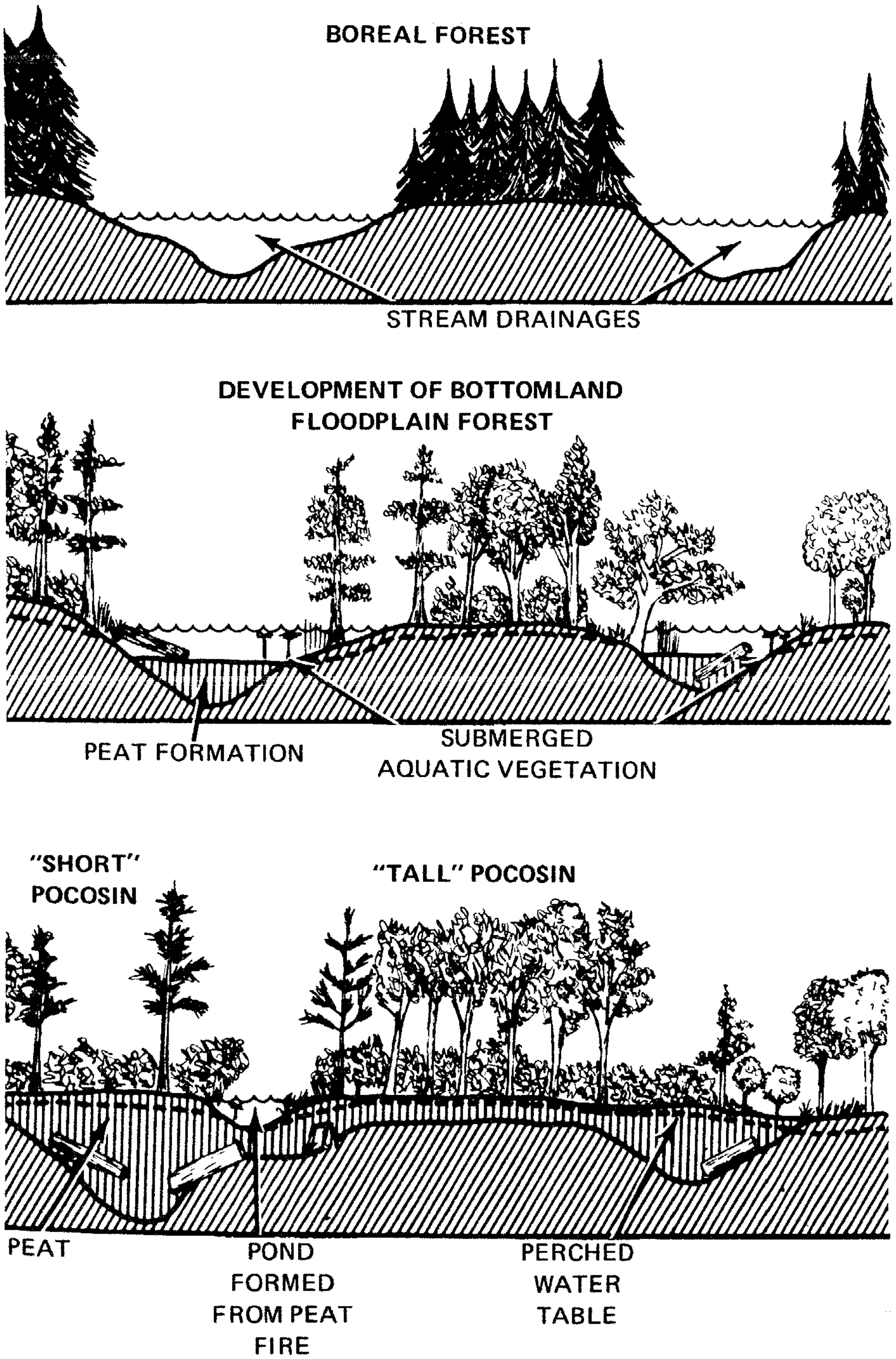


Figure 8 Conceptual model of one proposed means of pocosin formation and development in flat interstream areas of lower Coastal Plain terraces.

CHAPTER 2

PHYSICAL AND CHEMICAL CHARACTERISTICS

2.1 SIZE AND MORPHOLOGY OF COMMUNITY TYPES

Pocosins

Pocosins have no characteristic size or shape. In many instances well-defined boundaries are not apparent as the pocosin shrub bog habitat grades into other vegetationally related communities. A pocosin that would be a recognizable soil and vegetation community unit could conceivably be smaller than an acre or large enough to encompass thousands of contiguous acres. The largest identifiable pocosins occur in eastern North Carolina where 281,000 ha (695,000 acres) were recognized as undisturbed in 1979 (Richardson et al. 1981). Pocosins show no orientational aspects in regard to other topographic features other than location between old or active stream systems in many instances.

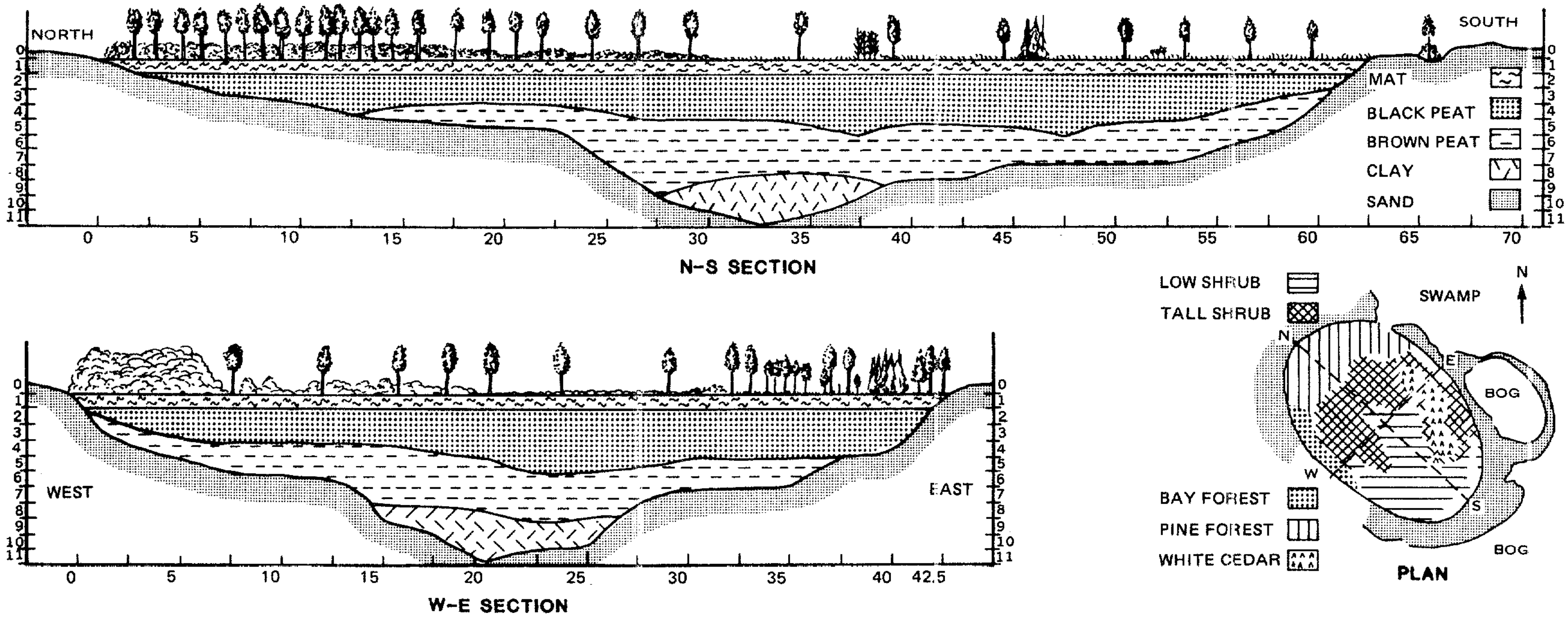
Carolina Bays

Carolina bays may range in length from 50 m (164 ft) to 8 km (5 mi). Lake Waccamaw in North Carolina, perhaps the largest, is 4.8 x 8 km (3 x 5 mi; Frey 1949). Carolina bays can be readily distinguished from other types of depressions on the southeastern Coastal Plain by a unique suite of characteristics (Figure 9). These include generally shallow depth, an ovate shape with the narrow end pointed in a southeasterly direction, and an orientation in which the long axis is in a northwest to southeast direction so that Carolina bays are essentially parallel (Prouty 1952). In most instances a low sandy rim borders each bay and is usually most pronounced on the southeastern margin of the ellipse. Although some authors (e.g., Melton and Schriever 1933a, b) emphasized the consistent parallelism of the long axis of Carolina bays, Johnson (1942a) strongly challenged this concept. He reported that although the predominant long axis orientation was northwest-southeast, the range of directional deviation was high and varied geographically. Bays that he measured in Georgia and southern South Carolina were oriented on the average along a S 20°E (= N 20°W - S 20°E) direction. The majority ranged from S 10°E to S 30°E, but a few extreme examples were oriented as westerly as S 26°W and as easterly as S 56°E. A large sample of Carolina bays measured in North Carolina and northern South Carolina averaged S 45°E and ranged from N-S to S 67°E (Johnson 1942a). Deviation from precise parallelism is a factor to be considered in a discussion of the geological origin of Carolina bays, but is of no consequence from an ecological standpoint. The basic ovate shape and shallow basin are always maintained and are the dominant physical features of ecological importance.

2.2 SUBSTRATE CONDITIONS

Pocosins

Both very poorly drained mineral soils and organic mucks and peats characterize areas of pocosin vegetation (Barnes 1981; Gilliam and Skaggs 1981). Barnes (1981) described the mineral subsoil of these wet coastal plain soils as consisting of layers of marine sediments varying in texture from heavy clays to sands. Clay layers permit the ponding of water at early stages of pocosin development and therefore can be an important soil feature. The shallow water table has prevented the development of a conventional soil profile typically formed by weathering and leaching processes. The pH of these pocosin soils is low. The pH of the organic horizons is commonly between 3.5 and 4.1, surface mineral soils average 0.3



Typical features

- General northwest-southeast orientation
- Consistency in ovate shape with large end at northwest
- Sand rim more prevalent at southeast margin (but may occur around entire perimeter)
- Shallow basin below surrounding habitat resulting in intermittent water that is dependent on rainfall and evaporation rates
- Evergreen shrubs that margin aquatic area
- Layers of peat, sand, and impervious clay typical of certain regions

Figure 9. Section and plan views of a typical Carolina bay, indicating key morphological features, soil profiles, and vegetation types (modified from Buell 1946a).

to 0.4 pH units higher than organic soils, and mineral subsoils frequently range between 4.1 and 4.7 in pH (Barnes 1981).

Although as many as 40 different soils may be recognized in the region of the northern North Carolina pocosins (Gilliam and Skaggs 1981), three major edaphic (soil) groups generally characterize these systems. These are (1) mineral soil with an organic epipedon (or high organic matter surface horizon) that does not extend deep enough (< 40 cm or 16 inches) for the soils to be classified as organic, (2) shallow organic soils with a high organic surface extending downward 40 to 130 cm (approximately 16 to 50 inches), and (3) deep colloidal organic soils in which the organic matter horizons extend deep into the soil profile (>130 cm or 51 inches). These deep organic soils frequently contain large amounts of buried wood. Jones (1981) characterized pocosin soils from 13 sites in South Carolina as having an extremely high organic content that generally extended deeper than 40 cm or 16 inches (Table 1). Although the water table is high and the soils may frequently be saturated, pocosins occasionally become dry enough to burn and some of the organic surface may be lost in combustion. Soils information for pocosins in North Carolina is provided by Lilly (1981a).

In a study of the distribution and relationships of plant communities of the Green Swamp in North Carolina, a major portion of which is characterized by pocosin vegetation (see Chapter 3), Kologiski (1977) described the soils of this area (Figure 10) and provided maps derived from various sources. He reported the following Coastal Plain soil series to be the major ones underlying the pocosin and related habitats.

Table 1. Substrate characteristics of 13 pocosins in the Coastal Plain of South Carolina (Jones 1981).

Substrate characteristics		$\bar{x}$	Range
Organic matter (%)		39.2	8.0 - 94.9
Organic surface depth (cm)		>40.0	25.3 - >100.0
Texture[a]:	Sand (%)	80.6	63.8 - 89.8
	Silt (%)	10.4	7.6 - 17.6
	Clay (%)	9.0	2.7 - 18.6

[a]Measured only in non-organic soils (6 of the 13 sites).

Organic Soils:

Four major organic soils series are represented, grouped into two mapping units (Figure 10). They differ chiefly in depth, permeability, and drainage characteristics.

Dare Dorovan Series. These are very deep, very poorly drained and slowly permeable soils formed from the remains of swamp vegetation. The water table is at or near the surface most of the year, and the soils are extremely acid. Dorovan soils appear to frequently extend deeper than those of the Dare Series. Dare and Dorovan soils characterize the major areas of pocosin and bay forest vegetation in the Green Swamp (Kologiski 1977).

Pamlico-Ponzer Series. These are moderately deep, very poorly drained, slowly or moderately permeable soils formed by organic deposits over marine sediments. They frequently occur in depressions, and the water table is at or near the surface 6 to 12 months of the year. Pamlico and Ponzer soils also underlie pocosin shrub communities in the Green Swamp.

Mineral Soils:

Kologiski identified seven mineral soils in the Green Swamp (Pantego, Rains, Lynchburg, Wrightsboro, Foreston, Leon, and Torhunta), all of which are deep, poorly to moderately drained, and usually moderately permeable. However, only the Torhunta series is mapped as occurring extensively in the pocosin areas of the Green Swamp. Like the organic soils, Torhunta soils are very poorly drained, with the water table at or near the surface 2 to 6 months of the year.

Despite high levels of organic matter, pocosin soils are deficient in available nutrients (Richardson 1982). The anaerobic conditions resulting from the long hydroperiods and shallow water table and the acidity of the peats preserve the organic constituents (Maki 1974). For

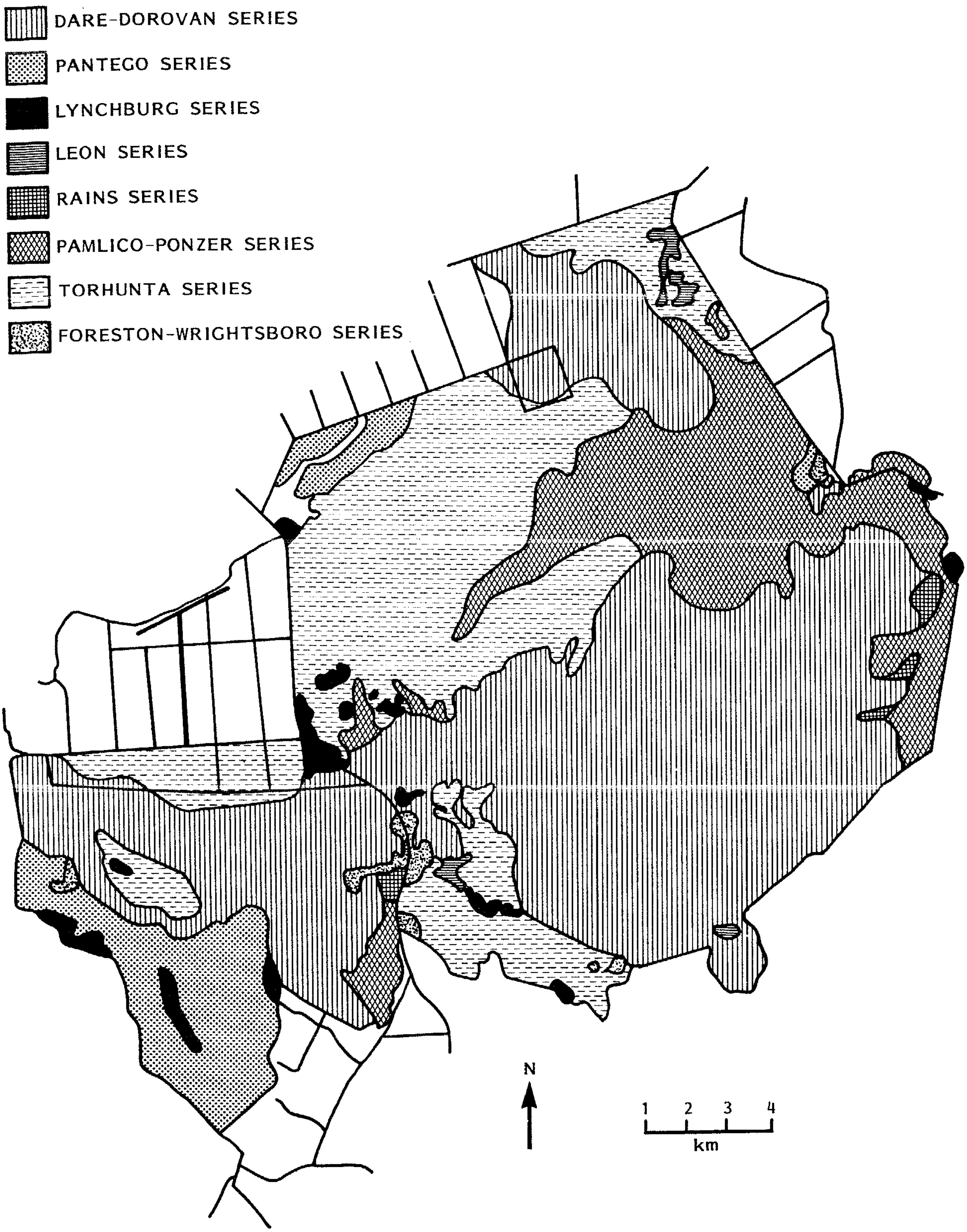


Figure 10. Soil types in North Carolina's Green Swamp pocosin (based on Kologiski 1977, as redrawn by the U.S. Department of the Interior, National Park Service 1979).

example, Barnes (1981) cited studies which indicate that although nitrogen levels are high, more than 70% of the total nitrogen may be in forms (such as fulvic or humic acids) unavailable to plants. Likewise, phosphorus, generally present in the organic form in pocosin soils, may have low availability. Even copper may be deficient (Barnes 1981). Thus, on these raised organic soils precipitation is the chief external source of plant nutrients (Richardson 1982). These wetlands may therefore be considered ombrotrophic[3] because their waters are low in available nutrients.

Carolina Bays

Carolina bays apparently have no consistent relationship to sub-surface strata types. Both Thom (1970) and Gamble et al. (1977), however, have reported that bays seem to be restricted to sandy surface deposits. The characteristic sand rim is extensive enough in some instances to make sand quarrying a profitable venture. Other than this association with sandy substrates, no consistent relationship with particular geological formations or topography in the Coastal Plain is apparent (Prouty 1952; Kaczorowski 1977).

Schalles (1979) described the upper sediments of Thunder Bay (Savannah River Plant, South Carolina) as sandy loam. The presence of 11% "charcoal fragments" in the upper soil layer results from the burning of a peat-type material. Schalles further reported the presence of an "impervious lens" of clay of unknown thickness about 20 to 30 cm (8 to 12 inches) below the upper sediments. This near-surface hardpan, composed of clay or a sand-iron-humate complex, may result in a perched surface water table (Schalles 1979).

In perhaps the earliest report of the substrata of Caroline Bays (Glenn 1895), a similar clay layer up to 8 m (25 ft) thick was described beneath the sand layer of the bays around Darlington, South Carolina. Likewise, Bryant and McCracken (1964) reported that surficial sands overlaid micaceous clays beneath 15 Carolina bays that they examined in Scotland County, North Carolina. In contrast, Bliley and Pettry (1979) reported sand to be the dominant soil type of surface and substrata soils of Carolina bays on the Eastern Shore of Virginia.

Carolina bays undisturbed by burning or land management practices commonly have organic surface horizons overlying the sand and clay layers. Jones (1981) described the substrate characteristics of five bays in South Carolina (Table 2), each of which had more than 30 cm (12 inches) of peat or highly organic soil. In addition, Ingram and Otte (1981b) indicated that many of the larger bays in eastern North Carolina contain high quality peat up to 4.6 m (15 ft) thick which might be of commercial value.

2.3 HYDROLOGIC CHARACTERISTICS

Pocosins: Water Quality, Storage, and Release

Hydrological fluxes in pocosins are influenced by four input-output events. Precipitation is normally the exclusive input source of water and must ultimately be equalled by the three outputs. Of these, evapotranspiration and surface runoff are the primary routes of departure of water from pocosin systems (Figure 11), and groundwater discharge (the sub-surface loss of stored water within the pocosin soils) is the least significant. Although the pocosin system is not hydrologically complex, the difficulties inherent in precise measurement of the output events in

Table 2. Substrate characteristics of five Carolina bays in northeastern South Carolina (Jones 1981).

Plant community type	Organic matter (%)	Organic surface depth (cm)	Texture[a] Sand %	Silt %	Clay %
Pocosin	76.5	>100.0	-	-	-
Pocosin	74.8	>40.0	-	-	-
Pocosin	29.5	>100.0	-	-	-
Pocosin	12.7	33.9	63.8	17.6	18.6
Bay Forest	14.8	38.9	73.3	9.1	17.6

[a]Measured only in non-organic soils.

[3]In ombrotrophic ecosystems most or all of the water and nutrients come from precipitation rather than from other sources such as ground water or stream flow.

such geographically extensive systems have resulted in few thorough studies of the hydrodynamics of natural pocosins.

Because pocosins do not drain effectively, groundwater discharge has the least effect on annual water flux. In the Albemarle-Pamlico peninsula, which comprises extensive pocosin habitat, groundwater discharges averaged less than 1.3 cm/year (Heath 1975), equivalent to 130,000 l/ha (1842 ft^3/acre), and were assumed by Brinson (1980) to be similar to the Croatan National Forest. Daniels et al. (1977) also reported that groundwater discharge was an insignificant proportion of the water flux in the Hofmann Forest of North Carolina. Overland runoff in the Croatan was calculated by Brinson (1980) to be approximately 52 cm (5.2 x 10^6 l/ha or 73,680 ft^3/acre) on the basis of a regional precipitation of 144 cm/year (57 inches/year) and cumulative evapotranspiration estimated at 91 cm/year (9.1 x 10^6 l/ha or 128,940 ft^3/acre). The relative contributions of transpiration and evaporation in pocosins are unknown, although Richardson (1982) reported that 60% to 70% of the water output may be through evapotranspiration during the summer and fall. Runoff becomes more important during the winter and spring because of increased precipitation. Quantitative information regarding the role of evapotranspiration would be a useful addition to our knowledge and understanding of the function of these systems.

Under natural conditions the surface runoff from pocosins surrounding Albemarle and Pamlico Sounds and elsewhere is as sheet flow in response to precipitation events. The input into estuaries or other receiving bodies of water occurs several days after a rain and is spread over wide areas rather than being confined to a few point locations (Ash et al., in press; Copeland and Hodson 1982).

The widespread installation of drainage ditches for land management has altered the hydrology of pocosins. Drainage ditches lower the water table to some extent, particularly in their immediate vicinity, and significantly affect surface runoff (Ash et al., in press). Runoff is greater than normal especially during periods of heavy precipitation and high water tables, conditions occurring most frequently in pocosin areas during winter and spring (Ash et al., in press). The increased runoff rates in drainage ditch

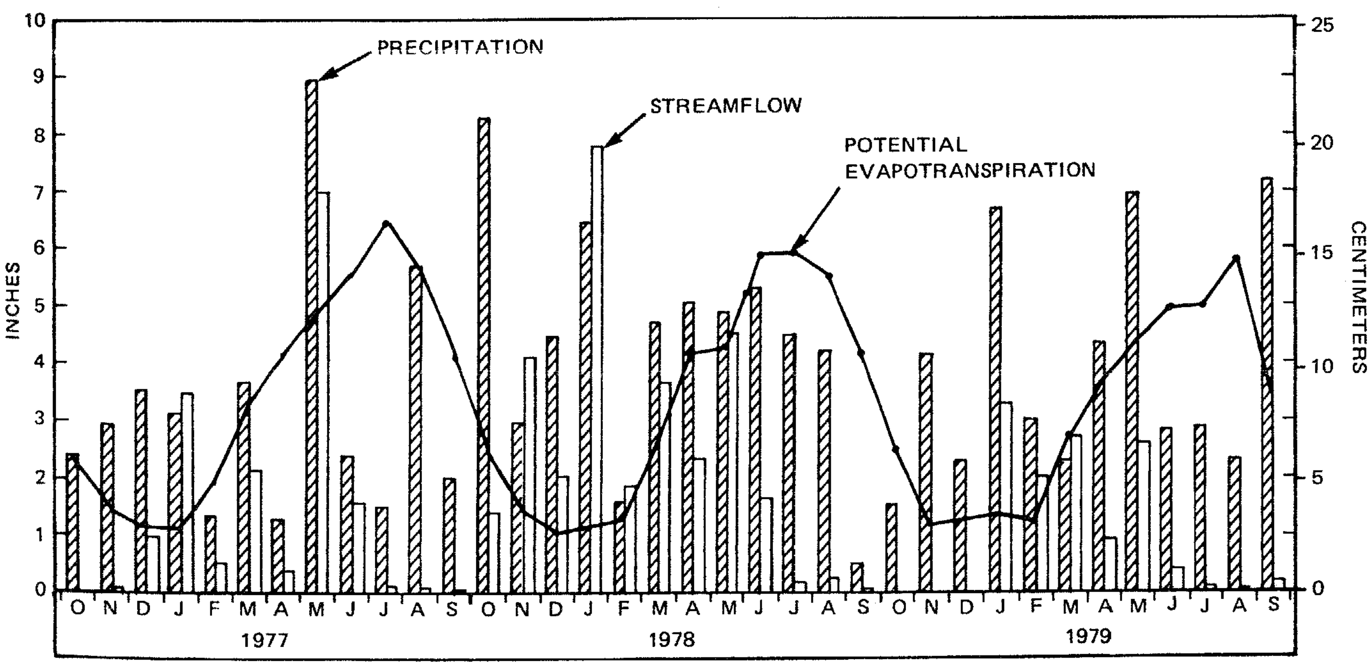


Figure 11. Relationships among precipitation, evapotranspiration, and streamflow in a pocosin habitat, Pungo National Wildlife Refuge, NC (Daniel 1981, in Pocosin Wetlands: An Integrated Analysis of Coastal Plain Freshwater Bogs in North Carolina, ed. by C. J. Richardson. Copyright 1981 by Hutchinson Ross Publ. Co., Stroudsburg, PA. Reprinted by permission of the publisher).

systems (three to four times above that in natural pocosin areas) may cause above-normal input for short periods into peripheral aquatic habitats such as estuaries. This increased input of water can alter the salinity and pH ratios in the estuarine systems. In addition, a variety of agricultural by-products present in the runoff water may cause chemical changes in the estuaries. Turbidity may also increase in the littoral zones of estuaries that receive pocosin runoff from drainage ditch areas (Kirby-Smith and Barber 1979; Ash et al., in press). Copeland and Hodson (1982) stated that the approximately 202,500 ha (500,000 acres) of pocosins around Albemarle Sound contribute organic matter into the estuarine system.

The quality of runoff water from agriculturally developed lands into drainage ditches differs greatly from that characteristic of natural streams that flow through pocosin habitat, based on two different North Carolina studies (Tables 3a and 3b). Thus, the water in agricultural drainage ditches is higher in available nutrients, sediment load, and pH than are the natural pocosin runoff waters, which, although darkly stained as a consequence of the leaching of organics, are of generally good quality.

Water storage in peat deposits can be affected in other ways than by direct water flux. Subsidence of the peat level can result from compaction of the soil in highly drained areas, although this phenomenon is less likely to occur under natural vegetation because of the structural support of plant roots and rhizomes (Brinson 1980). In addition, the shift from anaerobic to aerobic conditions with water loss results in oxidation of the organic soil and further subsidence. Consequences of this subsidence and water loss are increased possibilities of fire and reduced evapotranspiration.

<u>Carolina Bays: Water Quality and Storage</u>

As Carolina bays are typically landlocked aquatic habitats that have no tributary streams and are not spring-fed [with some exceptions, e.g., Lake Waccamaw (Frey 1949) and a spring-fed bay in Georgia (Wharton 1978)], water quality features should be characteristic of other lentic systems in the region. For instance, like surface waters of the southeastern region in general, pH levels of Carolina bays are acidic (Schalles 1979; Table 4).

The most prevalent environmental features of Carolina bays are their fluctuating water levels and concomitant changes in other factors such as water temperature and dissolved solids. In addition, population densities of plants and animals may characteristically change on an annual basis. Because of the influence of precipitation and water table, Carolina bays can be regarded in a long-term sense as dynamic aquatic habitats. Water levels may fluctuate greatly over years or seasons (Figure 12), and water temperatures may also vary in response to major water volume changes in such shallow aquatic habitats. Data from small Carolina bays that dry up periodically indicate that the seasonal timing of the disappearance of the water varies from year to year (Figure 12a).

Although many of the smaller, shallower bays may remain almost perpetually dry, and some of the larger deeper ones may contain permanent water, the majority of Carolina bays are essentially intermittent lakes that contain water during certain seasons or wet years and remain dry during other periods. No source of detailed, long-term data on the effect of hydrologic and meteorological variables on particular Carolina bays has been uncovered at this time. Nevertheless, the relationship between the change in water level and two major variables (precipitation and water temperature) is known for Ellenton Bay on the Savannah River Plant in South Carolina (Figure 12d), based on a 5-yr study.

The amount and seasonal timing of rainfall had the most apparent effect on changes in water level (Figure 12b, c). The seasonal relationship is primarily a consequence of a strong negative correlation between environmental temperatures and change in water level (Figure 12d), presumably because higher temperatures result in higher evaporation and transpiration rates. No quantitative data are available on the seasonal changes and relative importance of evaporation and transpiration in Carolina bays, although

Table 3a. Comparison of water quality data from a natural pocosin stream on Open Grounds Farm, NC, with the combined data from three drainage ditches in the same area (based on data from Kirby–Smith and Barber 1979). The surface runoff from the system ultimately flows into the South River Estuary in Carteret County.

Physical measurement	Natural stream			Ditches		
	$\bar{X}$	Range	N	$\bar{X}$	Range	N
Dissolved oxygen (ml/l)	2.7	0.5-6.5	31	3.5	0.4-6.3	105
pH	4.2	3.4-5.4	31	6.9	4.3-7.9	106
Turbidity (JTU)[a]	2.4	1.0-5.4	29	39	5.6-145.0	98
Nitrate (μg-atom/l)	0.3	0.3-1.2	25	5.9	0.3-47.1	99
Ammonia (μg-atom/l)	2.0	0.3-10.9	31	8.8	0.3-91.2	96
Phosphate (μg-atom/l)	0.4	0.2-0.8	30	2.1	0.2-25.5	100

[a]JTU = Jackson Turbidity Units.

Table 3b. Comparison of mean annual concentrations of constituents of pocosin seepage and farm ditch water during the clearing and drainage phase of wetlands development in North Carolina (Richardson et al. 1981, adapted from Barber et al. 1979).

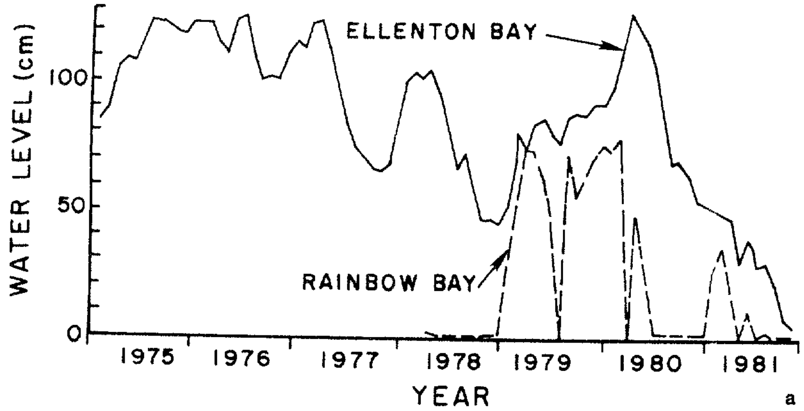
Constituents	Pocosin seepage water	Ditch water
Dissolved oxygen (mg/l)	2.7	3.2
pH	4.4	6.5
Turbidity (JTU)	2.3	62.4
Nitrate N (μg/g)	N.D.[a]	0.001
Ammonia N (μg/g)	0.02	0.05
Phosphate (μg/g)	N.D.	0.015
Seston[b] (μg/g)	6.6	120.0
Particulate organic carbon (μg/g)	1.7	50.4
Chlorophyll A (μg/kg)	0.7	3.5

[a]N.D. = Not detectable within a limit of 0.02 (μg/g).
[b]Seston = All suspended particulate matter.

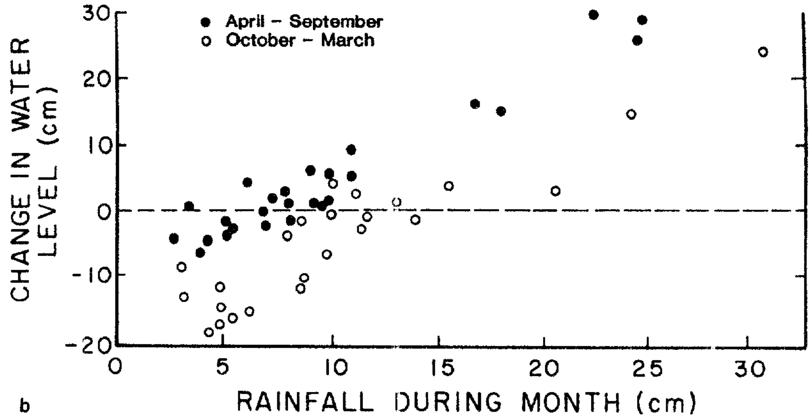
Note: μg/g = ppm, μg/kg = ppb, JTU = Jackson Turbidity Units.

Table 4. Water quality parameters of seven Carolina bays in South Carolina. The data for Clear Pond are taken from Tilly (1973). The data for the other six are from Schalles (1979), who surveyed bays on the Savannah River Plant. Water quality values represent means of numerous samples at each site.

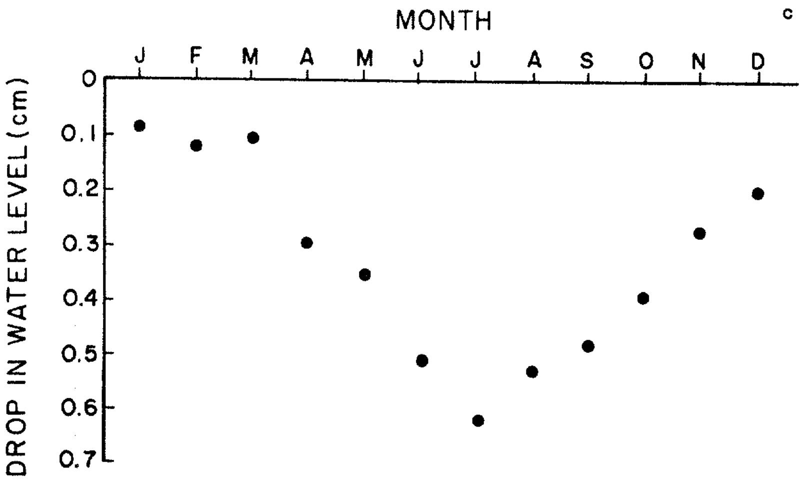
Water quality parameters	Clear Pond	Route 9 Bay	Cypress Bay	Thunder Bay	Long Pond	Ponding Area 1	Ponding Area 2
Depth (cm)	200	50	47	58	53	66	76
Area (ha)	11	-	-	~5.4	-	-	-
Total dissolved solids (ppm)	41.0	36.5	22.0	9.8	13.0	37.4	49.4
pH	6.4	4.5	4.3	4.3	4.3	6.1	6.0
Dissolved oxygen concentration (mg/l)	7.2	10.4	9.0	5.2	5.3	3.1	3.8
Acidity (mg/l)	-	18.6	14.0	10.5	11.8	5.1	10.9
Alkalinity (mg/l)	0.9	7.1	3.4	2.5	2.2	15.5	20.4
O_2 Sat. (%)	-	46.3	59.2	65.4	64.3	89.6	48.4
Ca^{++} (mg/l)	-	2.7	1.0	0.9	0.7	9.5	14.1
Mg^{++} (mg/l)	-	1.5	0.6	0.4	0.4	0.9	1.4
Na^{+} (mg/l)	-	2.1	2.1	1.1	1.6	1.4	1.8
K^{+} (mg/l)	-	4.6	3.9	0.4	1.0	1.4	1.7



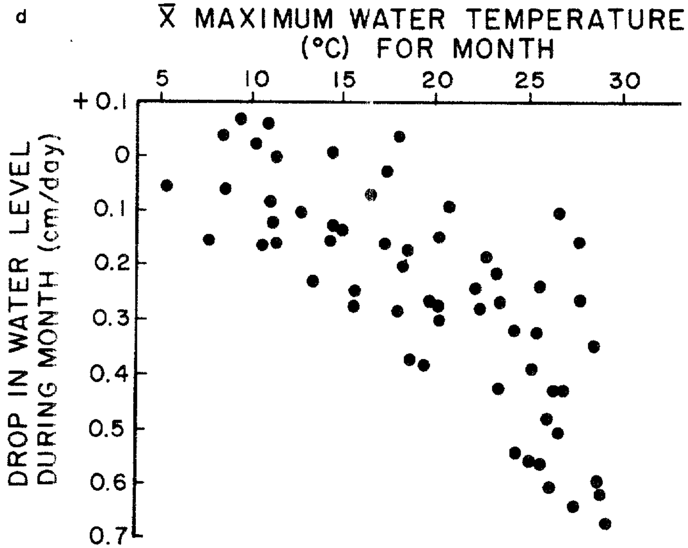
Mean monthly changes in water level, 1975–1981.



Changes in water level at Ellenton Bay with amounts of precipitation, based on a 5-year period.



Seasonal drops in water level due to evapotranspiration at Ellenton Bay, based on monthly means adjusted for precipitation over the 5-year period.



Changes in monthly mean water levels due to temperature (after adjustments for precipitation) over the 5-year period.

Figure 12. Water level changes in two Carolina bays (Savannah River Plant, SC) as influenced by precipitation and temperature.

obtaining this vital information will be critical to understanding the hydrodynamics of these systems.

The data for Ellenton Bay support a hypothesis that rainfall raises water level proportionally to the amount of rainfall, whereas water level is lowered as a consequence of evapotranspiration. Evaporative water loss is, as expected, greater at high temperatures (and therefore, during warm seasons) than at low ones. Evaporation rates would also be affected by wind and by relative humidity, which are unmeasured variables at Ellenton Bay. In addition, transpiration rates in bays with heavy aquatic vegetation might cause significant changes in water level during the growing season. Soil permeability and the surrounding watershed would also influence water collection and retention. Although groundwater recharge (Schalles 1979) has been considered as a potentially important factor in changing water levels in certain Carolina bays, there is little evidence to support a general hypothesis that the water table is influential in affecting water level fluctuations in Carolina bays.

This limited information for Ellenton Bay is the only published data available to address the influence of environmental factors on the fluctuations of water levels in Carolina bays. Long-term measurements of such basic phenomena as local precipitation, evapotranspiration rates, groundwater levels, soil permeability, and local topography and their relations to changes in water level would be valuable. Dynamic habitats such as these can support only species with effective adaptations to cope with such fluctuating conditions.

CHAPTER 3

BIOLOGICAL FEATURES

3.1 PLANT COMMUNITY COMPOSITION

Pocosins

Few studies provide more than a brief or superficial description of pocosin vegetation and fauna. The apparent lack of interest in pocosin ecosystems is no doubt due in part to their perceived low commercial value and the difficulty involved in working in these habitats. As Christensen et al. (1981) stated, "...their limited economic value, impenetrable character, and alleged dense populations of venomous or otherwise malevolent critters have successfully repelled ecologists for the past fifty years." In addition, disagreement regarding what actually qualifies as a pocosin and how the boundaries of these ecosystems are defined, coupled with the fact that many of their characteristic species occur in other wooded wetland systems, has hindered or confused ecological description. There is limited information on species composition, productivity, and successional development of pocosins and their relationships with other Coastal Plain ecosystems.

Developmental history of pocosin communities. Developmental history of the vegetation of the coastal area of the Mid-Atlantic States has been described by several investigators (e.g., Buell 1945; Frey 1951b, 1953, 1955b; Whitehead 1963, 1964, 1981), based primarily upon examination of pollen profiles obtained from soil cores. Although there exists no complete description of the vegetational history specific to pocosins, the development of this flora can be inferred from these studies and a more recent one by Otte (1981), which used samples taken from Carolina bay and pocosin sediments.

Frey (1951b, 1953, 1955b) sampled cores from a series of Carolina bays and described a pine-spruce forest that existed during the period of Wisconsin glaciation. Whitehead (1964) reported a greater dominance of pine during this period with some boreal species occurring primarily on more mesic sites. Late-glacial (about 10,000 to 15,000 B.P.) forests dominated by oak, hickory, hemlock, and beech replaced the pine and spruce forests as the glaciers retreated and the climate warmed. More recent post-glacial changes until the present time have included the gradual decrease in oak-hickory forests, development of southern pine forests, and an increase in cypress-gum dominated vegetation in wetter sites.

The development of shrub bog vegetation in pocosin areas is difficult to trace. Ingram and Otte (1981b) reported that peat began to build up about 8,000 to 10,000 years ago in the dissected depressions of the outer Coastal Plain, often building up to form broad, dome-shaped surfaces. As noted earlier, carbon-14 dating of sediments from the Great Dismal Swamp and the Chesapeake Bay indicates that deposition of organic clays and peat accumulation in these areas began between 10,340 ± 130 and 8,135 ± 160 years B.P. (Daniel 1981). These sediments contained late-glacial pine and spruce pollen or oak-hickory pollen. However, older peat samples (15,280 ± 200 years B.P.) containing abundant spruce pollen from the mid-glacial period have been recovered from one area of the Chesapeake Bay (Harrison et al. 1965). Furthermore, Richardson (1982) noted that radiocarbon dating of other areas of the Dismal Swamp indicates that much of the peat may be less than 3,500 years old. He interpreted these various ages along with information from pollen profiles, the presence of charcoal in the peat, and historic climatic changes to indicate a dynamic developmental history of pocosin substrates that includes fluctuations in oxidation and in the rates of peat accumulation and the occurrence of extensive fires.

Peat accumulation, fire, nutrient levels, hydroperiod, human use, and other ecological and environmental factors have contributed to the development of the present pocosin ecosystems. Opinions of investigators differ about which of these factors are primarily responsible for the establishment and maintenance of pocosin communities. From an extensive survey of North Carolina pocosins, Otte (1981) proposed a pattern of pocosin community development based upon peat profile analysis. He believes that most pocosins began as marsh systems dominated by aquatic macrophytes and grasses, succeeded to cypress and Atlantic white cedar (*Chamaecyparis thyoides*) forests, and finally to shrub bog pocosins. He reported that most of the pocosin ecosystems appear to have developed the evergreen shrub-dominated community relatively recently (in the last few thousand years) in terms of the overall age of the wetland. Only the Croatan National Forest pocosins (Figure 13) and southern Dare County pocosins appear to be relatively old (Otte 1981). The substrates of the Croatan pocosin consist of 0.6 to 1.2 m (2 to 4 ft) of white cedar peat overlain with pocosin peat 1.2 to 1.5 m (4 to 5 ft) thick (Figure 13). Otte noted, however, that within the pocosin peat are patches of marsh peat, indicating local wetter conditions and perhaps the sites of peat burns that left shallow open pools where marsh vegetation developed.

B. W. Wells (Wells and Whitford 1976) described the poorly drained interstream areas of the Coastal Plain as historically being covered by broadleaf swamp forests dominated by black gum (*Nyssa*), sweet gum (*Liquidambar*), and maple (*Acer*). Apparently, they dried out frequently enough for tree seeds to germinate and seedlings to become established. Wells further reported that fires by Indians and later by white settlers began to change these hardwood swamp forests into shrub bogs, or pocosins. He believed that the frequency of fire played a major role in the development of pocosin vegetation and in the relationship between pocosins and other plant associations. For example, if the hardwood swamps were burned as frequently as every decade, the deciduous forest disappeared or became dominated by pond pine (*Pinus serotina*) and southern cane (*Arundinaria gigantea*). When burning was even more frequent, fire resistant shrubs or shrubby trees such as sweet bay, (*Magnolia virgiana*), red bay (*Persea borbonia*), and leucothoe (*Leucothoe* spp.) became dominant, along with greenbrier. All of these species have the ability to sprout from stumps or roots following burning, and they form virtually impenetrable jungles. If these pocosin communities were burned annually, the shrubs practically disappeared and were replaced by grasses, sedges, and herbs. If fire frequency was reduced, these grassy habitats reverted to shrubby pocosin communities. Wells and Whitford (1976) noted that if fire was eliminated altogether, savannas and shrub bogs returned to swamp forests, although

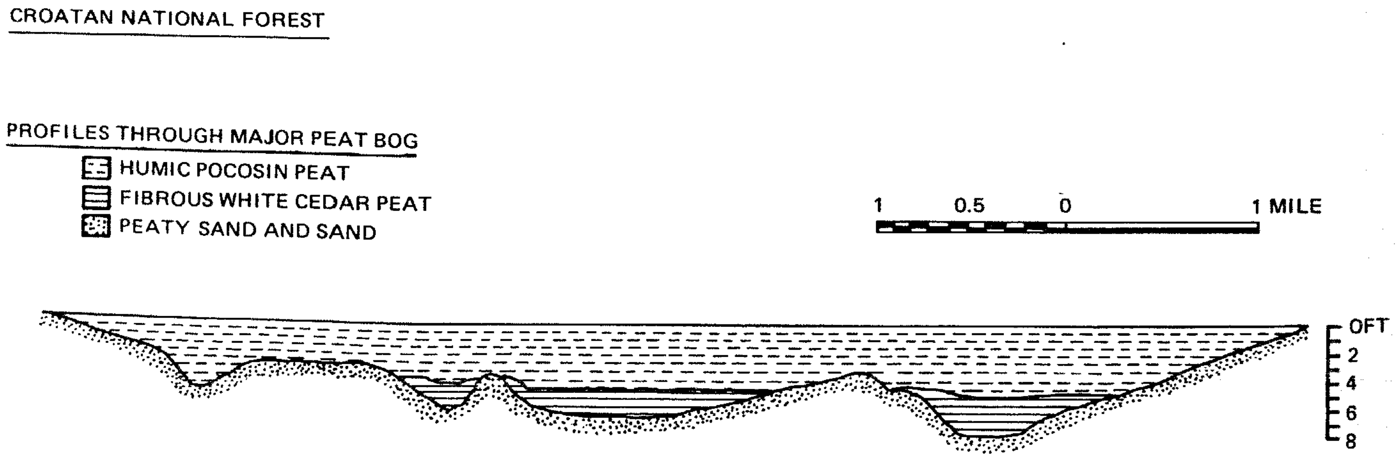


Figure 13. Representative cross section through the Croatan National Forest pocosin substrates (from Otte 1981).

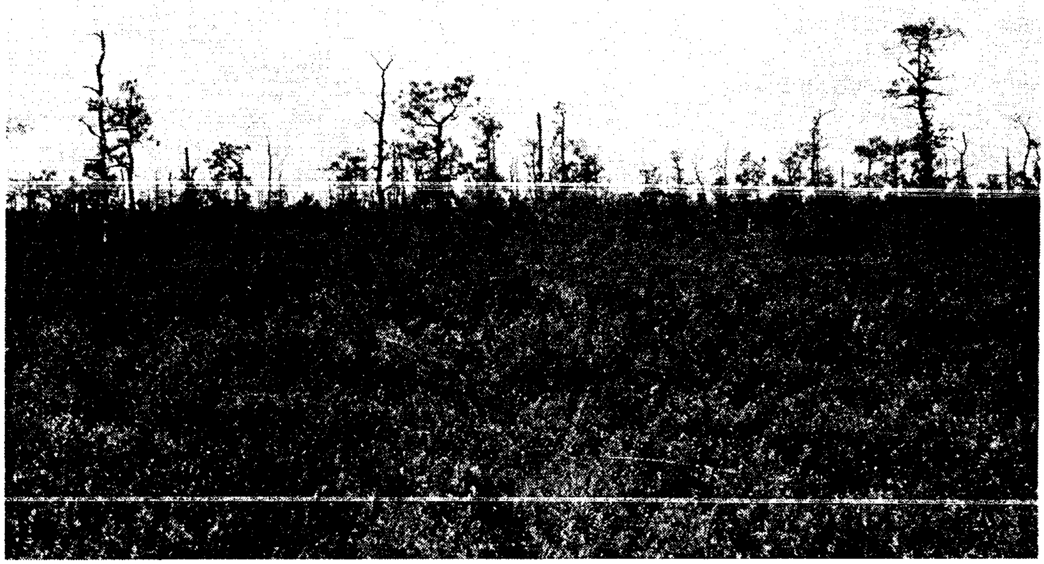
Otte (1981) suggested that pocosin on deep peat will remain unless the peat is severely burned.

Fire and other disturbances have played a major role in development of the pocosin vegetation of the Green Swamp in North Carolina (Kologiski 1977). Kologiski noted early reports that much of the area was once dominated by Atlantic white cedar swamps and extensive cypress-gum swamps. Logs buried under several meters of peat are all that remain of the white cedar forests believed to have been destroyed by fire. Recent surveys of the area revealed remnants of the cypress-gum forests that were heavily logged in the 1800's and early 1900's (Kologiski 1977).

Characterization of pocosin vegetation. Early accounts of pocosin vegetation, such as those of Kerr (1875) and Harper (1907), were primarily lists of plant species and brief descriptions. Wells (1928) included a description of pocosin or bay vegetation in his characterization of coastal plain plant communities and later provided some quantitative data on the pocosin vegetation of Holly Shelter Wildlife Management Area (Wells 1946). Other early studies (e.g., Buell 1939a, b, 1945, 1946a, b; Penfound 1952) added limited information to the characterization of pocosin habitats. More recently, Woodwell (1956, 1958), Kologiski (1977), Christensen (1979), Christensen et al. (1981), Otte (1981), and Jones (1981) have concentrated extensive sampling and analysis on this vegetation type. Most of the information regarding pocosin vegetation that is presented in this community profile is taken from the work of these researchers. Throughout this report, the use of plant names follows Radford et al. (1968).

The typical pocosin or shrub bog vegetation is characterized by a shrub understory with scattered emergent trees (commonly pond pine). The height of the shrub cover usually ranges from 0.5 m (1.5 ft) to 4 m (13 ft). If the woody vegetation (tree component) is less than 6 m (19.5 ft) high (scrub-shrub), it is generally called short pocosin; if greater than 6 m high (forested), it is considered to be tall pocosin (Figure 14), although these size designations differ among the investigators (e.g., Otte 1981). Pocosin communities are commonly termed evergreen shrub bogs; however, many of the characteristic pocosin species are partially deciduous (e.g., titi [Cyrilla racemiflora]) or wholly deciduous (e.g., sweet pepperbush [Clethra alnifolia], fetterbush [Lyonia lucida], zenobia [Zenobia pulverulenta], blueberry [Vaccinium spp.], huckleberry [Gaylussacia frondosa]). Some pocosin species, such as titi, may tend to be deciduous in more northern pocosin communities and to retain their leaves in more southern habitats. Deciduous species may even dominate in some of the shrub bogs (as may tree species rather than shrubs). In addition to pond pine, other pine species, especially loblolly (P. taeda) and longleaf (P. palustris), may occur in the better drained areas. In some pocosins, Atlantic white cedar and also cypress (Taxodium spp.) and gum (Nyssa spp.) may be found. Hardwood trees, especially sweet bay, loblolly bay (Gordonia lasianthus), and red maple (Acer rubrum) are common in many pocosin areas, particularly on less peaty sites.

One of the few comprehensive descriptions of pocosin and related wetland community types has been provided by Kologiski (1977) in an extensive survey of the Green Swamp in Brunswick County, North Carolina. He described the Green Swamp vegetation as a complex continuum of populations arranged according to soil, moisture, and disturbance factors (Figure 15). By using several ordination techniques designed to demonstrate relationships among samples, Kologiski examined data from 220 stands, including the evergreen shrub pocosin community as well as related communities. Although he reported much overlap between vegetation types, he identified discrete vegetational units, which he organized into a hierarchial system of classification adapted from the natural areas classification system of Radford (1977). Using this classification, Kologiski (1977) described five vegetational systems in the Green Swamp, based upon species composition and growth form, which he arranged in a successional sequence from a marsh grass pioneer community to a lowland forest. Within these systems, he separated nine community classes according to the dominant canopy, shrub and herbaceous understory species.



Low or short pocosin habitat, near the center of Angola Bay, Pender County, NC

High or tall pocosin habitat, Holly Shelter Wildlife Management Area, Pender County, NC (with evidence of a fire)

Figure 14. Comparison of two types of pocosin habitats. (Photographs by Charles B. McDonald, East Carolina University, Greenville, NC.)

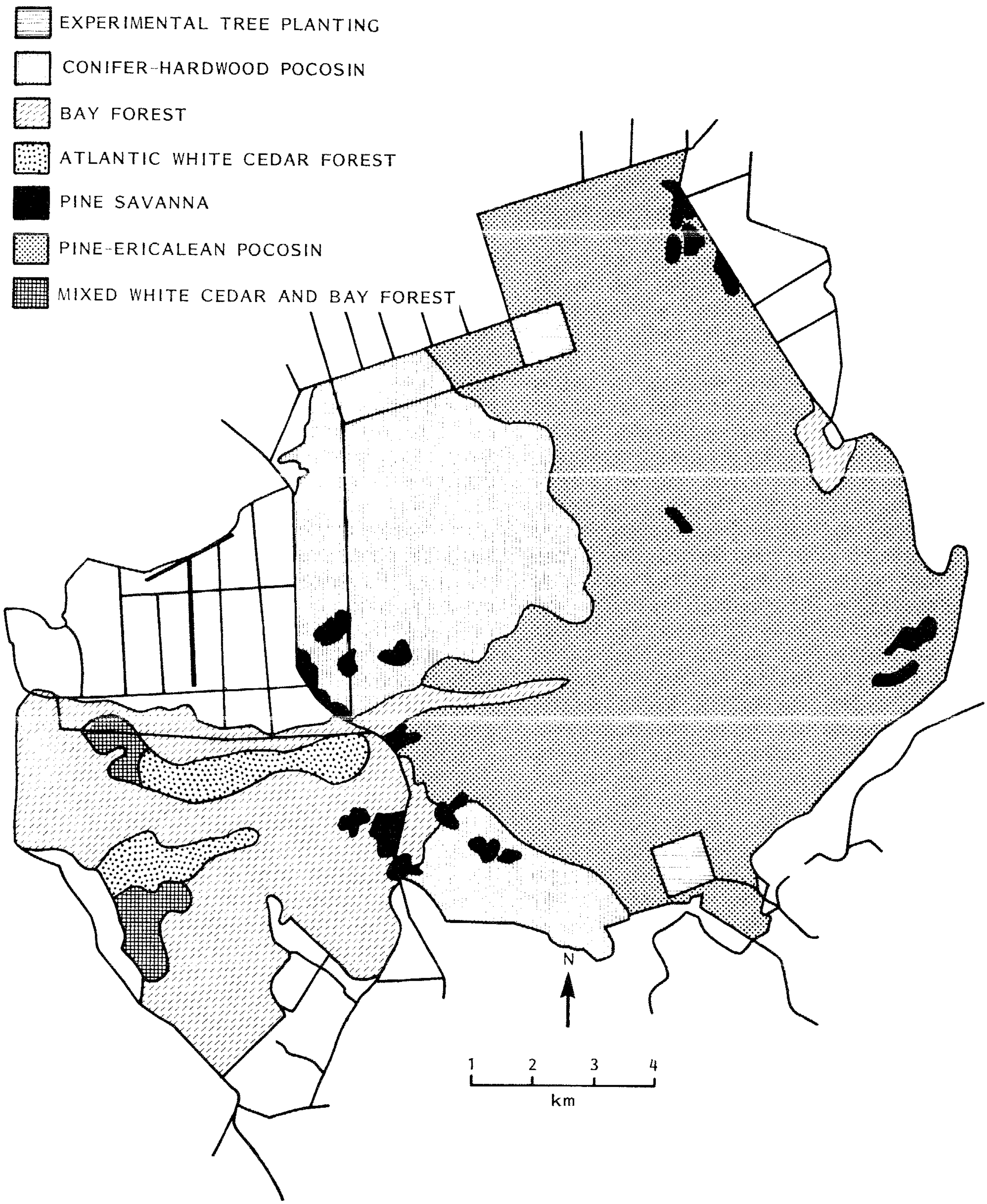


Figure 15. Vegetation types in Green Swamp, NC (based on Kologiski 1977, as redrawn by the U.S. Department of the Interior, National Park Service 1979).

Only one of the five vegetational systems in the Green Swamp (the "wet scrub-shrub system," as described by Kologiski) can be considered true "pocosin" according to the definition followed in this community profile. The wet scrub-shrub system contains the pocosin community cover class that includes those communities dominated by evergreen shrub and tree species characteristic of pocosins (Table 5a). Other vegetation systems of the Green Swamp (marsh grass; low woodland, which contains the pine savanna cover class; lowland gymnosperm including cedar bogs; and lowland angiosperm containing the evergreen bay and deciduous forests) represent peripheral and/or successionally related habitats (Table 5b).

The successional relationships among these vegetation types are still a matter of speculation, and the suitability of Kologiski's classification system outside of the Green Swamp has yet to be determined (Christensen et al. 1981). Furthermore, portions of the Green Swamp have been affected by land management practices since Kologiski's study, so that his map of the vegetation (Figure 15) is now out of date. Nevertheless, because it is one of the most complete vegetational studies, Kologiski's description and community classification are summarized here to provide an example of an interstream pocosin and related plant communities in North Carolina.

Kologiski described the wet scrub-shrub system (pocosin community cover class) as the dominant vegetation of the Green Swamp. According to Cowardin et al. (1979), who developed the system of classification of wetlands and deepwater habitats for the U. S. Fish and Wildlife Service, the class scrub-shrub includes areas of woody vegetation generally less than 6 m (19.5 ft) tall. Vegetation in this class includes shrubs and trees that are small or stunted because of environmental conditions (Figure 16).

The pocosin community of the Green Swamp is a complex unit containing two community classes (pine-ericalean and conifer-hardwood), each with two or more community types (Table 5a and Figure 17a). Distinct boundaries between community types are often difficult to determine. Kologiski indicated, however, several communities that differ primarily because of the length of hydroperiod and time since the last fire.

The Pine-Ericalean (pine and heath shrub) *Community Class* generally develops on deep to intermediate organic soils that are exposed to long hydroperiods and frequent fire (Table 5a). There are three community types:

(1) Pond pine (Pinus serotina) canopy with titi (Cyrilla racemiflora) and zenobia (Zenobia pulverulenta) shrubs. This vegetation usually occurs on deep organic soils with water at or near the surface throughout the year. Although the community is dominated by shrubs, widely spaced pond pines may form an open canopy. Growth of the pines is slow, and they frequently exhibit a gnarled, twisted, and stunted form. Their average height may range from 2 m (6 ft) to 12 m (39 ft).

Dominant shrubs are titi and zenobia, both of which may exhibit greater than 75% cover. Fetterbush is abundant, but it usually has a lower cover value. The height of the shrub layer ranges between 0.5 m (1.5 ft) and 2 m (6.5 ft). Other shrubs as well as herbaceous species such as broomsedge (Andropogon virginicus) occur, and greenbrier drapes over and twines through the shrubs.

(2) Pond pine (Pinus serotina) and loblolly bay (Gordonia lasianthus) canopy with fetterbush (Lyonia lucida) shrubs. This community occurs on slightly drier elevated (approximately 0.5 m or 1.5 ft) areas within the previous community type. These elevated areas resemble islands up to or greater than 100 m^2 (more than 1000 ft^2) and are most likely formed by an accumulation of sphagnum and litter around the stumps or bases of pond pine trees. In addition to the pond pine, loblolly bay, and fetterbush, shrubs that may form an almost impenetrable thicket include sweet gallberry (Ilex coriacea), bitter gallberry (I. glabra), and titi.

(3) Pond pine (Pinus serotina) canopy with titi (Cyrilla racemiflora) and fetterbush (Lyonia lucida) shrubs. This community occurs on intermediate to deep organic soils with intermediate to long

hydroperiods and is floristically similar to the pond pine/titi and zenobia type (1). The major difference is the increased dominance of fetterbush and decrease in zenobia. Titi and fetterbush may occur in almost pure stands or in combination with sweet gallberry and zenobia. Bay species also become more important in this community.

Dominance of zenobia in the Pine-Ericalean pocosin may indicate recent disturbance, especially by fire (Wells 1946; Woodwell 1956), whereas fetterbush may become the dominant on favorable sites within 5 years following disturbance (Woodwell 1956). Therefore, community type (3) may actually be a later successional stage of type (1). Kologiski (1977) reported that loblolly bay, sweet bay, red bay, and occasionally Atlantic white cedar, are also present in the Green Swamp pocosin communities. Pond pine, which is more resistant to fire than the shrubs, occurs in all phases of pocosin succession. If fire does not occur, the pocosin will succeed to a lowland angiosperm forest dominated by evergreen bay species.

The Conifer Hardwood Community Class in the Green Swamp occurs over shallow organic soils which have a slightly shorter hydroperiod (Table 5a). It differs from the Pine-Ericalean by being dominated by titi, fetterbush, pond pine, red maple, black gum, and occasionally pond cypress (Taxodium ascendens). Although sphagnum may be present, the substrate is not a quaking bog. Kologiski described it as hummocky and often wet, with standing water most of the year. The two community types found in the Green Swamp are:

(1) Pond pine (Pinus serotina) canopy with titi (Cyrilla racemiflora), fetterbush (Lyonia lucida), red maple (Acer rubrum), and black gum (Nyssa sylvatica var. biflora) in the shrub layer. As in the other pocosin communities, a sparse canopy of pond pine occurs; however, growth is better and mature trees are taller (between 2 and 20 m or 6 and 65 ft) and less deformed than in the Pine-Ericalean pocosin. The dense shrub stratum is dominated by red maple, titi, and black gum along with other species such as sweet pepperbush (Clethra alnifolia), dahoon (Ilex cassine var. myrtifolia), bitter gallberry, sweet gallberry, sweet bay and red bay. Their heights range from 1 to 6 m (3 to 20 ft), and the shrubs often blend into the canopy. Greenbrier (Smilax laurifolia and S. walteri) are abundant. Virginia chain-fern is the dominant herb in undisturbed areas; in disturbed or open areas, pitcher plants (Sarracenia flava, S. purpurea, and S. rubra) can be found.

(2) Pond pine (Pinus serotina) and pond cypress (Taxodium ascendens) canopy with red maple (Acer rubrum), titi (Cyrilla racemiflora), fetterbush (Lyonia lucida), and black gum (Nyssa sylvatica var. biflora) in the shrub layer. This community is similar to the previous one except that pond cypress is a co-dominant. Cypress is scattered throughout the Conifer-Hardwood pocosin; however, because of past selective cutting of this species, it seldom dominates a given site.

Kologiski (1977) described the Conifer-Hardwood Community Class as having many species in common with the other communities in the Green Swamp. For example, all of the dominant deciduous bay forest species are present in the conifer-hardwood communities. He assumed that the Conifer-Hardwood pocosin is an early seral stage (after disturbance) of the deciduous bay forest and, if left unaltered, it will probably develop into a bay forest vegetation type dominated by red maple, black gum, and pond cypress.

Few quantitative studies of pocosin vegetation have been attempted because of the obvious logistical difficulties involved and the perceived low value of these ecosystems. Woodwell (1956) compared the vegetational composition of 54 shrub bogs in North Carolina, and his data provide the most complete regional phytosociological study of this ecosystem. He classed pocosins into three associations, based on the dominant shrub species: titi, fetterbush, and zenobia. The titi-dominated pocosins are found in northeastern and central North Carolina, whereas fetterbush is more abundant further south and zenobia appears to dominate in both areas after fire.

Recently, Christensen reanalyzed Woodwell's original data (Christensen

Table 5a. Classification of pocosin communities in the Green Swamp, according to Kologiski (1977).[a]

POCOSIN Community Cover Class (Wet scrub-shrub system)

PINE-ERICALEAN Community Class

Pond pine/titi-zenobia community type

Characteristic of deep peats, long hydroperiods, and frequent fires. Low productivity and low pine density. "Short pocosin."

Pond pine-loblolly bay/fetterbush community type

Characteristic of elevated areas ("islands") within the above type. Apparently formed by accumulation of litter and *Sphagnum* around the tree boles and stumps.

Pond pine/titi-fetterbush community type

Intermediate to deep peats with moderate to long hydroperiods. Longer fire return times. "Tall pocosin."

CONIFER-HARDWOOD Community Class

Pond pine/titi-fetterbush-red maple-black gum community type

Shallow organic soils with shorter hydroperiods. *Sphagnum* may be present, but no deep peat. Mature trees are taller and less deformed than in Pine-Ericalean pocosins.

Pond pine-pond cypress/red maple-titi-fetterbush-black gum community type

Similar to above, but with a larger component of swamp forest species. Clearly successional to swamp forest.

[a]Modified from Christensen et al. 1981.

Table 5b. Associated communities peripheral to and perhaps related to pocosins (from Kologiski 1977).

SEDGE BOG Community Cover Class (Marsh grass system)

Sedge community type

Occurring in depressions, often formed by fires. Standing water most of the year. Dominated by dense stands of sedges. May succeed to shrub bog as depressions fill.

PINE SAVANNA Community Cover Class (Low woodland system)

Longleaf pine/wire grass-sedge community type

Relatively well drained mineral soils, short hydroperiod during rainy season. More frequent fires than shrub bogs.

Pond pine/wire grass-sedge community type

Similar to above, but more hydric.

Longleaf pine/huckleberry-bitter gallberry community type

Denser canopy than other savannas, with a better developed shrub subcanopy. Relatively well drained mineral soils.

CEDAR BOG Community Cover Class (Lowland gymnosperm forest system)

Atlantic white cedar/fetterbush-sweet gallberry community type

Relatively few stands on deep organic peats. High water table, wet soils throughout the year. Canopy almost a monospecific cedar stand.

Atlantic white cedar-loblolly pine/fetterbush-sweet gallberry

Similar to above except grows on shallower organic soils.

BAY FOREST Community Cover Class (Lowland angiosperm forest system)

Sweet bay-red bay-loblolly bay/titi-fetterbush/Virginia chain-fern community type

Evergreen bay forest. Characteristic of deep organic soils. Poorly drained, with long hydroperiods. May succeed pocosins and cedar bogs in the absence of fire.

Red maple-black gum-pond cypress/titi-fetterbush/Virginia chain-fern community type

Deciduous bay forest. Often associated with above in areas of shallower organic soils with shorter hydroperiods.

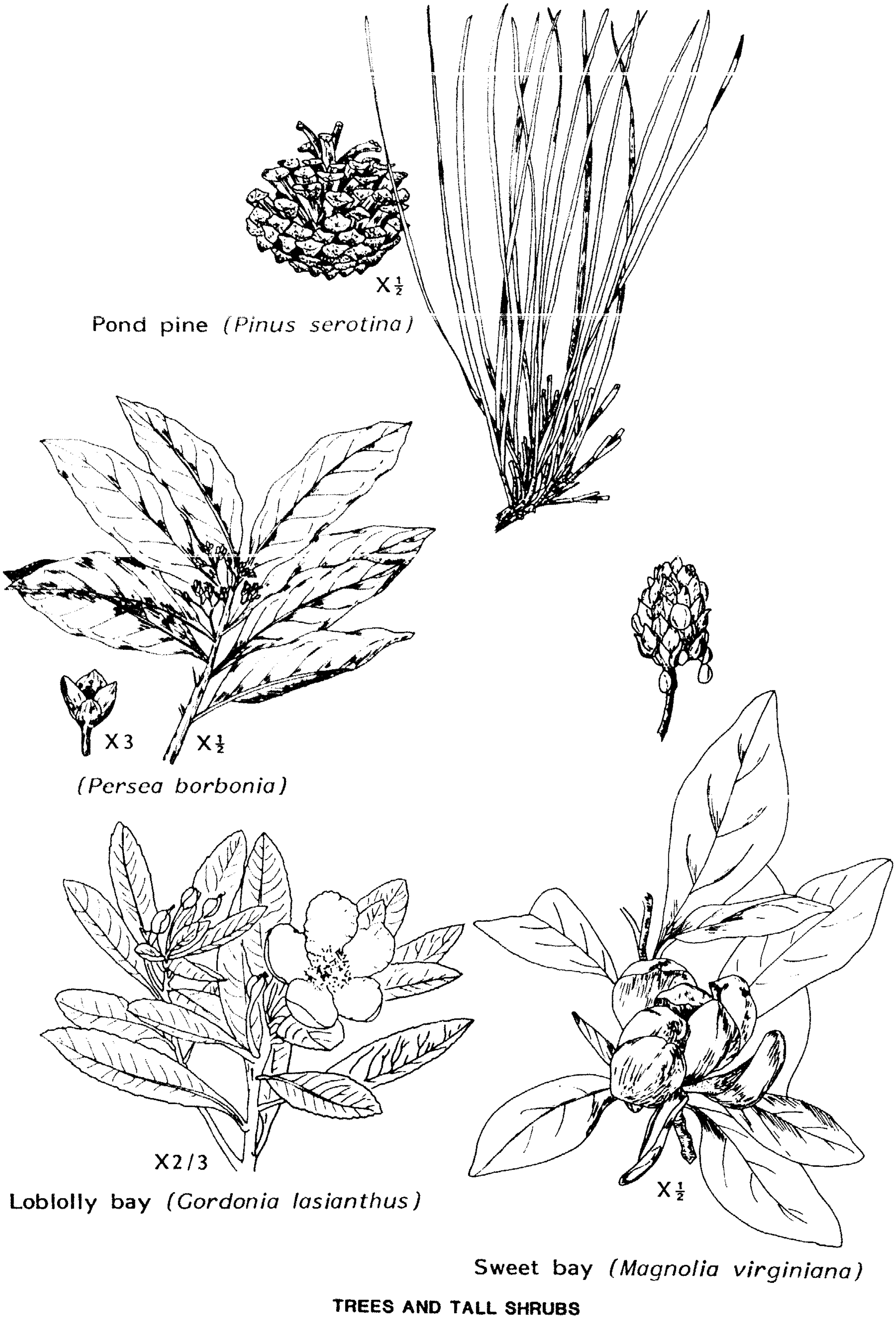
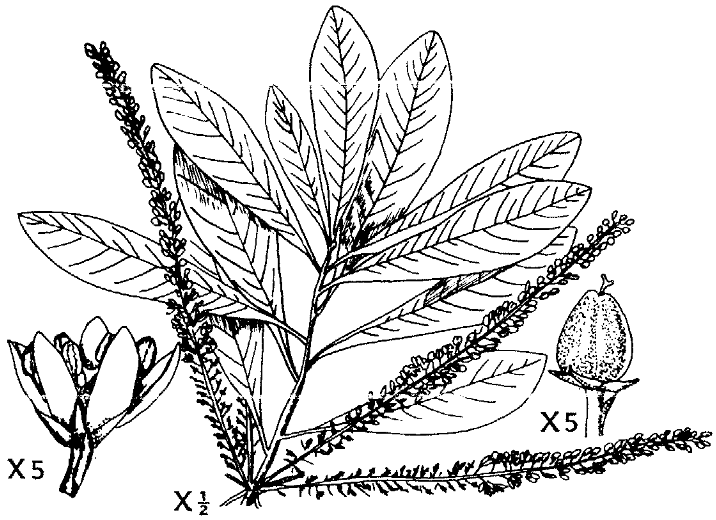


Figure 16. Dominant woody plant species of pocosin communities (line drawings modified from Gleason 1963; Radford et al. 1968).



Titi *(Cyrilla racemiflora)*

Zenobia *(Zenobia pulverulenta)*

Fetterbush *(Lyonia lucida)*

LOW SHRUBS

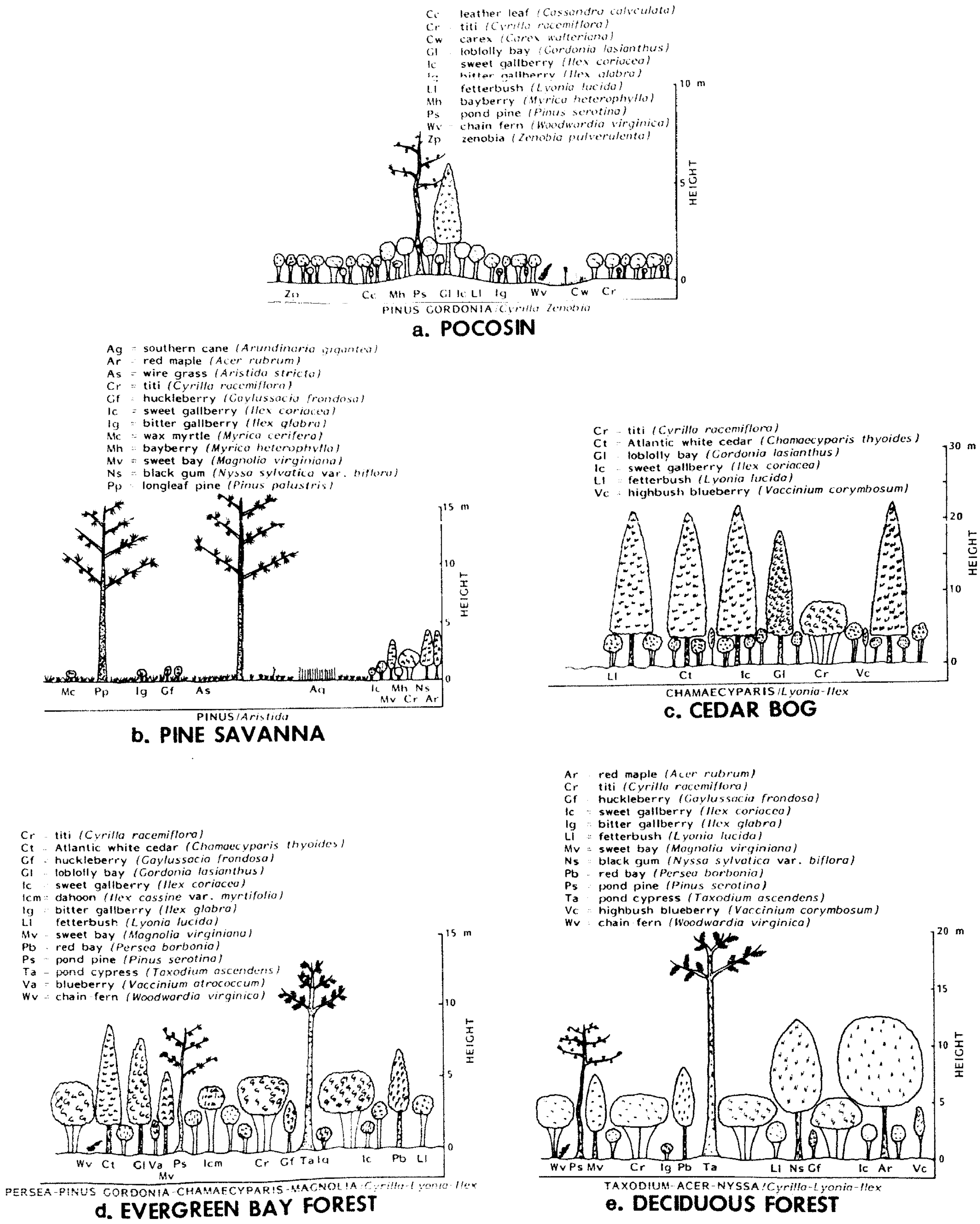


Figure 17. Major woody plant community cover classes in Green Swamp, NC (based on Kologiski 1977).

1979; Christensen et al. 1981). Using reciprocal averaging ordination to evaluate Woodwell's (1956) classification, Christensen determined that although the three categories do not fall into discrete groups, they do tend to dominate specific parts of the ordination. Christensen et al. (1981) further attempted to relate species dominance to known environmental features including geologic type of pocosin, peat depth, water table depth, substrate type, and age of the community since burning. They also concluded that zenobia tends to dominate in recently disturbed areas in which the shrub community has relatively low productivity and higher diversity, whereas titi and fetterbush occur in more productive bogs. They were unable, however, to add much additional insight about the causes of variation among pocosins.

Jones (1981) described 52 lowland forests in the northern Coastal Plain of South Carolina, including 13 pocosins. Densities and basal areas of trees from a typical pocosin site (Table 6) are low in comparison with other wetland forests. Pond pine dominated these communities, with loblolly bay and pond cypress being next in density. The chief shrub was fetterbush, with greenbrier often the second most important species (Table 7). The gallberries, blueberries, wax myrtle (*Myrica cerifera*), and zenobia also contributed significantly to the shrub cover which commonly reached or exceeded 100% ground coverage and was the highest coverage measured by Jones (1981) in any of the wetland communities.

Associated communities. In addition to the pocosin community, Kologiski (1977) described four peripheral and perhaps related community cover classes in the Green Swamp: sedge bog (representing the marsh grass system), pine savanna (low woodland system), cedar bog (lowland gymnosperm forest), and bay forest (lowland angiosperm forest; Table 5b). Each of these vegetation systems will be briefly characterized.

Table 6. Density and basal area of trees in a pocosin in South Carolina (from Jones 1981).

Species	Density (stems/ha)	Basal area (m^2/ha)
Pinus serotina (pond pine)	538	8.70
Gordonia lasianthus (loblolly bay)	125	0.88
Taxodium ascendens (pond cypress)	103	1.34
Nyssa sylvatica var. *biflora* (black gum)	77	0.42
Persea borbonia (red bay)	18	0.06
Magnolia virginiana (sweet bay)	7	0.02
Myrica cerifera (wax myrtle)	11	0.04
Acer rubrum (red maple)	7	0.07
Ilex cassine (dahoon)	4	0.01
Total	890	11.54

Table 7. Density and transect cover of shrubs, woody vines, and tree seedlings in a South Carolina pocosin (from Jones 1981).

Species	Density (stems/ha)	Transect cover (cm/m)
Lyonia lucida (fetterbush)	10144	45.12
Smilax spp. (greenbrier)	3480	11.08
Ilex glabra (bitter gallberry)	2016	6.67
Vaccinium spp. (blueberry)	1401	9.12
Persea borbonia (red bay)	1231	7.79
Magnolia virginiana (sweet bay)	594	6.25
Myrica cerifera (wax myrtle)	446	2.92
Gaylussacia spp. (huckleberry)	446	0.58
Ilex coriacea (sweet gallberry)	403	4.50
Sorbus arbutifolia (chokeberry)	191	3.00
Gordonia lasianthus (loblolly bay)	255	2.46
Pinus serotina (pond pine)	255	1.12
Rhus radicans (poison ivy)	85	0.29
Ilex cassine (dahoon)	64	1.42
Nyssa sylvatica var. *biflora* (black gum)	42	1.42
Lyonia ligustrina (fetterbush)	21	< 0.01
Total	21074	103.74

Sedge bog. This is the most hydric community type included in Kologiski's classification of the Green Swamp vegetation. The community type represented in this area is dominated by the sedge Carex walteriana and occupies shallow depressions in organic soils that contain standing water during most of the year. It is therefore "wetter" than the pocosin shrub community. Such depressions are frequently formed by fires burning into the peat during periods of low water.

Sedges, especially C. walteriana, are usually the first plants to invade the wetter sections of a pocosin after fire or other major disturbances. These sedges often form dense stands with almost 100% cover, although other herbaceous as well as shrub species may be found in this community type. After the depressions begin to fill, zenobia and then titi invade, and the community becomes shrub dominated.

Pine savanna. This vegetative community cover class has a widely spaced canopy of pines with an understory ranging from predominantly grasses to a mixture of grasses, shrubs, and ferns (Figure 17b). According to Kologiski (1977), the savanna communities of the Green Swamp are characterized by mineral soils, short hydroperiods, and frequent fires. The soils are usually well drained; however, because of a perched water table, water is within a meter (3 ft) of the surface most of the year. Although the moisture gradient from pocosin to pine savanna is generally gradual, the vegetational ecotone may be sharp (Christensen et al. 1981), largely because of the higher frequency of fire in savanna areas. Three types of pine savanna occur in the Green Swamp:

(1) Longleaf pine (Pinus palustris) canopy with wire grass (Aristida stricta) and sedges (Rhynchospora spp.) as ground cover. This savanna type occurs on mineral soils that are usually well drained, although in the more hydric areas, water may be at or near the surface during the rainy season. Pond pine is the chief canopy species and wire grass dominates the ground cover. Several species of sedge may share the dominance with wire grass.

(2) Pond pine (Pinus serotina) canopy with wire grass (Aristida stricta) and sedges (Rhynchospora spp.) as ground cover. In the more hydric savannas, pond pine becomes the canopy dominant. A similar community with switchcane (Arundinaria gigantea) as the ground cover develops in response to frequent burning, although it is not common in the Green Swamp.

(3) Longleaf pine (Pinus palustris) canopy with huckleberry (Gaylussacia frondosa) and bitter gallberry (Ilex glabra) in the shrub layer. This community, which occurs on better drained mineral soils than (1) and (2), has a more closed pine canopy and a low shrub layer. Huckleberry and bitter gallberry are the most important species of the latter. Other shrubs include sweet gallberry, leucothoe (Leucothoe axillaris), lyonia (Lyonia mariana), wax myrtle (Myrica cerifera), and several species of blueberry (Vaccinium spp.).

As in the Green Swamp, savannas frequently occur in association with pocosins. They develop on ridges or high areas that are elevated sufficiently to prevent peat accumulation (such as the rims of Carolina bays). A difference in elevation of only a few centimeters may be sufficient to separate pine savannas from the surrounding pocosins (Ash et al., in press).

Fire maintains the savannas by limiting invasion by shrubs. Without frequent fire, the savannas will become pine-dominated forests with an evergreen shrub understory. Succession will proceed more rapidly in areas with greater surface drainage. The extent of savannas is usually limited. In the Green Swamp, only 93 ha (230 acres) of the 5,609 ha (13,860 acre) nature preserve is savanna (McIver 1981).

Cedar bog. Atlantic white cedar forests are often associated with pocosins. White cedar may become established in open habitats on organic soil, especially after fires when the water table is high (Figure 17c). It commonly forms dense even-aged stands in areas of highly acidic peat and stagnant water (Dean 1969). Seedlings may become established under shrubs and parent trees, but since they require sunlight, growth is decreased once the canopy begins to close. Kologiski identified two community types:

(1) Atlantic white cedar (Chamaecyparis thyoides) canopy with fetterbush (Lyonia lucida) and sweet gallberry (Ilex coriacea) in the shrub layer. According to Kologiski, in the Green Swamp this type is best developed over deep organic soils that are usually wet throughout the year, although standing water is unusual. The ground is covered with a mat of white cedar leaves and other organic debris, and fallen white cedar logs and stumps are abundant. These stands commonly form a dense canopy. The understory of smaller deformed white cedars and the distinct shrub layer form an almost impenetrable thicket. The shrub layer ranges in height from 1 m (3 ft) to several and is dominated by fetterbush and sweet gallberry. Greenbrier and yellow jessamine (Gelsemium sempervirens) are important vines. The herb layer is almost absent.

(2) Atlantic white cedar (Chamaecyparis thyoides) and loblolly pine (Pinus taeda) canopy with fetterbush (Lyonia lucida) and sweet gallberry (Ilex coriacea) in the shrub layer. Loblolly pine is prominent in the canopy of this community, although it is never actually a codominant with white cedar. While very similar to the previous community (1), this type is usually found on shallow organic soils underlain by sandy clay loam.

Successional studies (Buell and Cain 1943) indicated that burned white cedar forests typically become evergreen bay forests. These cedars have no resistance to fire, and burning usually kills all the trees in a stand. Successful regeneration following fire depends upon a store of viable seeds in the upper layers of peat (Ash et al., in press). If fires occur during extremely dry periods and burn the peat, the seed source may be eliminated. In such areas where the cedars have been destroyed completely, pocosin and bay species will become dominant.

Bay forest. The bay forests described by Kologiski (1977) are characterized by shallow to deep organic soils, intermediate to long hydroperiods, and canopies dominated by combinations of red maple, Atlantic white cedar, titi, loblolly bay, sweet bay, black gum, red bay, pond pine and pond cypress. One or all of the bay trees (sweet bay, red bay, loblolly bay) are present in both the evergreen and deciduous phases of this forest (Figures 17d and e). Community types are:

(1) Sweet bay (Magnolia virginiana), red bay (Persea borbonia), and loblolly bay (Gordonia lasianthus) canopy with titi (Cyrilla racemiflora) and fetterbush (Lyonia lucida) shrubs and Virginia chain-fern (Woodwardia virginica) as ground cover (Figure 17d). This lowland evergreen bay forest develops on deep organic soils that are poorly drained and have long hydroperiods. Standing water is typically present during part of the year and the water table is always near the surface. The three bay species (loblolly bay, red bay, and sweet bay) dominate the canopy, which may be shared by Atlantic white cedar, titi, dahoon, pond pine, and deciduous species such as red maple, black gum, and pond cypress. The canopy is 3 to 10 m (10 to 32 ft) high, and the shrub stratum usually blends into it. Major shrubs include titi, huckleberry, fetterbush, sweet gallberry, bitter gallberry, smooth winterberry (Ilex laevigata), dahoon, bayberry (Myrica heterophylla), swamp azalea (Rhododendron viscosum), highbush blueberry (Vaccinium atrococcum, V. corymbosum), and zenobia. Greenbrier is abundant and Virginia chain-fern is the most important herb.

Kologiski (1977) believes that in the Green Swamp, this evergreen bay forest succeeds the titi-zenobia pocosin and probably the white cedar forest (following logging). He reported that the most common seedlings in many of the evergreen bay forest stands were red bay, indicating eventual domination by this species. A major fire may cause this forest to revert to a pocosin or white cedar forest (with a shallow burn), a sedge bog (with a deep burn and high water table), or a deciduous bay forest (with a deep burn and temporarily low water table).

(2) Red maple (Acer rubrum), black gum (Nyssa sylvatica var. biflora), and pond cypress (Taxodium ascendens) canopy with titi (Cyrilla racemiflora) and fetterbush (Lyonia lucida) shrubs and Virginia chain-fern (Woodwardia virginica) as ground cover (Figure 17e). This lowland deciduous forest develops on shallow organic soils with intermediate to long

hydroperiods and an absence of major fires. Standing water may be present over the hummocky substrate for at least several months of the year. Most of the same species are present in both the evergreen bay and the deciduous forests and the two types blend into one another. In the Green Swamp, the dominant canopy species in the deciduous forests are red maple, black gum, and pond cypress, with frequent occurrence of red bay, pond pine, and loblolly pine. The height of the canopy ranges between 10 and 25 m (32 to 82 ft). Although the dense understory contains a number of shrubs, titi and fetterbush are usually the dominants. Several species of greenbrier are abundant, and Virginia chain-fern is the dominant herb.

Kologiski reported that the presence of canopy seedlings and saplings indicates that the lowland deciduous forest in the Green Swamp is perpetuating itself. He suggested that under existing environmental conditions, it can be assumed that a mature lowland deciduous forest is relatively stable. Over time, however, especially if drainage occurs, the area will become dominated by more upland species. Extensive disturbance such as fire or cutting would probably revert this type to conifer-hardwood pocosin.

Only the Pine-Ericalean and the Conifer-Hardwood Community Classes as described by Kologiski (1977) in the Green Swamp typify the shrub bog definition of pocosin used in this community profile. However, the other marsh, swamp, and forest associations represent related community types. A comparison of various ecological attributes of several of these communities, based upon the work of Jones (1981), is given in Table 8. Kologiski's ordination of 220 stands sampled in evergreen shrub and related communities provides a rough reflection of the soil moisture gradient. Sites with relatively dry mineral soils, dominated by pond pine, wire grass, sedges, huckleberry, and bitter gallberry, are located at one extreme of the arrangement; and sites with highly organic wet soils, dominated by Carex spp., zenobia, and titi, are located at the other extreme. Proposed relationships between the vegetation units of the Green Swamp and environmental factors are depicted in Figure 18. General patterns of community classes as influenced by soil/hydroperiod and fire frequency can be interpreted from this scheme. Kologiski (1977) noted that hydroperiod is probably the most important of the factors since it controls the establishment and the growth of the plants and also, to some extent, the severity of fire and its effect on the vegetation.

Around lakes or ponds, or in areas with distinct drainage patterns, pocosin communities may intergrade with swamp forest vegetation. Only at their margins, however, do these upraised shrub bogs appear to be succeeding to swamps (Christensen et al. 1981). Characteristic bay forest species (cypress, black gum, and white cedar) are usually absent except in these wetter areas. At the other end of the moisture gradient, shrub bog vegetation becomes pine flatwoods and savannas dominated primarily by loblolly and longleaf pine with a diverse herbaceous understory.

<u>Successional relationships</u>. As noted earlier in the discussion of the historical development of pocosin communities, evidence from peat profiles suggests that most of these shrub bog communities developed in the last few thousand years. Otte (1981) reported that the pocosin peats were typically underlain by organic remains of marsh vegetation with Atlantic white cedar and cypress common in deeper layers of the peat, especially near ancient stream channels. Paludification, or expansion of these pocosin wetlands, proceeded as a result of peat accumulation and an associated gradual rise in the water table.

There are basically two theories of pocosin succession which are in sharp contrast to each other. The first, proposed by Wells (1928), assumes that the frequency and intensity of fire controls successional development. According to this theory, short pocosin is a pioneer stage leading to bay forest as a climax. The successional process could therefore be completed 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. According to this hypothesis, the successional sequence is marsh → swamp forest → bay forest → tall pocosin → short pocosin. This sequence of events may require thousands of years for the modification of the substrate and development of an upraised bog with a perched water table to occur.

Relationships of pocosin communities to other wetland plant associations have been mentioned throughout the above descriptions. A delicate balance of environmental factors controls these community relationships. The three major factors directly controlling the distribution of vegetation within the pocosin ecosystem are thickness of the peat, length of the hydroperiod, and frequency and severity of fire (Otte 1981). These factors are interrelated in such a complex way that an alteration of one will affect the others. Therefore, it is impossible to separate their individual effects and relative significance to the maintenance and integrity of pocosins.

In general, the evergreen shrub bog pocosin communities occur on the deepest peat substrates. Following an extensive survey of pocosins in North Carolina, Otte (1981) proposed that peat thickness, along with hydroperiod and associated nutrient availability, is primarily responsible for the maintenance of short versus tall

Table 8. Comparison of various geological and ecological parameters of pocosins, pine savannas, and bay forests in South Carolina (from Jones 1981). Values represent means for all sites of each community sampled unless indicated otherwise.

Parameters		Pine savanna	Pocosin	Bay forest
No. of tree species		7.7	7.9	11.0
No. of shrub species		8.2	11.3	13.8
Total no. of woody species		15.9	19.2	24.8
Tree basal area (m^2/ha)		14.5	14.3	33.3
Shrub cover (cm/m)		22.6	117.2	88.9
Depth of organic substrate (cm)		18.0	>40.0	>40.0
% organic matter		6.5	39.2[a]	53.8
Mineral soil:	% sand	81.2	80.6[a]	59.3
	% silt	12.8	10.4[a]	31.2
	% clay	6.0	9.0[a]	9.5
No. of sites sampled		6	13	6

[a]Measured only in non-organic soils (6 of the 13 sites).

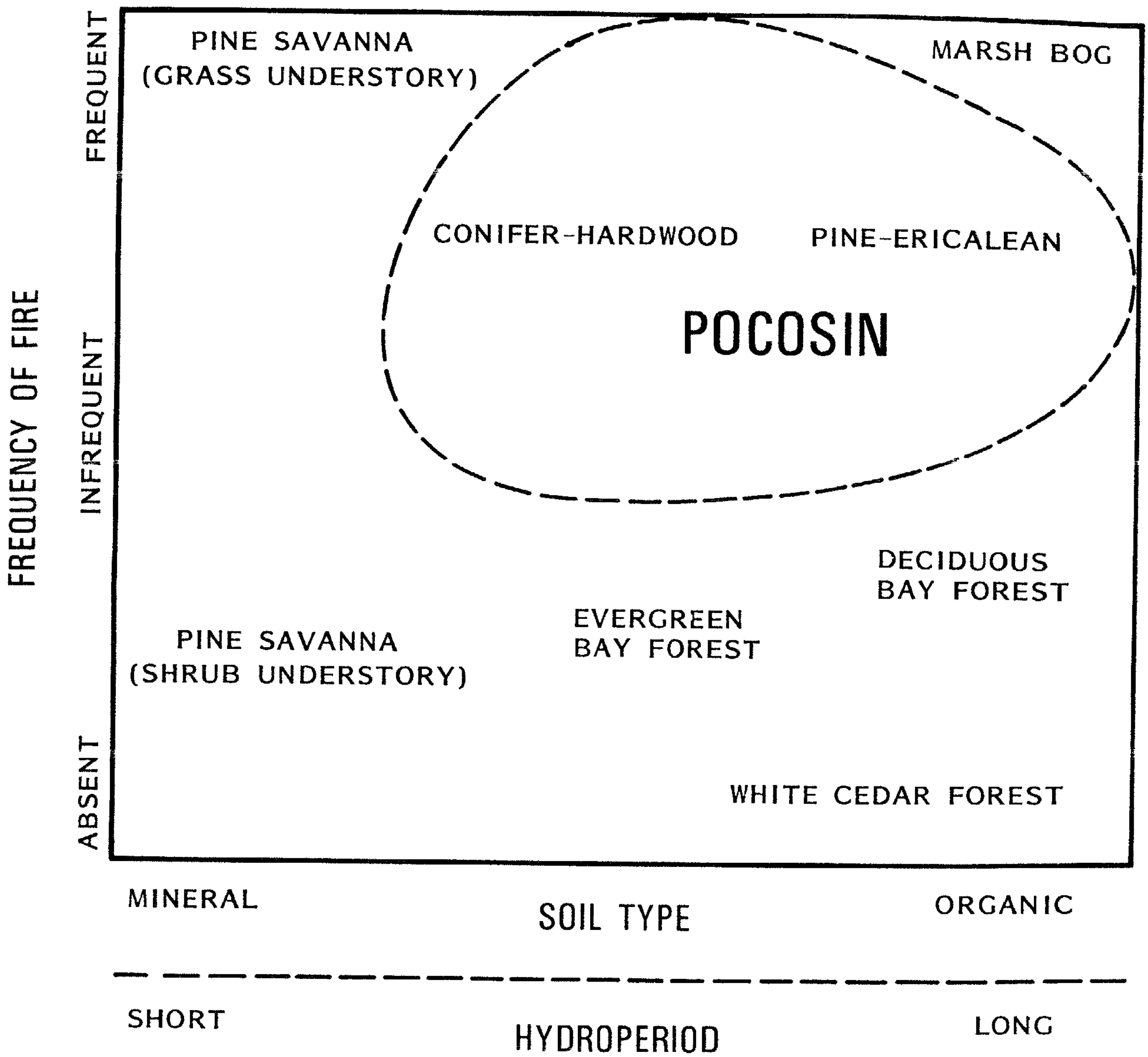


Figure 18. Proposed relationships among vegetation types, hydroperiod, and fire in pocosin habitats (based on Kologiski 1977).

pocosin vegetation. According to his theory, the deeper portions of the thicker peat substrates are always saturated with water because the water table rarely falls lower than 1.2 to 1.5 m (4 to 5 ft) below the surface. Thus the root systems of plants never reach the underlying mineral sediments and are confined to the nutrient-poor organic substrates. Such plants are therefore stunted (short pocosin). In contrast, in the shallower peats the water table frequently drops below the peat-sediment interface (Otte 1981). In this circumstance, downward-growing roots can reach the more nutrient-rich mineral sediments and growth is enhanced (tall pocosin). Furthermore, Otte suggested that the short pocosin is the only pocosin community that can be considered a true climax community. Once peat substrates become so thick as to prevent plant roots from reaching the mineral soil, the short pocosin will remain a permanent feature unless a major fire or other disturbance removes part of the peat.

Pocosins typically occur in areas of relatively long hydroperiod with the water table at or near the surface for 6 to 12 months of the year. This prolonged exposure excludes many of the bottomland hardwood species characteristic of stream floodplains and bay forests as well as the upland pines and hardwoods. Water-tolerant swamp species such as cypress and black gum are occasionally associated with pocosin communities, but seldom become dominant, presumably because of the low nutrient availability of the organic pocosin substrates. An important difference between swamps and pocosins is in the direction of water flow (Otte 1981). Water flows into and through swamp ecosystems, replenishing nutrients. In pocosins, the major direction of water flow is out of the ecosystem via runoff; therefore, precipitation is the only major source of water and nutrients.

The frequency and intensity of fire also influence the vegetation of pocosins. Obviously, since the highly organic soils burn readily when dry, the potential severity of a fire is related to the depth of the water table. Following shallow peat burns that destroy surface vegetation and the surface layer of peat, but do not damage the root and rhizome mat, the original pocosin type will recover quickly (Otte 1981). A burn that destroys the rhizome and root mat will be followed by recolonization from seeds and vegetation growing inward from the edge of the burned area.

A fire that burns the peat to a depth such that the roots of the recolonizing vegetation can more readily come in contact with the mineral soil may permit recovery of the same species as originally present. However, because of increased nutrient availability, their growth may be enhanced (Otte 1981). A severe burn over shallow peat that removes all the organic material above the mineral sediments will probably lead to the development of a non-pocosin community. On the other hand, a severe burn in deep peat substrates during a period of low water table could open up an area that would become a lake upon return of a high water table (Otte 1981).

On better-drained soils, commonly associated with slight increases in elevation (such as the rims of Carolina bays), frequent occurrence of fire will tend to maintain a pine savanna community. Shrubs and upland hardwoods may become established if fire is prevented.

Adaptations of pocosin vegetation. Many of the characteristic pocosin species are not only tolerant of fire, but they may also actually be dependent upon it for completion of their life cycles. Pond pine trees are resistant to fire and typically sprout from the roots as well as from epicormic buds (those along the trunk of the tree) following fire (Christensen et al. 1981). In addition, heat from fire stimulates opening of the cones that are serotinous (delayed in opening), some of which may remain closed after seed maturation for up to 10 years. Such opening of the cones following fire ensures seed dispersal at a time when open areas are available for successful establishment of seedlings. Many of the pocosin shrubs may also sprout vigorously from their roots after being burned. Little is known about germination requirements of many of these shrub species, but seedlings may more commonly be found in recently burned areas than in undisturbed pocosin habitats (Christensen et al. 1981).

Many pocosin shrubs, in addition to being fire tolerant, also have evergreen sclerophyllous leaves (reinforced with lignin and having thickened cuticles). Just how this feature may serve as an adaptation for survival in these environments is not understood. Such sclerophylly is usually considered to be an adaptation to drought rather than to high moisture conditions (Christensen et al. 1981). An early theory regarding the occurrence of sclerophyllous shrubs in these wet habitats proposed by Schimper in 1898 (cited by Christensen et al. 1981) is that anaerobic conditions in the rooting zone prevent water uptake and produce an effect similar to that of drought. This theory, however, has been considered unlikely by more recent investigators (Schlesinger and Chabot 1977).

Other workers (Monk 1966, 1971; Schlesinger and Chabot 1977) have speculated that sclerophyllous leaves could be an adaptation to conserve nutrients in these nutrient deficient habitats, although the specific mechanisms of such nutrient-conservation are neither understood nor agreed upon. Schlesinger and Chabot (1977) have further suggested that certain evergreen pocosin species (e.g., fetterbush) may have a significantly higher efficiency of nutrient use (especially of nitrogen) than do their deciduous counterparts. Direct measurements of photosynthesis and of nutrient-use efficiency in pocosin species necessary to compare evergreenness and deciduousness have not yet been conducted (Christensen et al. 1981).

Evergreen sclerophyllous leaves may be more resistant to herbivory than are deciduous leaves (Christensen et al. 1981). In addition, the leaves of many pocosin species contain large quantities of secondary chemicals that may also have a role in defense against herbivores. High levels of these aromatic compounds also increase the caloric contents of these tissues (Hough 1969) and their flammability (Christensen 1980).

It should be noted that the presence of insectivorous plants, especially pitcher plants (Sarracenia flava and S. purpurea) and sundews (Drosera spp.), in open areas of these shrub bogs also suggests adaptations to low nutrient levels (Figure 19). The leaves of these plants are morphologically modified to attract and trap insects. Enzymes secreted by the plants then digest the bodies of the insects. In this way, insects may serve as alternative nutrient sources to meet nitrogen and phosphorus requirements in these species (Plummer 1963; Christensen 1976).

Little is known about the productivity or standing crop of biomass in pocosin communities. Christensen et al. (1981) cited data (Wendel et al. 1962) indicating that in very nutrient-poor areas aboveground biomass, excluding tree trunks, may be 1200 to 1800 g/m^2. Such values may be characteristic of low or short pocosin (Figure 14). In more productive areas (high or tall pocosin), biomass may be 3300 to 4700 g/m^2. Apparently, no reliable estimates of belowground biomass have been published.

Figure 19. The pitcher plant (Sarracenia purpurea) is adapted to nutrient-poor pocosin soils. (Photograph by Trip Lamb, University of Georgia.)

Carolina Bays

Because Carolina bays are the dominant lentic habitats of a large portion of the southeastern Coastal Plain, they have a major ecological influence on plant and animal distribution patterns. In addition, because of their probable age, they may have influenced the evolution of some species.

A number of wetland community types typical of undrained Coastal Plain sites are found within Carolina bays (Figures 20 and 21). These moist wetland habitats are readily distinguished in aerial photographs from surrounding upland pine and oak forests. The gradually sloping contours that characterize Carolina bay depressions result in gradients of water depth or soil moisture, as well as substrate characteristics, across the basins. In response to these gradients, plant communities typically show a marked pattern of zonation from the periphery of the bays to their center.

Figure 20. Aerial view of vegetational zone pattern around a Carolina bay.

Schalles (1979) noted that topographic relief and hydrology are the principal physical determinants of vegetational composition, although edaphic (soil) conditions also play a role. The duration and magnitude of inundation create a range of conditions favoring different vegetation associations. Although many of the bays contain pocosins or similar evergreen shrub communities (Figure 2), other types of plant associations such as cypress-gum forests are also common.

Characterization of Carolina bay vegetation. Carolina bays have received even less ecological study than pocosins. In 1946, Buell (1946a and b) described the vegetation of Jerome Bog in Bladen and Cumberland Counties, North Carolina, as an open pocosin community on peaty soils with low evergreen shrubs overtopped by pond pine. In more recent mapping of the vegetation of Bladen County, Whitehead and Tan (1969) indicated that many of the bays of this region contained either mixed pine communities or shrub bogs. Where the water table was close to the surface, a bay forest developed, dominated by pond pine along with loblolly bay, sweet bay, red bay, and sweet gum over a shrub layer of titi, sweet pepperbush, and wax myrtle. The pocosin community, which occurred in peat beds, was dominated by the typical bay shrubs and small trees (loblolly bay, sweet bay, and red bay) as well as red maple, pond pine, sweet gum, cypress, Atlantic white cedar, and black gum overtopping a shrub layer of titi, sweet pepperbush, holly, gallberry, Virginia willow, fetterbush, zenobia, leucothoe, blueberry, and greenbrier. Whitehead and Tan (1969) also provided basal area data for the tree species in these communities. The nature of pocosin vegetation has been extensively described in the previous section of this community profile. Therefore, the discussion at this point will be directed toward other plant communities found in Carolina bays and their relationships to the pocosin type.

Porcher (1966) surveyed the vegetation zonation patterns of selected Carolina bays in Berkeley County, South Carolina (Figure 21). Several of the bays were dominated by evergreen shrub bogs characterized by both tall and short shrub zones of pocosin species. In addition to

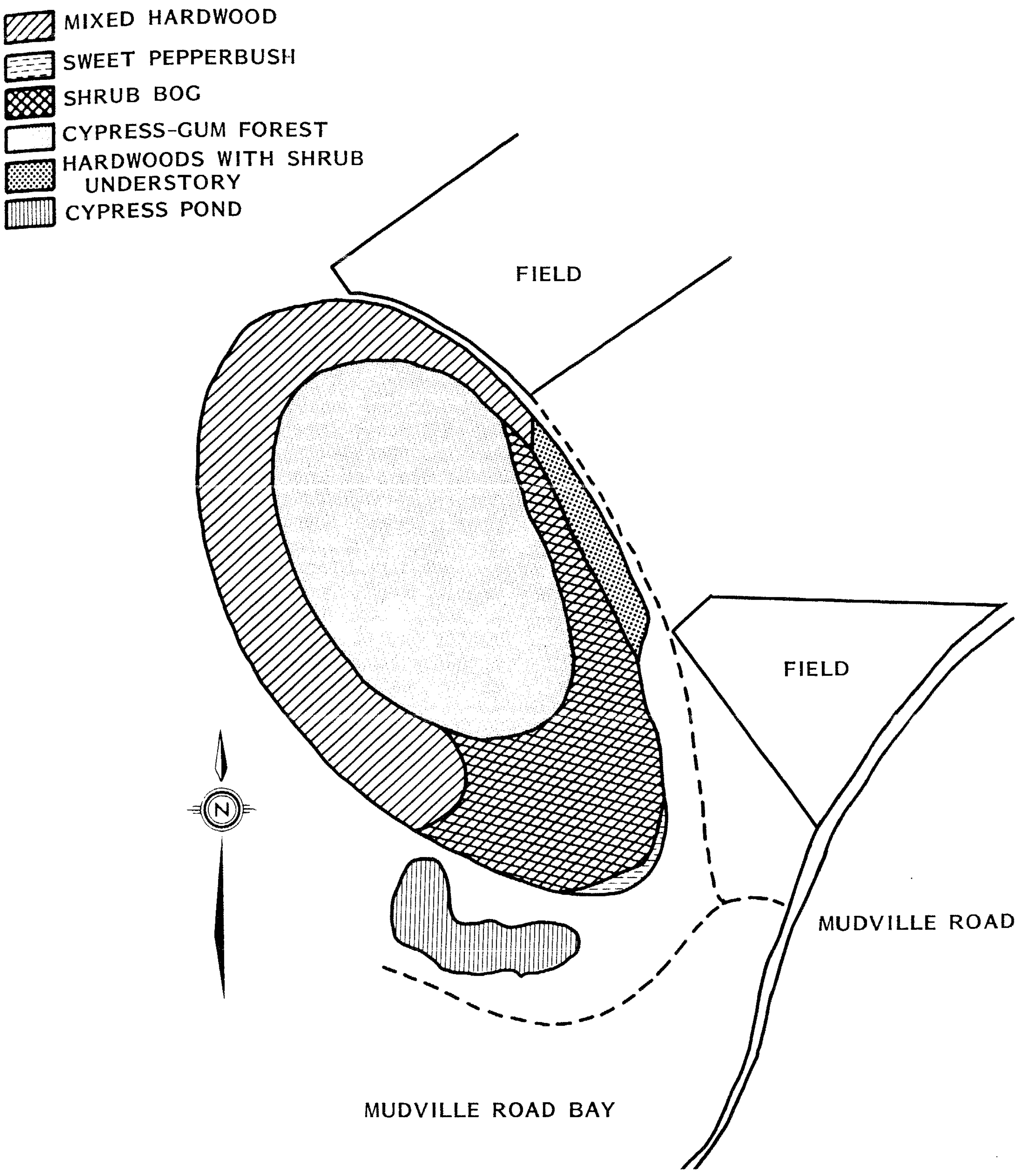


Figure 21. Vegetation types of a Carolina bay that are characteristic of many undisturbed sites (from Porcher 1966).

pocosins, several of these bays had a cypress-gum community with pond cypress and black gum and a low herbaceous zone containing species of yellow-eyed grass (*Xyris* spp.), pipewort (*Eriocaulon decangulare*), clubmoss (*Lycopodium alopecieroides*), St. Peter's-wort (*Hypericum stans*), zigadenus (*Zigadenus galberrimus*), cinnamon fern (*Osmunda cinnamonea*), and others. The edges of these bays were commonly dominated by pond pine or loblolly pine along with a variety of shrubs or by a mixed mesophytic hardwood forest characterized by red maple, mockernut hickory (*Carya tomentosa*), flowering dogwood (*Cornus florida*), water oak (*Quercus nigra*), and sweet gum.

In the other bays, Porcher (1966) found cypress and gum forests to dominate. A mixture of shrubs including fetterbush, leucothoe, sweet pepperbush, zenobia, highbush blueberry, and Virginia willow (*Itea virginica*) commonly grew around the bases of the cypress and gum or on slightly higher areas. The three species of bay trees also were commonly present. A mixed hardwood forest typically occurred on the edge of these bays, and aquatic macrophytes dominated the open water areas.

Patterns of vegetation zonation. Craig Pond, a bay approximately 1400 m (4,600 ft) long on the Savannah River Plant in Barnwell County, South Carolina, demonstrates the marked zonation pattern of vegetation characteristic of many of these wetlands (Kelley and Batson 1955). The outermost zone lies along the sandy rim of the bay and is dominated by trees such as loblolly and longleaf pine, black gum, blackjack oak (*Quercus marilandica*), turkey oak (*Q. laevis*), and sweet gum. Several shrubs, such as sumac (*Rhus copallina*), gallberry, and sweet bay also occur here. Interior to this zone of woody species are several bands of vegetation, each of which is dominated by grass species. The first is characterized by broomsedge, but also contains numerous herbs including pitcher plants. Inside of this zone is a band in which three-awn grass (*Aristida affinis*) is dominant, and in deeper areas surrounding the central pool of water, species of maidencane (*Panicum* spp.) are abundant. The pond in the middle of the bay contains typical aquatic plants such as the water lilies, *Nymphaea odorata* and *Nymphoides aquaticum*. Kelley and Batson interpreted this zonation pattern as a successional series that developed as the pond receded and new soil surface was exposed for plant invasion. Those areas farthest from the pool that have been exposed longest have developed a woody flora. The more recent exposures show successively earlier successional stages. However, no temporal comparisons have been made on Craig Pond or other Carolina bays to document that Carolina bays follow a classical pattern of hydric succession.

Based upon descriptions of Carolina bay vegetation by Penfound (1952), Porcher (1966), and Wharton (1978), a qualitative arrangement of these wetland communities was proposed by Schalles (1979) using the average water level and hydroperiod amplitude as controlling environmental factors. Major types of communities ordinated along these environmental gradients included pine forests or savannas, herbaceous marshes, shrub bogs, deciduous forests dominated by black gum, evergreen bay forests, pond cypress swamps, pond/grass prairies, and lakes. Many of these community types are partly maintained by burning (Wharton 1978). In the absence of fire, peat accumulates and the changing substrate conditions allow new plant species to invade. During drought, however, the peat becomes vulnerable to fire, which can set back the process of ecological succession.

Vegetative dominance in Carolina bays may be strongly related to patterns of disturbance as well as to hydrologic regime. A large bay in Bullock County, Georgia, which had been heavily forested with cypress and subsequently logged, had a fringe of black gum surrounding zones of emergent grasses and sedges and of submerged water milfoil (*Myriophyllum* spp.; Wharton 1978), which replaced the timbered trees as dominant species. A less disturbed bay in Jenkins County, Georgia, exhibited at least five zones of vegetation (Wharton 1978): (1) a rim dominated by a scrubby forest of red cedar (*Juniperus virginiana*) and black cherry (*Prunus serotina*); (2) a second zone of loblolly pine, sweet gum, and greenbrier, (3) a more moist zone of wax myrtle and red maple; (4) a zone of water willow (*Decodon* verticillata), lizard's tail (Saururus cernuus), bulrush (Scirpus cyperinus), and giant plume grass (Erianthus gigantea), and (5) open water with scattered buttonbush (Cephalanthus occidentalis) and cypress trees. A third bay in Telfair County, Georgia, which showed signs of being burned about 20 years earlier, contained no trees but an almost pure stand of maidencane and several species of water lilies (Wharton 1978).

Few studies of the primary productivity of these diverse wetlands have been conducted. Schalles (1979) described the vegetation of Thunder Bay on the Savannah River Plant in Barnwell County, South Carolina, as having an interior herbaceous community dominated by maidencane and cutgrass (Leersia spp.), and a deeper central area of water lilies and water shield (Brasenia schreiberi). Root materials dominated the biotic structure of the ponded area with an average dry weight standing crop of 780 g/m^2. Root/shoot ratios were high and averaged about 8, with a range between 4 and 13.5. Total net primary production of the macrophytes averaged about 260 $g/m^2/yr$ dry weight.

3.2 ANIMAL COMMUNITY COMPOSITION

Pocosin Fauna

Pocosin communities are invaluable to the welfare of certain animal species in some regions because they provide the only habitat available. Although few or no species of animals are known to be dependent on pocosins per se, a basic problem may be that pocosin dependents have not been identified because only limited formal studies have been conducted in these shrub bog habitats. The finding that certain subspecies (e.g., the Dismal Swamp southeastern shrew, Sorex longirostris fisheri; Cooper et al. 1977) are endemics in particular pocosin areas is indicative that these specialized habitats may be critical for many species.

Another problem in recognizing endemic species may be confusion in taxonomic classification. For example, the Dismal Swamp short-tailed shrew (Blarina telmalestes) was described as a distinct species by Merriam (1895) and recognized as such by Hamilton (1943). Later general accounts (e.g., Blair et al. 1968; Burt and Grossenheider 1976) include the Dismal Swamp short-tailed shrew within the species Blarina brevicauda, but the taxonomic status is still controversial.

Whether or not true endemic species actually exist, the apparent lack or limitation of such endemism may merely be a function of insufficient research. This seems to be the message of Wilbur (1981), who indicated that a thorough literature search in ecological journals revealed little on pocosin fauna. This dearth of such fundamental information as formal lists or basic life history studies indicates a need for primary level studies of animals in these areas.

Although no animal species has yet been recognized as a true endemic of pocosins, Wilbur (1981) stated that the pine barrens treefrog (Hyla andersoni; Figure 22) might be considered to be a vertebrate "pocosin endemic." He permitted, however, the widest possible definition of a pocosin. In fact, the potential occurrence of pine barrens treefrogs in non-pocosin habitats (Martof et al. 1980; Tardell et al. 1981) and in geographic regions outside pocosin areas (Conant 1975) make this species only marginally qualified as an endemic. Nevertheless, pine barrens treefrogs can firmly be declared as characteristic of and indigenous to pocosin shrub bogs as well as to similar habitats in other areas.

Another vertebrate species characteristically found in pocosins where such habitat is within its geographic range is the spotted turtle (Clemmys guttata, Wilbur 1981). Both spotted turtles and pine barrens treefrogs thrive in the temporary, shallow ponds (Ernst and Barbour 1972; Martof et al. 1980) found on many pocosin sites. Presumably, any reptile or amphibian species whose geographic range encompasses pocosins, at least as transients, would not be excluded from species lists, unless some feature of its natural history (such as dependence on flowing water or sandy, arid conditions) precluded its presence. The same would presumably be true for small mammals. Again, the paucity of research on this facet of pocosin ecology severely limits our understanding of the true situation.

Many bird species in the region feed or nest in tall evergreen shrub bogs as readily as in other similar habitats. Monschein (1981) listed bobwhite quail (Colinus virginianus), mourning dove (Zenaida macroura), and American woodcock (Scolopax [formerly Philohela] minor) as utilizing pocosins to some extent. Bobwhite quail and dove are able to subsist under agricultural regimes whereas woodcock do not fare as well. Therefore woodcocks probably benefit most from pocosins because of the destruction and elimination of other suitable habitats. Robinson and Barkalow (1979) reported that the development of an edge habitat and herbaceous vegetation in pocosins converted to pine plantations enhanced bobwhite quail populations at least initially. Waterfowl, of course, utilize lakes associated with pocosins during migratory activities, but, as far as is known, to no greater extent than other lakes of a region. Lake Mattamusket and Pungo Lake within the extensive pocosin area of the Albemarle-Pamlico peninsula in North Carolina are established waterfowl refuge areas (Ash et al., in press). Potter (1982) reported 83 species of wintering birds in pocosins, including both shrub areas and areas with trees in Dare County, North Carolina. She concluded that the species were those expected to be found during winter in other parts of North Carolina's lower Coastal Plain.

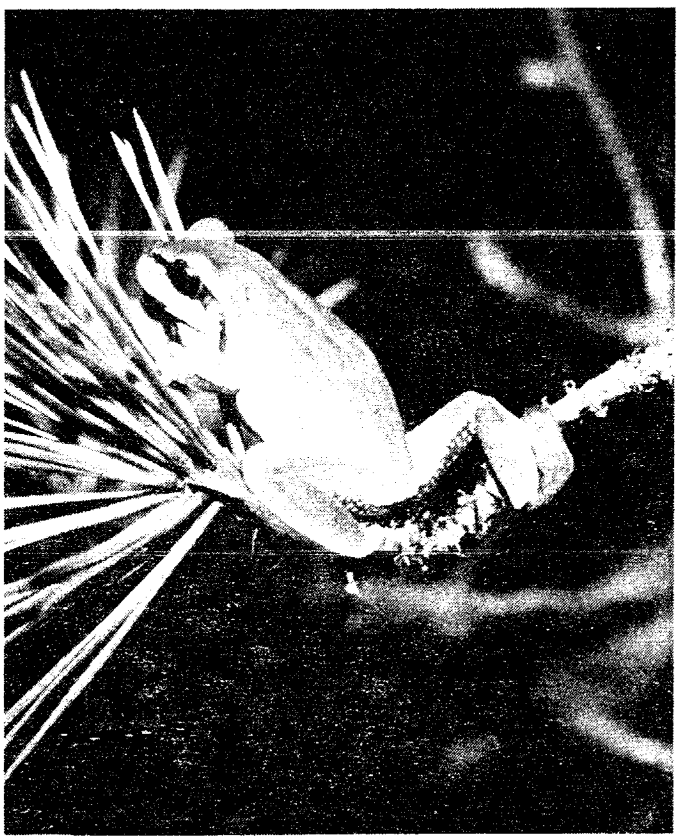


Figure 22. The pine barrens treefrog (Hyla andersoni), an amphibian species indigenous to pocosin habitats. (Photograph by Trip Lamb, University of Georgia.)

Permanent aquatic sites associated with pocosins have species of fishes typical to the region, although no species has been classified as a pocosin endemic. Monschein (1981) listed nine species of game fishes commonly found in such aquatic habitats, including two pickerel (Esox spp.), yellow perch (Perca flavescens), and several sunfishes (Centrarchidae).

Three small game mammals (marsh rabbit, Sylvilagus palustris; cottontail, S. floridanus; and gray squirrel, Sciurius carolinensis) are found in pocosins (Monschein 1981), but only the marsh rabbit can be considered characteristic. Cottontails and gray squirrels are usually associated with habitats marginal to pocosins rather than being found throughout the shrub bog communities.

Among the mammals, the black bear (Ursus americanus) is considered to be characteristic of pocosins in parts of North Carolina (Figure 23). This relationship is partially one of default in that few of the other remaining natural habitats in the region are extensive enough to support bears (Monschein 1981). Monschein estimated that 750 to 1000 black bears are left in the region of eastern North Carolina. Most of these are found in pocosins, presumably indicating the importance of the shrub bog habitat to this species regardless of the condition of surrounding habitats. The Great Dismal Swamp National Wildlife Refuge and associated areas are the last refuge of the black bear in the Virginia Coastal Plain (Rose 1981). The largest remaining population of the bobcat (Lynx rufus) in that region is probably also located there (Rose 1981).

White-tailed deer (Odocoileus virginianus) inhabit pocosins, although their population densities are far below those in certain other natural habitats of the region. For example, 6 deer/mi^2 are found in pocosins compared with 18/mi^2 along pocosin borders and up to 40/mi^2 in bottomland hardwood forests in the coastal region (Monschein 1981). This may be a function of limited amounts of available deer browse plants in pocosins. Most of the regional furbearing mammals are also found in pocosins (Monschein 1981). Bobcat, gray fox (Urocyon cinereoargneteus), raccoon (Procyon lotor), and opossum (Didelphis marsupialis) are found throughout the shrub bog community, whereas river otter (Lutra canadensis), mink (Mustela vison), and muskrat (Ondatra zibethicus) are restricted to suitable aquatic areas within pocosins.

The most likely endemic fauna to pocosins are to be found among invertebrate species that have parasitic or mutualistic relationships with indigenous plant species. Two lepidopteran species -- a swallowtail (Papilio palamedes) and Hessel's hairstreak (Mitoura hesseli) -- are dependent as larvae on particular plant species (red bay and Atlantic white cedar, respectively) characteristically associated with pocosins (Wilbur 1981), although both tree species are also found elsewhere. Intensive studies of particular species of plants that are indigenous to and practically restricted to pocosin-type habitats might reveal dependencies that restrict certain animal species to pocosin areas. Further studies are needed to address this issue.

Figure 23. The black bear (Ursus americanus), a major game species dependent on pocosin habitat in the lower Coastal Plain of North Carolina. (Photograph by T. R. Smith, University of Tennessee.)

A final consideration is that sufficient research might reveal that pocosins are key habitats for certain assemblages of animals. That is, whereas any given species might be expected to be found in other habitat types, the community makeup of animal species may be unique to pocosins. Such possibilities can only be investigated by thorough faunal surveys of these ecosystems throughout their range.

Carolina Bay Fauna

Carolina bays are vital focal points in the life histories of a variety of non-aquatic vertebrate and invertebrate species. Although larger Carolina bays have resident fish populations of several species (Frey 1951a; Bailey and Frey 1958), it is likely that the majority do not have permanent fish inhabitants because of their often transitory aquatic status. Of more than 150 Carolina bays on the Savannah River Plant in South Carolina (Shields et al. 1980), fewer than 10% are known to have permanent populations of fish, although overwash from neighboring swamps or streams may re-establish the ichthyofauna of previously dry basins. The situation is different in some of the larger bay lakes (Frey 1948a) that are never threatened by drought.

The most thorough fish studies have been conducted on several Carolina bays in North Carolina, revealing the presence of 8 to 17 species in each of five bays and 25 in a sixth (Lake Waccamaw) (Frey 1951a). Four of the species from Lake Waccamaw, which covers more than 3200 ha (approximately 8000 acres), were originally reported as endemic to this particular Carolina bay (Fowler 1942; Hubbs and

Raney 1946). The species are the Waccamaw minnow (Notropis waccamanus), the Waccamaw killifish (Fundulus waccamensis), the Waccamaw glassminnow (Menidia extensa), and the Waccamaw darter (Etheostoma perlongum).

Of these species, the endemic status has remained intact and unquestioned for the glassminnow and the darter (Lee et al. 1980). The Waccamaw killifish may also be endemic to Lake Waccamaw if a recent sample of the species reported from Phelps Lake (which is located within a pocosin area in North Carolina) is an introduction and it does not occur there naturally. The Waccamaw minnow, originally reported by Fowler (1942) as endemic to Lake Waccamaw, was later considered to be a variation of N. petersoni (Hubbs and Raney 1946; Frey 1951a), a wide-ranging minnow species. Nonetheless, at least two, possibly three, fish species are natural endemics of this particular Carolina bay. Perhaps because of the fluctuating water levels and the potential for complete drying, ichthyologists have not focused on these habitats as study sites. Therefore, although fish populations may occur in many bays for temporary periods (sometimes up to several years), few intensive studies have been made.

Lake Waccamaw is further recognized as a unique habitat in having three endemic species of mollusks. These are the Waccamaw spike (Elliptio waccamawensis), the Waccamaw mucket (Lampsilis radiata), and the Waccamaw lance (Elliptio sp., not yet officially described), all of which are known only from Lake Waccamaw (Fuller 1977). As with the aforementioned fish species, however, the mollusks are endemic to the particular lake, not to Carolina bays as a habitat.

Although fishes are not a dominant feature in most bays, secondary productivity may still be high. The use of bays by vertebrates is sometimes astonishing (Table 9), as revealed by the high number of semi-aquatic animals migrating to or from the water (Figure 24). Rainbow Bay (on the Savannah River Plant in South Carolina), which has an aquatic perimeter of less than 450 m (1476 ft), had approximately 10,000 southern leopard frogs (Rana utricularia) moving in or out in 1 year. This is an average of one frog for every 2 cm of lake margin. A similar calculation for Ellenton Bay, which is much larger, indicates that more than one adult mole salamander (Ambystoma talpoideum) per 20 cm (8 inches) of perimeter enters the lake for breeding purposes each winter (Patterson 1978) and as many as 11,000 recently metamorphosed individuals may exit during 1 week. These 11,000 salamanders are equivalent to 1/11 cm of aquatic perimeter and a total biomass of 70 kg that emigrated from a single Carolina bay in 1 year.

The abundance of amphibians even in Carolina bays altered by agricultural, forest management, or construction activities (e.g., Sun Bay, Table 9; Lost Lake, Bennett et al. 1979) may be higher than expected. In 1979, more than 500 ornate chorus frogs (Pseudacris ornata), 5,000 southern leopard frogs, and 500 mole salamanders entered or left Sun Bay, an area on the Savannah River Plant of less than 1 ha (2.5 acres) drained by construction activity in the previous year. Similarly, Lost Lake on the Savannah River Plant has undergone human alterations in the form of agricultural impacts prior to the 1950s and the later release of industrial products into the lake (Bennett et al. 1979). Half of this bay is now bordered by managed pine plantations. Nonetheless, extrapolation of captures by intermittent fencing and pitfall traps to the entire portion of the lake surrounded by the pine plantations yields an estimate of more than 5,000 southern toads (Bufo terrestris), 2,000 mole salamanders and 1,000 spadefoot toads (Scaphiopus holbrooki) that left or entered Lost Lake during a single summer.

These numbers provide convincing evidence that the Carolina bays are important natural habitats for many species, some of which may have a high resiliency to environmental disturbance. This does not imply that extensive municipal or agricultural development of such sites would not result in the eventual demise of the amphibian populations. Controlled, quantitative studies of such impacts have not been conducted and are badly needed to make suitable assessments.

Table 9. Secondary productivity associated with Carolina bay habitats is revealed by the level of utilization by small terrestrial vertebrates. Numbers indicate selected vertebrate species captured (original and recaptured) in drift fences with pitfall traps at Rainbow Bay and Sun Bay, Savannah River Plant, SC, for 1 year, March 1979 – March 1980. (Adapted from Gibbons and Semlitsch 1982.)

Species	Rainbow Bay				Sun Bay			
	Entering		Exiting		Entering		Exiting	
	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.
Class Amphibia								
Order Caudata								
Ambystoma talpoideum	1,750	154	449	3,856	6,028	0	938	0
Ambystoma t. tigrinum	129	46	42	992	57	1	4	1
Notophthalmus v. viridescens	1,625	968	609	15,013	3,452	5	2,100	23
Total of all salamanders (9 species)	3,953	1,201	1,212	19,874	9,595	6	3,087	24
Order Anura								
Scaphiopus h. holbrooki	69	33	39	34	1,803	134	483	58
Bufo terrestris	424	644	79	689	580	375	98	622
Hyla c. crucifer	346	212	205	1,329	594	12	239	50
Pseudacris ornata	235	28	89	1,158	392	9	79	18
Gastrophryne carolinensis	1,122	18	418	15	887	1	420	0
Rana clamitans	27	30	19	1,136	27	35	1	7
Rana utricularia	699	2,024	610	52,287	154	29	24	7
Total of all frogs (16 species)	3,197	3,053	1,569	57,106	4,486	680	1,355	767
Class Reptilia								
Order Chelonia								
Kinosternon s. subrubrum	29	6	25	6	49	59	14	11
Deirochelys r. reticularia	8	9	10	2	14	14	4	1
Total of all turtles (6 species)	43	16	39	9	70	74	19	14

(continued)

Table 9. Concluded.

Species	Rainbow Bay				Sun Bay			
	Entering		Exiting		Entering		Exiting	
	Adult	Juv.	Adult	Juv.	Adult	Juv.	Adult	Juv.
Order Squamata								
Suborder Sauria								
Anolis c. carolinensis	26	2	19	2	5	0	12	0
Sceloporus u. undulatus	18	1	8	3	9	3	5	6
Cnemidophorus s. sexlineatus	2	2	1	0	19	7	19	2
Total of all lizards (9 species)	53	7	43	5	36	11	40	9
Suborder Ophidia								
Storeria o. occipitomaculata	26	1	37	0	4	0	2	0
Diadophis p. punctatus	7	2	10	0	7	1	15	3
Tantilla coronata	17	0	11	0	42	0	46	0
Total of all snakes (19 species)	92	7	88	2	68	5	85	5
Class Mammalia								
Blarina brevicauda	68	1	40	0	26	0	20	0
Reithrodontomys h. humulis	16	0	146	8	1	0	0	0
Sigmodon hispidus	7	0	14	0	5	0	18	0
Total of all mammals (13 species)	168	3	251	9	76	1	63	1
Total of all species	7,506	4,287	3,202	77,005	14,331	777	4,649	820

Although amphibians are the prevalent terrestrial vertebrate species utilizing Carolina bays (Patterson 1978; Bennett et al. 1979; Semlitsch 1980) and the major contributors to secondary productivity in such communities, other vertebrates often depend on Carolina bays. Indigenous reptiles include the American alligator (Alligator mississippiensis) (Figure 25) and several species of aquatic turtles (Table 9, Figure 26; Gibbons 1970) and snakes (Table 9; Gibbons et al. 1977). Though quantitative data are unavailable, large animals like deer, raccoons, and skunks may use bays for water or feeding sites. In sandhill regions of the Carolinas, various aquatic birds such as egrets, coots, and migratory waterfowl use bays during part of the year. In areas with standing water and mature trees with cavities for nesting sites, as around the perimeter of some Carolina bays, wood ducks (Aix sponsa) may also be found. Again, quantitative estimates are lacking, but personal observations and those of associates indicate the presence of these animals in most water-containing Carolina bays that have been studied on the Savannah River Plant in South Carolina.

Quantitative data are available for many small mammals using the periphery of Carolina bays (Table 9). Though shrews (Blarina brevicauda and Sorex longirostris) and small rodents (Sigmodon hispidus, Peromyscus gossypinus, and Microtus pinetorum) may be abundant, only certain species, e.g., the rice rat

Figure 24. A drift fence with pitfall traps at Ellenton Bay, SC, the most thoroughly studied Carolina bay from a faunal standpoint. See text for description of technique.

(Oryzomys palustris), are actually confined to marshy areas. Many small mammals captured by drift fences and pitfall traps (Figure 24; Gibbons and Semlitsch 1982) around Carolina bays are equally abundant in strictly terrestrial habitats in the region (Briese and Smith 1974; Brown 1980).

While numbers of individuals of certain small terrestrial or semi-aquatic vertebrate species are extremely high, no species are known to be endemic to any particular Carolina bay or to the habitat type. This is due in part to the highly transient nature of most species that rely on Carolina bay depressions as aquatic sites.

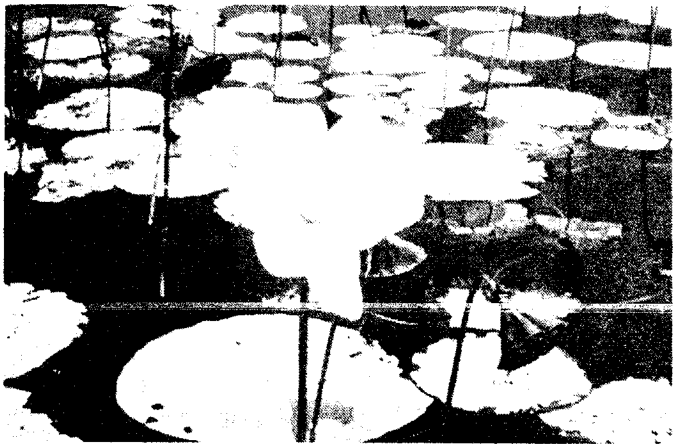
Total animal biomass often cannot be ascertained because obtaining field weights is difficult. Approximations for some species are possible on the basis of weight-length relationships. The overland movement of juvenile and adult mole salamanders at Ellenton Bay in 1 year (1981) was estimated at more than 60 kg (132 lb). Based on presumably an exceptionally high survivorship in 1979, about 30 kg (66 lb) of southern leopard frogs, predominantly juveniles, left Rainbow Bay.

The total biomass of all amphibians utilizing a Carolina bay habitat is more difficult to estimate. However, based on the length-weight relationships and abundances of five dominant species typically found in Carolina bays on the Savannah River Plant in South Carolina [redspotted newts (Notophthalmus viridescens), southern toads, mole salamanders, southern leopard frogs, and spadefoot toads], it was estimated that animals constituting a biomass of several hundred kg moved between land and water in a typical year. The average distance traveled away from the aquatic habitat by one of these species (the mole salamander) is about 200 m (660 ft) (Semlitsch 1981b), which would represent an estimated density of 1.7 kg/ha (9.2 lb/acre) of adults and juveniles around Rainbow Bay in 1981. Such estimates for the Southeastern United States are not surprising when considering the estimates (~1.8 kg/ha or 9.8 lb/acre) of Burton and Likens (1975) for terrestrial salamanders at the Hubbard Brook Experimental Station in New Hampshire. The estimates for the Savannah River Plant are extremely conservative and may represent absolute minimal levels for most Carolina bays.

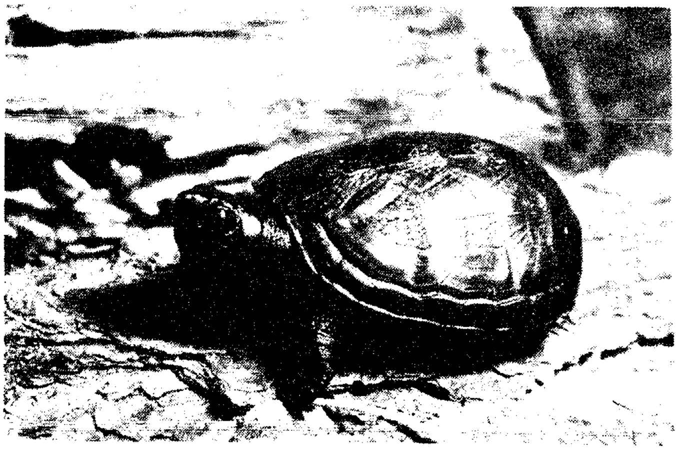
Figure 25. A "gator hole," indicating how a single species, the American alligator (Alligator mississippiensis), can influence the ecology of a Carolina bay during a drought. This subhabitat in the depression of Ellenton Bay on the Savannah River Plant in South Carolina is approximately 1 m (3 ft) deeper than the surrounding area and is 2 m (6 ft) deep during most years, when the remainder of the bay (about 10 ha or 25 acres) is 0.5 to 1 m (1.5 to 3 ft) deep. Larval salamanders, tadpoles and a single species of fish (Gambusia affinis) are the only vertebrates remaining in the "gator hole."

3.3 ENDANGERED AND THREATENED SPECIES

Although pocosins or Carolina bays cannot be classed as essential to the welfare of any species throughout its range, these ecosystems can be vital in certain regional situations, sometimes because they are the only available refuge areas for wildlife species. No endangered species of plant or animal is endemic to pocosins or Carolina bays. However, many species recognized as threatened or endangered at State or Federal levels (e.g., the American alligator and pine barrens treefrog) use these habitats, even though the use is not exclusive except in restricted areas. Likewise, many plant species indigenous to pocosins [e.g., white wicky (Kalmia cuneata) and rough-leaf loosestrife (Lysimachia asperulaefolia)] may be uncommon and in danger (Richardson 1982) although legal endangered status is not recognized. With the present limited level of biological information available about pocosins and Carolina bays, neither ecosystem can be considered the sole suitable habitat available for any plant or animal, but more thorough study may reveal unexpected dependencies of certain species to these areas.



Water lily (Nelumbo lutea)



Mud turtle (Kinosternon subrubrum)

Figure 26. Species adapted to fluctuating water levels characteristic of Carolina bays.

3.4 POCOSINS AND CAROLINA BAYS AS REFUGE AREAS

Few data have been collected on the use of shrub bog communities as refuge areas by animals. The importance of pocosins as refuge habitats in the man-influenced Coastal Plain region was noted in a general manner by Wilbur (1981) and specifically for black bears by Monschein (1981). The Dismal Swamp is a last refuge for bears in coastal Virginia (Rose 1981). Pocosins may be used as last resort refuges because they represent the only extensive, unexploited habitat in certain areas (Wilbur 1981). Thus, they serve as sanctuaries because of the limited access by man and not because they are particularly desirable habitats from the standpoint of community diversity or productivity.

Carolina bays are refuges in a different manner although they are characteristically smaller, disconnected habitats that cannot serve as effective retreats for larger animals such as black bears. Nevertheless, for smaller-sized species, particular bays may provide critical aquatic habitat during droughts. Larger Carolina bays can become refuge areas for some animals (e.g., turtles) that normally reside in smaller bays in the vicinity. During periods of drought, the smaller bays may dry up, but the larger ones may continue to retain water to which mobile species can migrate. In urban or intensively farmed areas, many species of amphibians, reptiles, and small mammals unquestionably have clumped distribution patterns, with the areas of highest densities being associated with Carolina bays. This phenomenon is comparable to that of pocosins in that other communities (e.g., bottomland hardwood) might be more desirable, but their elimination leaves the Carolina bay as the most suitable remaining habitat.

Although qualitative observations have revealed the importance of these wetlands as refuges under various circumstances, no quantitative assessment of the extent to which pocosins or Carolina bays serve as refuge areas for animals has been made. Such studies would be particularly valuable in establishing how important these particular habitats are to wildlife confronted with urban, agricultural, or other land-use practices that are rapidly eliminating most natural habitats including these potential refuge areas.

3.5 TROPHIC RELATIONSHIPS IN POCOSIN AND CAROLINA BAY ECOSYSTEMS

No quantitative studies have been carried out on food web dynamics or the interactions among trophic levels of shrub bog communities. Certain conclusions, however, can be drawn from general ecological information about the dominant plants and animals inhabiting the communities and the nutrient conditions that are known to exist. One feature of evergreen shrub vegetation is sclerophylly, a characteristic resulting in highly cutinized, protected leaves that are not suitable for most grazing herbivores, either insect or vertebrate. Although data have not been collected on this subject, our prediction is that the shrub bog terrestrial plants are highly conservative in regard to nutrient loss (through grazing or deciduousness). Therefore, the energy flow from primary producer to primary consumer is probably extremely low. Consequently, secondary and tertiary consumers should be accordingly reduced. A comparative difference between evergreen shrub bog communities and surrounding, high productivity habitats should be that the terrestrial animals in the food chain would have a much lower biomass in relationship to the total standing crop biomass. Secondary productivity and turnover in an evergreen shrub bog community would be appreciably lower per standing crop of terrestrial vegetation than would be true for most other Atlantic Coastal Plain communities. This idea is testable by standard field techniques and studies that would provide a better understanding of trophic dynamics in these systems.

The insectivorous plants of these acidic peat bogs present a fascinating module for studies of trophic dynamics and evolution. Insectivory is apparently an adaptation to the low availability of nutrients in a peat substrate and is a mechanism for obtaining a nutrient supply to augment that provided through the soil. Two questions arise from a nutrient dynamics standpoint: (1) What proportion of a plant's nutrients are provided by insects? (2) What proportion of the consumed insects have obtained their own resources from outside of the pocosin or Carolina bay community? These questions deserve attention by ecologists interested in the biology of insectivorous plants and their value in the shrub bog community.

The most poorly studied aspect of trophic dynamics in these systems is the aquatic community. Aquatic plants and animals are found in pocosins and Carolina bays, and in the latter there is evidence that the semi-aquatic, temporary species sometimes occur in remarkable numbers. A primary question, unanswered by present information, is what proportion of the animal biomass inhabiting the aquatic portion of a Carolina bay or pocosin represents energy and resources obtained <u>within</u> the shrub bog ecosystem? Secondly, what is the turnover rate of aquatic plant biomass relative to its standing crop and also relative to the turnover rate of the terrestrial plant portion of the community? Information on these and similar aspects of these communities would enhance our understanding of the biology of these complex ecosystems and could lead toward greater predictability of how particular environmental perturbations might affect these ecosystems.

Trophic dynamics is a critical, essentially unstudied, aspect of the biology of shrub bog communities. Food webs and trophic interaction are complex biological phenomena that are seldom quantitatively known for an entire community. Therefore, it is not surprising that the trophic dynamics of shrub communities are poorly known. This area deserves special attention at this time to develop our understanding of the trophic relationships within these communities and between them and adjoining ecosystems. Shrub bogs are potentially linked with human food chains through various waterfowl and wildlife species. This could be particularly important in areas where direct chemical contamination of the environment through industry, pesticides, or herbicides occurs. Such contamination could result in transfer to humans of substances that are toxic or harmful. In addition, movement of contaminants to adjacent ecosystems, such as estuaries, could result in uptake of toxic substances by other species, such as fish or shellfish, consumed by humans.

CHAPTER 4

INFLUENCE OF HUMAN ACTIVITIES ON POCOSINS AND CAROLINA BAYS

4.1 HISTORICAL PERSPECTIVES

Pocosins and Carolina bays have been under the influence of humans for several hundred years, and it is difficult in many instances to establish what a particular habitat would be like, had there been no human intervention. The earliest effects came as a result of burning by Indians (Wells and Whitford 1976), although it is obvious that natural fires would have created similar situations. The usual events associated with fire in these habitats came as a consequence of heavy peat build-up, a dry period, and then a sweeping fire that burned not only vegetation but the peat soil itself. Thus, many pocosin ecosystems, including the Carolina bays, may have much shallower organic deposits today than at some point in the past. This consequence of fire must be taken into account in evaluating previous and future studies in regard to the level of the peat deposit and what interpretations should be given to it.

The next major impact on all such habitats came in the early development period of the Eastern United States as a result of widespread timbering operations. Large trees in the pocosin expanses, particularly in North Carolina, were removed during this time and have not been replaced. Therefore, it is not known how much of what is now shrub bog was once sparsely or densely populated by larger trees. The same would be true for some Carolina bays in which tree removal around the margins could have taken place more than 200 years ago. Timber removal has undoubtedly had a major impact on the character of these communities, particularly the pocosins, and its total influence may never be thoroughly resolved.

Because of its accessibility, one of the first areas that included pocosin vegetation to be drained and logged was associated with the Great Dismal Swamp (Lilly 1981b). The Virginia Assembly in 1764 chartered the Dismal Swamp Land Company, of which George Washington was a member, to drain 16,188 ha (40,000 acres) of rich timberland in the swamp. To facilitate logging, a canal (the Washington Ditch) was dug across swamp land to Lake Drummond (Lilly 1981b). Plans by the company to farm the swamp after timbering failed.

Although several other shallow swamp lands were drained for agriculture in the late 1700's, a major boom in development came after the Revolutionary War, spurred by interest in cultivating rice and in logging cypress and by the attitude that draining swamp lands would reduce malaria (Lilly 1981b). Major draining, logging, and clearing took place in the Dismal Swamp, at Lake Phelps, and elsewhere on the Albemarle-Pamlico peninsula, including Lake Mattamuskeet, Alligator Lake, and Pungo Lake, and in the Open Ground Swamp in Carteret County, North Carolina. Numerous land ownership companies were established for development purposes. However, by the late 1800's the failure of many of these organic soils to sustain high agricultural yields was becoming apparent, although plant nutrition was not well understood. Most of these efforts to develop pocosins for agriculture subsequently failed without the input of commercial fertilizers, and by 1880 emphasis had shifted from agriculture to forestry (Lilly 1981b).

The logging history of the Green Swamp in Brunswick County, North Carolina, is typical of that of many pocosin areas. According to Kologiski (1977), logging began shortly after 1861 when the Green Swamp Company purchased a large portion of the property and selectively cut large cypress trees to be processed into shingles. The timber resources of the Green Swamp were described as tremendous in an 1870 survey in which cypress, gum, white cedar, and yellow pine were listed as dominant species. Between 1870 and the early 1900's, much of the property changed ownership several times. In 1906 it was purchased by the Waccamaw Lumber Company, which cut most of the forested areas of the swamp during the next 34 years. Large areas of brush and tree remnants were left from the lumbering activities and these waste areas were commonly burned. Growth of fire-tolerant species such as titi, zenobia, and pond pine was therefore favored in the successional recovery of the disturbed pocosin and swamp areas.

Drainage of the Green Swamp had begun by 1937 when Riegel Paper Corporation purchased much of the land. Secondary roads and additional drainage ditches were constructed, and an active land management program was developed that included wild fire control, controlled burning, road and canal building, and reforestation (Kologiski 1977). By clearing and draining, areas of the Green Swamp dominated by pond pine are presently being converted to pine plantations. In 1977, approximately 4800 ha (12,000 acres) per year were being planted with loblolly pine.

To complete the history of the Green Swamp, it should be noted that in 1974 the Secretary of the Interior designated it as a Natural Landmark as prescribed by the National Park Service. In 1977, 5540 ha (13,850 acres) were deeded to the Nature Conservancy by the Federal Paper Board Company, Inc., which purchased land from Riegel Paper Corporation in 1972 and still retains ownership of part of the area. Other portions are still being managed as pine plantations.

4.2 CURRENT LAND MANAGEMENT PRACTICES AND PERTURBATIONS

Forestry

During the last half-century, increasing acreages of pocosins and coastal swamp lands have been managed for wood and wood products. Based on a survey of coastal tax office maps, industrial use maps and State maps, Richardson et al. (1981) estimated 44% of North Carolina pocosins to have been under ownership by major timber companies in 1980 (Figure 27). The increased use of these wetlands may be attributed to rising costs associated with upland pine management, an increasing demand for wood products, and a decline in the commercial forest land base because of urbanization and industrial land use (Jones 1981). Because lumbered forest land of the Coastal Plain was relatively cheap, paper companies purchased large tracts from lumber companies and converted them to pine plantations (Lilly 1981b). This more intensive form of land management required ditching and canal construction. By the 1960's most pocosins were crisscrossed with networks of drainage ditches (Ash et al., in press; Figure 28) and only areas of deep organic soils unsuitable for loblolly pines were left unmodified.

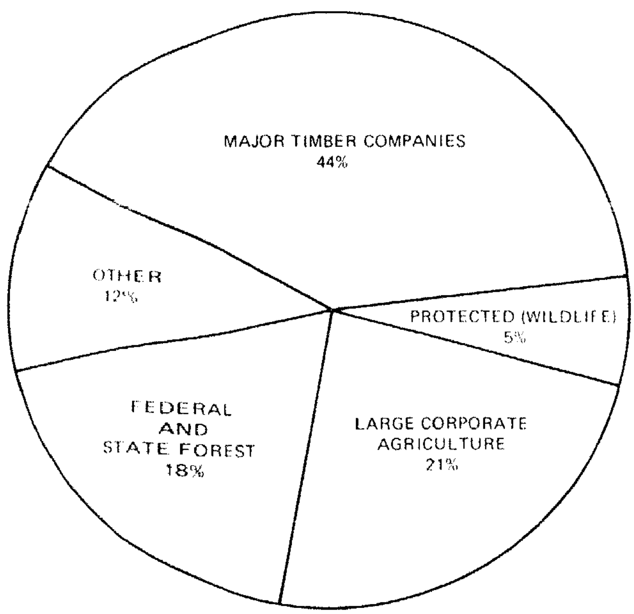
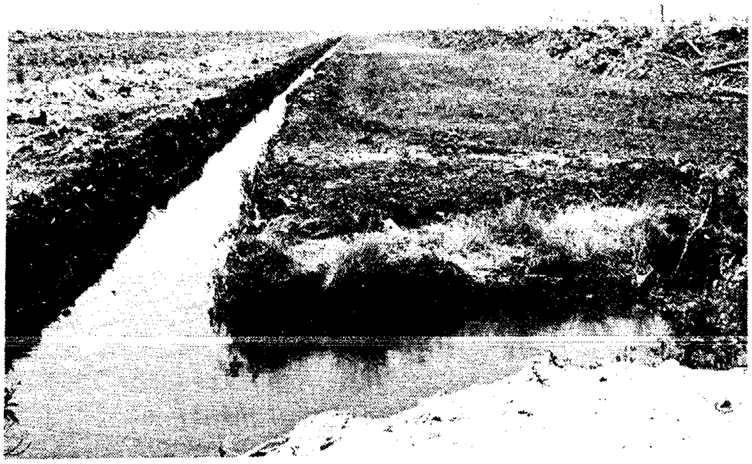


Figure 27. General pattern of ownership of pocosin habitats of North Carolina. (Redrawn from Richardson et al. 1981, in Pocosin Wetlands: An Integrated Analysis of Coastal Plain Freshwater Bogs in North Carolina, ed. by C. J. Richardson. Copyright 1981 by Hutchinson Ross Publ. Co., Stroudsburg, PA. Reprinted by permission of the publisher.)

Newly constructed ditch (photograph courtesy of U. S. Fish and Wildlife Service).



Field ditch emptying into collector ditch (photograph by Emilie S. Kane, East Carolina University).

Electric pump station in eastern Hyde County, NC (photograph by Charles B. McDonald, East Carolina University).

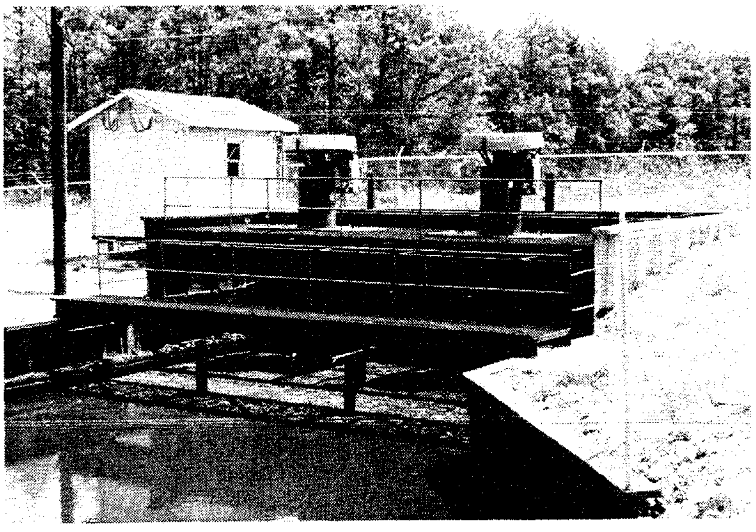


Figure 28. Pocosin drainage for agricultural or forestry management.

Agriculture

A major determinant of present-day habitat character that occurred during and subsequent to timber removal has been the agricultural development of many parts of the Coastal Plain. The low nutrient soils characteristic of pocosins and Carolina bays, as well as much of the region as a whole, resulted in marginally successful croplands that required extensive clearing, burning, and draining. These activities greatly altered many of the shrub bog ecosystems. Farming required the removal of much of the shrub vegetation (along with the trees) in many areas. This resulted in a permanent change that is reflected in the plant communities present today. Agricultural activity has been centered in the Albemarle-Pamlico peninsula where three corporate farms have acquired over 160,000 ha (400,000 acres; Carter 1975 in Ash et al., in press). These farming activities converted pocosins and cut-over pine plantations to row crops. Since such farming involves repeated use of heavy machinery, drainage had to be far better than required for pine plantations.

Large-scale drainage with the construction of major ditches and canals that traverse much of the pocosin ecosystem is therefore a required feature of such wetland agriculture in the Carolinas (Figure 28). Drainage ditches are also characteristic of a large number of Carolina bays (Figures 29 and 30). In addition, surface vegetation and buried wood must be removed from the pocosin substrates by bulldozing and burning, and the land is commonly graded to an even slope of 0.5% prior to planting (Heath 1975). Thus the actual topography of such habitats may be changed in some instances. The ditches have resulted in surface water alterations by serving as collection points for surficial water and by altering the drainage pattern of standing water of the localized watershed. In areas close to sea level, dikes and pumps may be installed to insure drainage, especially during periods of high rainfall.

Agricultural development of the organic pocosin soils requires the addition of nitrogen, phosphorus, potassium, and copper, along with adjustment of the pH with lime (Ash et al., in press). Subsequently, runoff waters from these developed lands may be altered. Kirby-Smith and Barber (1979) reported that turbidity increased 10 to 20 times, pH increased toward a neutral level, and nutrient concentrations in the ditches were 5 to 10 times higher in run-off from a pocosin converted to a pasture than from a natural pocosin stream. Little is known about the potential movement of pesticides from developed pocosin land in run-off water to adjacent aquatic habitats. However, Ash et al. (in press) pointed out that most nonionic pesticides are strongly adsorbed in soils of high organic content and may

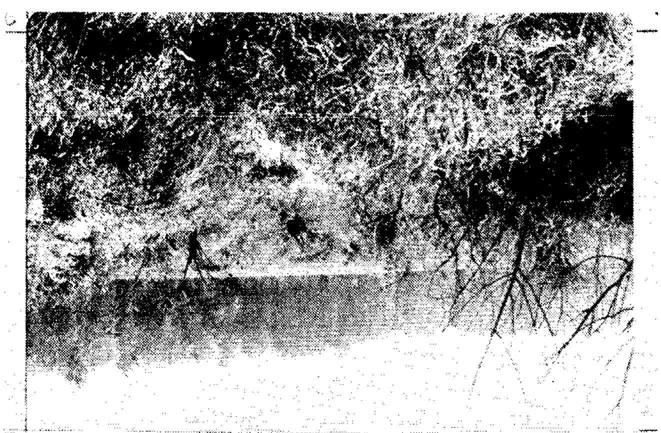


Figure 29. Two views of major drought conditions in a ditched Carolina bay (Dry Bay, Savannah River Plant, SC) in November 1981. Water level is normally more than 1 m higher.

be removed chiefly by erosion rather than by leaching in solution from the substrate. Additional studies of the fates of individual pesticides in these highly organic substrates are required before general statements of their potential impact on receiving waters can be made.

Drainage Systems

Artificial drainage ditches in major pocosin areas lower water tables in the vicinity of the canals, increase runoff rates following precipitation, result in water quality alterations in runoff waters, and concentrate runoff into estuaries, both temporally and spatially (Kuenzler et al. 1977; Kirby-Smith and Barber 1979; Daniel 1981; Ash et al., in press). The high retention of water in porous, organic peat soil typically results in slow but consistent lateral movement of groundwater in a natural pocosin. Therefore, the lowering of the water table that results from the movement of groundwater into drainage canals occurs primarily within a few meters of the canal itself. Surface runoff into drainage canals is greatly affected by development of the surrounding land such that peak runoff rates are earlier and higher than is true of undeveloped lands. In addition, agricultural development slightly increases inorganic nitrogen and sediment load in drainage waters and has statistically significant but slight effects on various water quality features, such as dissolved oxygen, biochemical oxygen demand, and pH (Skaggs et al. 1980).

Ellenton, Barnwell County, SC

Figure 30. Aerial view of Carolina bay habitats in an agricultural region in 1951 before development of the Savannah River Plant. The large bay is Ellenton Bay; the smaller bay was drained by a ditch to provide additional useable land for corn and cotton crops. Arrows indicate location of drainage ditches leading through three Carolina bays into a natural drainage system.

In a natural pocosin, high precipitation periods result in the accumulation of surface water on the flat surface, a gradual absorbtion into the subsurface layer, and a slow lateral, but slightly downhill, movement to lower elevations. This lateral movement is dependent upon the level of the water table and depth of the peat layer, degree of saturation, and state of decomposition of the peat. Lateral conductivity of water in undecomposed peat is as high as 37 m (120 ft)/ day (Boelter and Verry 1977, cited by Daniel 1981) and as low as 0.030 m (0.097 ft)/day in well-decomposed peat (Lohman 1972, cited by Daniel 1981). Even at the highest rates of movement, sheet flow under natural conditions is a moderately slow process that integrates peak precipitation periods so that final entry into an estuary is widespread and temporally consistent, with rate changes being gradual. Ditching results in an immediate runoff response followed by point entries into the estuary rather than a broad, peripheral input into the system. Although runoff is increased during peak flows, runoff amounts during average flow periods are reduced so that the annual runoff in ditch-drained areas is not appreciably different from natural conditions (Daniel 1981).

Many water quality characteristics of runoff into drainage ditches are different from natural stream waters in pocosin habitats (Tables 3a and 3b; Kuenzler et al. 1977; Kirby-Smith and Barber 1979; Richardson et al. 1981, adapted from Barber et al. 1979). In a comparison of three natural streams and four man-made channels flowing through various habitats in Pitt County, North Carolina, Kuenzler et al. (1977) found that channelized streams, compared to natural areas, were higher in conductivity, turbidity, pH, phosphorus concentration, and nitrates. Although the studies were based on the channelization of tertiary streams draining upland areas with loamy and sandy soil, some of the interstream areas were low-lying "with scattered, large pocosins which form the headwaters of many of the streams" (Kuenzler et al. 1977). Therefore, these findings can be applied to artificial ditches draining pocosin ecosystems. In a comparison of a natural stream with ditches flowing through a pocosin that had been converted to agricultural use in Carteret County, North Carolina, Kirby-Smith and Barber (1979; Table 3a) found runoff water in the ditches to be significantly higher in turbidity, pH, phosphates, and nitrates. Ammonia levels were also higher in the channels. Kuenzler et al. (1977) considered water quality differences between channelized and natural streams to be functions of (1) channels being straight and clear so that stream velocity (and turbidity) is increased; (2) channels cutting deeper into the substrate so that inorganic soils are exposed and contribute to increased solution of sodium, calcium, and phosphorus (thus increasing conductivity and pH); and (3) continual flow year-round compared with intermittent flow in natural streams. In addition, channelized streams are more likely to be located in heavily managed areas where soil amendments or other surface additions are prevalent, thus affecting the quality of surface waters as they enter the stream.

In summary, draining ultimately affects the input into estuaries by concentrating peak input periods into narrow time frames and localized points (Copeland and Hodson 1982). Thus, the natural sheet flow that distributes input waters in an equable manner under natural conditions is severely altered. In addition, the water quality is markedly different in several critical features. Thorough studies have not been conducted on how these changes affect estuarine flora and fauna that have evolved under the natural sheet flow conditions. It is not known which water quality characteristics of pocosin runoff will prove to be most influential in the estuaries. Presumably the abnormal decreases in salinity, the raising of pH levels, the increase in siltation, and the increase in key nutrients could all have obvious as well as subtle effects on the estuarine ecosystems, although as Richardson et al. (1981) pointed out, the levels attained in the ditches may be reduced by the time of entry into the estuary.

Localized industrial activities (besides pocosin clearage and mining) such as the Texasgulf phosphate plant at Aurora, North Carolina, may also affect the estuaries bordering the North Carolina pocosins. Effects of pocosin clearage may be indistinguishable from these activities. For example, phosphate levels in the Pamlico Estuary near the Texasgulf plant are already higher than normal for the area (Hobbie 1970, cited by Ash et al., in press). Future research will be necessary to document the important modifications in the plant and animal communities of the estuaries adjacent to pocosin habitats. The economic benefit of additional research efforts is evidenced by the report of Street and McClees (1981) that the coastal fishing industry in North Carolina is more than $300 million annually and could be jeopardized by abnormal inputs of freshwater pocosin runoff.

No quantitative assessment has been made on the extent or the hydrological impact of ditching on Carolina bays. It is apparent, however, from personal observations that the practice was extensive in heavily farmed areas of South Carolina (Figure 30) and that the draining effect was probably major. Carolina bays with large ditches generally dry up and can begin to support terrestrial vegetation while standing water remains in the ditch. How the water table itself responds and how far the influence of the ditch extends laterally are unknown.

Peat Mining

Besides alterations resulting from draining, major environmental impacts have followed in the form of utilization of the substrate itself. A major commercial exploitation of the substrate of shrub bogs in the southeastern Coastal Plain could result from peat mining (Figure 31), an activity that may increase considerably in the future. Peat mining is most likely to be carried out in North Carolina where thousands of acres of pocosin are now owned by agricultural companies, some of which are involved in limited peat mining at this time.

The peat substrates of the pocosins and Carolina bays have formed through decomposition of organic matter for several thousand years in a water-saturated, anaerobic situation. Campbell (1981) described such peat as "young coal" and reported that the peat from First Colony Farms on the Albemarle-Pamlico peninsula of North Carolina has a British thermal unit (Btu) value of 10,189 per pound dry weight and a low sulfur content. It therefore compares favorably with coal (11,500-13,000 Btu/lb) in energy output (Campbell 1981). North Carolina peats generally have a lower layer about 1.2 m (4 ft) thick of brown, decomposed fibrous peat derived from Atlantic white cedar and herbaceous marsh plants (Ingram and Otte 1981a) and an upper layer of similar thickness of black, highly decomposed humic peat derived chiefly from cypress, tupelo, and pocosin vegetation with some white cedar (Otte 1981).

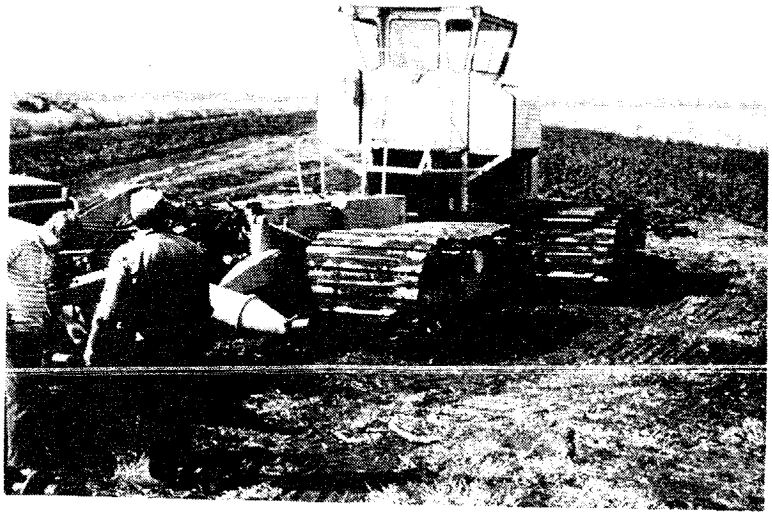
Because of their large size, the peat deposits in the broad interstream pocosins are being most actively developed for mining. The Albemarle-Pamlico peninsula has 932 km^2 (360 mi^2) of peatland, and First Colony Farms alone has over 58,580 ha (145,000 acres) of peat deposits that may be harvested (Campbell 1981). Other large peat deposits occur in the Great Dismal Swamp, the Croatan National Forest, and numerous other interstream pocosins and Carolina bays. With the establishment of a peat-methanol gasification plant in Creswell, North Carolina, the potential use of peat substrates as an energy resource may become more economically attractive.

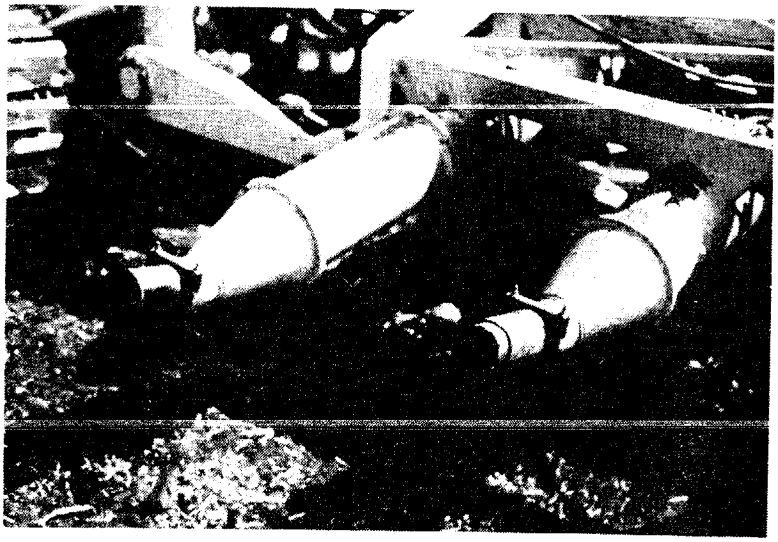
A variety of impacts may result from peat mining in pocosin systems. The land must be drained and cleared as for agricultural purposes, and subsurface wood must be removed, usually to a depth of 40 cm (16 inches). The land is then graded to a uniform slope (1.5%) to enhance drainage (Campbell 1981). Harvesting is conducted either by a mill method in which a thin top layer of peat is worked into small particles, allowed to dry and removed with a vacuum harvester, or by digging out the moist peat to a depth of 40 cm (16 inches) and extruding it into cylinders 8 cm (3.2 inches) in diameter and approximately 30 cm (12 inches) long (Campbell 1981; Figure 31).

The most significant impact of peat harvesting on pocosins is the loss of natural pocosin habitat and the subsequent effects of this habitat attrition on wildlife and natural plant communities. It is unlikely that pocosin communities will recover to the natural shrub bog condition in these areas after mining operations are completed.

A second major effect of peat mining is a lowering of the substrate surface as a result of removal and from natural subsidence that results from carbon loss by oxidation during irreversible drying of the surface peat. Lilly (1981a) reported subsidence rates of 2.7 cm/yr (about 1 inch/yr) for the first 2 years and 0.4 to 1.2 cm/yr (up to 0.5 inch/yr) thereafter in eastern North Carolina. With continual harvesting and subsidence, mineral soil that is at or below sea level may eventually be exposed. In such cases, continual water level management becomes necessary to maintain the land in a productive state. Such conditions may also allow salt water intrusion into freshwater aquifers. The required drying of the surface peats increases the probability of a severe burn. In addition, the dried peat granules may contribute to particulate air pollution when winds sweep across the peat fields and may affect water quality in adjacent aquatic habitats (Ash et al., in press).

No other extensive mining activities are associated with the Carolina bays per se at this time other than in an agricultural sense (Figure 30). Sand quarrying, Peat harvester





Close-up view of peat extruder

Peat pellets after extrusion

Figure 31. Peat mining in First Colony Farms, NC, a pocosin habitat. (Photographs courtesy of U.S. Fish and Wildlife Service.)

in which the sand rim associated with Carolina bays has been utilized, has been a limited enterprise, but has resulted in major habitat alterations in some instances.

4.3 CURRENT OWNERSHIP OF POCOSINS AND CAROLINA BAYS

Of the 907,933 ha (2,243,550 acres) of pocosin habitat mapped in North Carolina by Wilson in 1962, only about 281,000 ha (695,000 acres) remained in a natural state by 1979 (Richardson et al. 1981; Figure 4). Furthermore, Otte (1981) noted that since Richardson's survey, additional large tracts of pocosin have been developed, including areas of the Dismal Swamp peripheral to the Dismal Swamp National Wildlife Refuge, additional areas of the Albemarle-Pamlico peninsula, and many of the Carolina bays in Bladen and Cumberland Counties. Ash et al. (in press) compared the present status of the Green Swamp vegetation with Kologiski's (1977) map based on 1973 aerial photographs. They noted extensive newly converted land, chiefly to loblolly pine plantations.

In North Carolina, 48,000 ha (119,000 acres) of pocosin are receiving some degree of protection, either active or passive (Taggart 1981); however, many of these areas had been drained and logged prior to receiving protected status (Richardson et al. 1981). The acreage that is now protected is a low percentage of the original pocosin land in North Carolina. Taggart (1981) listed the major natural pocosin areas of North Carolina. Among the largest of these are the Holly Shelter Game Land (12,000 ha or 30,000 acres) and the Angola Bay Game Land (8,000 ha or 20,000 acres, both managed by the North Carolina Wildlife Resources Commission; the Croatan National Forest (10,342 ha or 25,284 acres), managed by the U. S. Forest Service; the Hofmann Forest (6,010 ha or 15,025 acres), owned by Champion International Corporation; and the Green Swamp (5,605 ha or 13,850 acres), managed by The Nature Conservancy.

Major timber companies are the largest pocosin landowners, claiming as much as 44% of pocosin wetlands (Figure 27) although the actual percentage of timber company holdings is not known (Richardson et al. 1981). Large corporate farms (or megafarms) own another 21%. The remaining pocosin land is owned by State and Federal government (18%), various forms of protected ownership (5%), and by other land owners (12%), including small, private owners who may be using the land for various purposes (Richardson et al. 1981).

The economic aspects of pocosin management (development and preservation) are addressed by Richardson (1982). As he pointed out, different interest groups may value pocosins quite differently. For example, they may be viewed simultaneously as unique natural refuges (to preservationists), exploitable game lands (to hunters), valuable potential energy resources (to peat mining operations), marginal to productive lands (to foresters and agriculturalists), wastelands (to industry and the uninformed general public), and invaluable ecological resources (to the scientific community). Therefore a consideration of the economic value of these areas requires the impossible assignment of values to nonmarketable commodities such as these natural areas. Present scientific knowledge of the function of these wetland ecosystems and their relationship to other components of the ecology of the mid-Atlantic Coastal Plain is far too limited to allow complete and adequate judgment of the worth and importance of these systems. However, as Richardson (1982) admonished, if immediate consideration is not given to a management approach that combines ecological and ethical concerns with economic values, the long-term stability of the southeastern Coastal Plain may be in jeopardy.

4.4 RECOMMENDATIONS FOR RESEARCH

One of the most informative features of this report has been the revelation of where research efforts are needed to understand the natural shrub bog environments and the potential consequences of man-made alterations to them. The specific research recommendations that could be made would be endless, but certain general information gaps are readily apparent and can be singled out.

Hydrology

The hydrodynamics of pocosin areas have been fairly well established in a general sense, but certain components need more thorough investigation if a complete model of the hydrology of these systems is to be developed. One of the areas needing attention is that of water loss through transpiration. Data on transpiration rates of pocosin areas as affected by vegetation type, soil and water table conditions, precipitation levels, and drainage canals are crucial to completion of a hydrologic model. Evaporation rates under different conditions and at specific localities must also be determined although regional data are already available. Detailed analyses of the impact of drainage canals on water tables and runoff must be pursued in more depth to confirm present models and to answer certain unresolved questions. For example, the rate of lateral movement in peat soils is influenced by several variables such as proximity of ditches, water table level, and level of organics in the soil. Hydrologic responses should be analyzed under a variety of conditions so that the level of predictability about subsurface water movement can be increased.

The hydrology of shrub bogs in Carolina bays has not been thoroughly investigated. Certain aspects should differ from those of pocosins because Carolina bays are discrete units rather than being extensive, continuous systems like many pocosin areas. Little is known about factors that influence surface water levels or the relationships between subsurface water, precipitation, and above-surface water. This report provides some of the limited data available on what influences water levels in Carolina bays. Detailed studies on specific bays are strongly recommended.

Water Quality and Soil Characteristics

Soil composition and characteristics are known for major pocosin areas because of the emphasis on agricultural uses. Only limited soil research has been carried out, however, on Carolina bays or on pocosins outside of the North Carolina areas of peat mining, crop, and tree farming. The collection of basic soil data in shrub bogs throughout the region would be worthwhile in establishing basic environmental information.

Water quality is also known for certain pocosin areas and particular Carolina bays, but collection of basic limnological information would be useful. Of particular importance is knowledge of the sensitivity of natural biotic communities to changes in certain water quality parameters (e.g., pH or phosphate levels) that can be dramatically altered by commercial activities. Research efforts to establish such information should be encouraged. These would include estuarine studies to determine how anadromous fishes and brackish water organisms are affected by subtle water quality changes resulting from runoff through channelized or heavily fertilized pocosin areas.

Biota

The most poorly studied and least understood facet of shrub bog communities of the Atlantic Coastal Plain is the basic biology. Vegetational analyses have been carried out in both habitats, particularly in the pocosins, but plant studies in Carolina bays have been few. Regional analyses of vegetational variation among these and related wetlands with a strong focus on the relationship of vegetation pattern to various environmental features (e.g., soil type, moisture levels, and recent land use history) would provide a fundamental understanding of the range of botanical variation in these habitats. Practically no faunal studies have been made on pocosins as an identifiable habitat and very few in-depth studies have been undertaken of animals in Carolina bays. In fact, the original data from the Savannah River Plant presented in this report are the most extensive quantitative information collected in such habitats. Besides the limited research on basic population phenomena, species diversity and composition, and structural and functional characteristics of the biotic communities, few studies have posed ecological questions related to the qualities and characteristics of shrub bogs: for example, how the community responds, collectively and through its individual species, to the low-nutrient conditions, the low pH, or the annual and seasonal fluctuations in water level.

Fire

The effects and long-term environmental consequences of fire in shrub bog areas are poorly understood even though certain ecological impacts are apparent. Prescribed burning is being used on a more frequent basis to control wildfire danger and to prepare sites for various management activities. Little quantitative information, however, is available on the short- or long-term effects of such fires on vegetational composition and productivity, nutrient releases into the soil or atmosphere, water quality, or rates of peat accumulation. Research in areas where prescribed burning is carried out would provide general information on fire ecology in these ecosystems and give a basis for understanding the influence and importance that natural fires have had on shrub bog communities.

Recommendations

Recommending ecological studies associated with a topic can be open-ended, but the following seem to be essential research efforts that should be undertaken at this time:

1. As a first priority, basic lists, relative population sizes, and extent of utilization by the animal species associated with pocosins and Carolina bays need to be established. The vegetational component of the shrub bog community has been documented (although inadequately) but knowledge of pocosin fauna is exceptionally scanty. Information on Carolina bay fauna is limited in the scientific literature. This fundamental aspect of needed research on shrub bogs should be strongly encouraged and supported by State and Federal agencies that oversee these natural wetlands and by private enterprises that cause an environmental impact to them.

2. Plant ecology of Carolina bays is poorly known. Questions should be asked of whether geographic changes occur in vegetational aspects or how certain variables, such as size of the depression or moisture levels, influence the vegetation. Natural succession of pocosins and Carolina bays is poorly understood both spatially and temporally. Intensive research efforts are recommended to address these botanical issues.

3. The interaction among plants and animals within the shrub bog ecosystem and between that system and other natural ecosystems is a key aspect of having an understanding of the biology of a region. The drift fence studies with small vertebrates on the Savannah River Plant have revealed the unsuspected importance of Carolina bays to transient and resident animal species. Studies in pocosin habitats might reveal a similar importance. Although the basic studies mentioned above are strongly recommended immediately, in-depth and long-term studies of biotic interactions and dependencies should also be initiated.

4. Certain non-biotic forces have a critical influence on the biological character of these ecosystems. Basic research directed toward quantitatively establishing how the timing and intensity of either fire or precipitation influence key community processes such as primary productivity and elemental cycling would be extremely valuable in understanding shrub bog ecosystems.

5. Studies of natural succession in pocosins and Carolina bays would provide a much-needed understanding of the evolution of communities in these ecosystems. Such studies could be carried out through the initiation of long-term research at particular localities, through soil profile analyses, or possibly through a careful study of aerial photographs from prescribed habitats. Natural succession in these communities has not been investigated in sufficient depth for conclusive statements to be made about this process.

All of the basic, fact-finding research needed will be directly applicable to the environmental problems associated with these ecosystems. Only by acquiring these fundamental data for natural systems can we begin to assess the environmental impact that man-caused alterations have had or will have on them. Furthermore, such studies are necessary to establish a value system for the preservation of ecologically important pocosins and Carolina bays throughout the southeastern Atlantic Coastal Plain.

CHAPTER 5

RECOMMENDATIONS FOR CONSERVATION, PRESERVATION AND MANAGEMENT

Making management recommendations for a general community type is a difficult, if not futile task, especially when the [illegible]

ecological studies need to be encouraged by appropriate agencies to investigate pocosins and Carolina bays in an in-depth [illegible]

In a most generalized sense, certain conclusive statements and recommendations can be made on how to enhance the future well-being of shrub bog communities of the Atlantic seaboard as follows:

Increase Ecological Research

The level of ecological information about these communities and their importance to fauna and flora of a region is presently inadequate to assess their overall importance to southeastern ecosystems. Coupled with this dearth of understanding of the natural communities of plants and animals that inhabit or are transients to such areas is the limited information on

or by State and National Forests. In addition, some sites receive passive protection by virtue of being on private lands that do not have activities that jeopardize the integrity of the natural habitats. However, Otte (1981) noted that essentially all the smaller pocosins in North Carolina are altered to the point that they may not be salvagable as natural wetlands. Some of the larger ones are provided some protection by the Federal government (e.g., Croatan National Forest, Dismal Swamp National Wildlife Refuge, and Dare County Bombing Range); by the State (e.g., Bladen Lakes State Forest); or by private ownership (e.g., The Green Swamp Nature Conservancy). Even so, since 1979

Green Swamp in Brunswick and Columbus Counties (Otte 1981).

Although there are still pocosins and Carolina bays remaining in a natural state, an active program of protection needs to be developed at this time at both public and private levels. This can come through formulating wetlands legislation to protect both Carolina bays and pocosins as natural wetlands and by means of various land management incentives to protect such areas. Development of a program directed toward private land owners that gives appropriate credit for actively protecting pocosin or Carolina bay wetlands might be an incentive to some individuals. Tax incentives by State and Federal governments could be established in the private sector in a manner that would effectively contribute to habitat protection. A judicious approach to habitat use should be instituted at least until appropriate research can be carried out to determine the importance of these habitats to regional flora and fauna.

Develop Region-Specific Management Schemes

Specific restrictions and constraints should be placed on particular geographic areas where problems are apparent. For example, potential peat mining should be limited in areas of North Carolina where hundreds of square miles per year could be heavily affected by such activities. One of the major problems affecting both pocosins and Carolina bays is lowering of the water table. This, of course, is a regional, perhaps a national, problem that needs to be addressed. These rainfall-dependent ecosystems are severely affected by reduced water tables. A continued reduction in water tables will ultimately lead to the elimination of many of the smaller, shallower Carolina bays and to a large portion of pocosin habitat. Local consideration must be given to the best approaches that should be taken in protecting each of these wetland types. A pocosin-related problem concerns impact of runoff in estuarine systems, such as the Pamlico-Albemarle Sound area. Thus, inland activities may have to be restricted or controlled in some manner because of the actual or potential effects on contiguous ecosystems. The most appropriate regional management scheme to implement such programs would need to be agreed upon by the various Federal, State, and local agencies concerned with a particular region.

Increase Public Awareness

A major problem in developing an environmental protection attitude about pocosins and Carolina bays is that most laymen are uninformed about them. Many people are unaware of Carolina bays in areas even where densities are moderate (1 bay/2 mi^2) because the habitats have been altered to a level where they are no longer recognized as wetland ecosystems or because distinctiveness of Carolina bays as natural wetlands has not been pointed out. A common attitude among inhabitants of pocosin regions is that they are wasteland areas. Knowledge of the biota and of the hydrological regime is generally minimal. Ecologists themselves know little about the dependency of wildlife on pocosin and Carolina bay habitats, although the limited information available suggests they are vital to the livelihood of some species in certain areas or environmental situations.

Because professional ecologists and environmental managers are limited in their knowledge of these ecosystems, the transfer of information to the public is diminished even further. A major public education effort needs to be made at this time about the presence, the values, and the rapid rate of disappearance of these natural wetlands. An uninformed public cannot be expected to develop sympathetic attitudes toward the inexorable decline of these wetland systems. Professional ecologists and various agencies and institutions can be considered responsible for the conduct of appropriate research and the transmittal of scientific information about shrub bogs. Additionally, these groups must accept the charge of assuring public awareness of the value of these ecosystems and of the environmental problems they presently face.

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THE ECOLOGY OF SOUTHEASTERN SHRUB BOGS (POCOSINS) AND CAROLINA BAYS: A COMMUNITY PROFILE

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6.

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16. Abstract (Limit: 200 words)

Shrub bogs of the Southeast occur in areas of poorly developed internal drainage that typically but not always have highly developed organic or peat soils. Pocosins and Carolina bays are types or subclasses of shrub bogs on the coastal plains of the Carolinas and Georgia. They share roughly the same distribution patterns, soil types, floral and faunal species composition and other community attributes, but differ in geological formation. Carolina bays may contain pocosin as well as other communities, but are defined more by their unique elliptical shape and geomorphometry.

The pocosin community is largely defined by its vegetation, a combination of a dense shrub understory and a sparser canopy. The community is part of a complex successional sequence of communities (sedge bogs, savannas, cedar bogs, and bay forests) that may be controlled by such factors as fire, hydroperiod, soil type, and peat depth.

Pocosins and Carolina bays harbor a number of animal groups and may be locally important in their ecology. Although few species are endemic to these habitats, they may provide important refuges for a number of species.

These communities are simultaneously among the least understood and most rapidly disappearing habitats of the Southeast. Forestry and agricultural clearage are current impacts

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Ecology, ecological succession, peat deposits, perched water, animal ecology, plant ecology

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Shrub bogs, pocosins, Carolina bays, fire ecology, palustrine wetlands

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