NPS CPSU - Technical Report

The Disturbance History

of Buxton woods,

Cape Hatteras, North Carolina

CPSU TECHNICAL REPORT 16

Susan P. Bratton

Kathryn Davison

National Park Service Cooperative Unit
Institute of Ecology
The University of Georgia
Athens, Georgia 30602

The Disturbance History of Buxton woods, Cape Hatteras, North Carolina

CPSU TECHNICAL REPORT 16

Susan P. Bratton

Kathryn Davison

Cooperative Unit, National Park Service

Institute of Ecology

University of Georgia

Athens, Georgia 30602

October 1985

PURPOSE AND CONTENT OF THE REPORT SERIES

In order to make data and results from managerial studies more easily and quickly available to interested scientists, the U.S. National Park Service Cooperative Unit at the Institute of Ecology (Athens, Georgia) has initiated a numbered technical report series. This series produces limited printings of data matrices, bibliographies, review papers and scientific project reports concerning the U.S. National Parks and park-related problems. The reports are from various sources, not all federally funded, and are intended to supply scientific information rather than deal with park policy. The reports are subject to technical editing and review for scientific accuracy by Institute staff, but are not necessarily reviewed by external experts and are not refereed in regard to overall quality or importance to the scientific community.

ABSTRACT

Historic records, interviews and palynological data indicate that since colonial times, logging, live-stock grazing and fire have altered the species composition and structure of Buxton Woods. Although evergreen oaks dominated the woods until the colonial period, loblolly pine is presently the most important tree in terms of basal area. Since the beginning of this century, disturbance frequencies and intensities have fluctuated. Major logging of loblolly pine took place about 1910. Grazing animals, including goats, hogs, ponies, sheep and cattle were removed about 1937, causing release of overgrazed understories. Human-caused fire was common in the early part of the century, but rarely resulted in major burns, probably as a result of low fuel loadings. There was more than one intense fire during the 1940's, followed by a decline in fire frequency. Since 1937 pine reproduction has declined, indicating succession to hardwoods and a slow return to a species composition similar to that of the pre-colonial forest.

INTRODUCTION

Buxton Woods is one of the largest surviving stands of maritime forest on the Outer Banks of North Carolina, and is therefore an important botanical resource. Occupying the central portion of Hatteras Island, the southern half of the woods is protected by Cape Hatteras National Seashore and is presently managed as a natural area. Although live oak (Quercus virginiana), dominates scrub forest neighboring the dunes, stands of mature loblolly pine (Pinus taeda)(henceforth, referred to as "loblolly"), mixed hardwood stands and freshwater marshes dominate the island interior. A number of studies have described the maritime forest of the Outer Banks including Burk (1962), Oosting (1954), Oosting and Bourdeau (1959), and Wells (1939), but little attempt has been made to relate species composition to disturbance history. The purpose of this study is to determine:

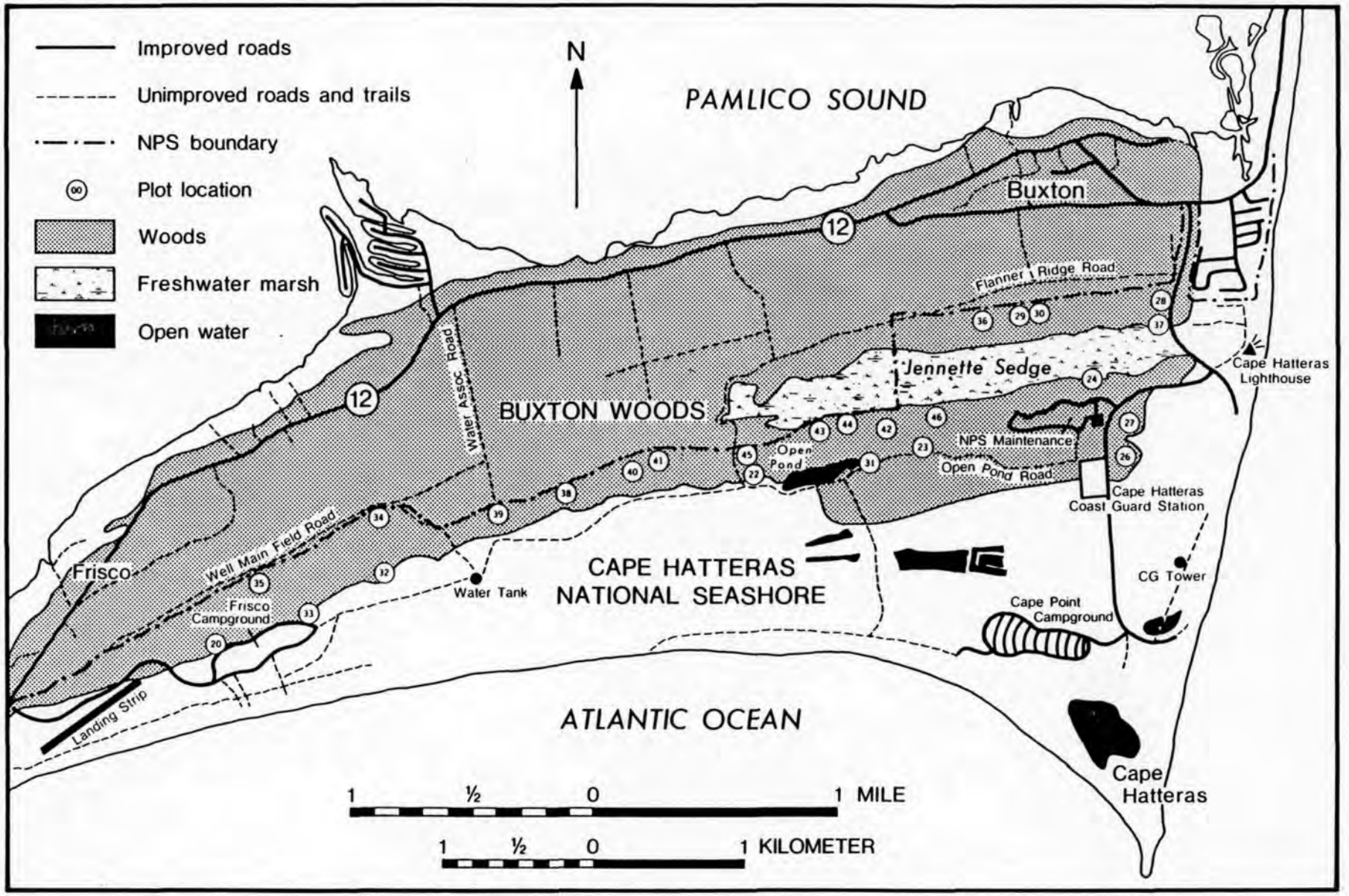
1) the post-colonial disturbance history of the Buxton Woods;
2) changes in species composition since colonial times; and
3) the present successional trends within the Woods.

METHODS

Information on the past vegetation of the area and on disturbances such as fire, grazing and logging was collected by searching historic records, courthouse files, and historic maps, and by interviewing ten local residents with knowledge of burning or logging practices. Interviews were conducted during June and July 1984. Two palynological studies, one on Jeanette Sedge in Buxton Woods (Brown 1983) and one on Nags Head Woods (Burney and Burney 1984) were already available. Aerial photos dating from the 1940s to the present were used to locate possible logging sites and other major disturbances. A single increment boring was taken from each of four to six trees at twenty-one different locations, representing stands of different sizes and species compositions. In most cases, cores were taken at breast height (about 1.3 m) but some small trees were cored basally at 20 cm above ground level. A few cores crumbled or were truncated by heart rot and could not be read. Twenty-five sites were selected for plot sampling on the basis of photo interpretation (of false color infra-red 1:24000 scale photos taken in 1982) and field observations. Within each site, a 20 x 40 meter plot was placed in homogeneous vegetation (Fig. 1). The long axis of the plot was usually located parallel to any local ridge. Distance and azimuth of plot sides in reference to 2-4 aluminum tagged witness trees was recorded as was the aspect of the 40 meter side of the plot.

All trees greater than or equal to 2.5 cm diameter at breast height (dbh) were tallied for species and size to the nearest millimeter. Total Basal area was calculated from the diameter tallies by species. Woody and herb species percent ground cover were estimated within ten

FIGURE 1. A map showing the location of sample plots and other major features, including the park boundary.


Improved roads
Unimproved roads and trails
NPS boundary
Plot location
Woods
Freshwater marsh
Open water
N
PAMLICO SOUND
Buxton
Flanner Ridge Road
Jennette Sedge
Cape Hatteras Lighthouse
BUXTON WOODS
Water Assoc Road
NPS Maintenance
Open Pond
Open Pond Road
Cape Hatteras Coast Guard Station
Frisco
Well Main Field Road
Frisco Campground
Water Tank
CAPE HATTERAS NATIONAL SEASHORE
CG Tower
Cape Point Campground
Landing Strip
ATLANTIC OCEAN
Cape Hatteras
1 ½ 0 1 MILE
1 ½ 0 1 KILOMETER

2 x 2 m subplots along alternating sides of one of the plot lines. Woody species (shrubs and pines) cover and stems counts were divided into four size classes (0-2 mm, 2-6 mm, 6-10 mm, and 10-20 mm). Herbaceous species cover was estimated within subplots of one square meter located in the northeast corner of the woody sample subplots. The ten subsamples were averaged by species to yield an estimate of species percent ground cover for each plot. Taxonomy follows Radford et al. (1968).

Plots were inspected for charred stumps, charcoal, and fire scars on the bases of trees. Roads outside the National Seashore Boundary were walked to inspect stands logged since the National Seashore was established (Fig. 1).

All computations were done by Ordiflex of Cornell Ecology Programs (Gauch 1972). Transcripts of interviews have been placed in the park archives at Manteo, NC.

RESULTS

Disturbance history

The Colonial forest

Pre-settlement descriptions of the Outer Banks are few and there are no detailed descriptions of the Buxton area. Author Barlowe (1584-5, cited in Quinn 1955) may have been on Hatteras Island when be noted "vallies replenished with goodly Cedar trees" and "Pynes, Cypres, Sassaphras, the Lentisk or the tree that bearth the Masticke" (possibly sweet gum) and "those Oaks that we have, but farre greater and better." Thomas Hariot (1588, cited in Quinn 1955) described a predominance of pine on Roanoke Island, but also mentions cedars, sweet gums, "chestnuts" (probably chinquapin) "walnuts" (probably hickories), and oak that were "faire, straight, tall and as good timber as any can be,...". Jonathan Price (1926, originally published 1795) describes the woods on Hatteras as "covered with large evergreen trees, such as live oak, pine and cedar..." and also reports that Ocracoke Island, which now supports almost no native forest, as covered with woods of small live oak and cedar. Price describes "three large and remarkable sand hills, called Stowe's Hills..." on Hatteras, and reports the remainder of the beach as "bald... intersperced with a few low sand hills" until one came to a group of trees called six mile Hammock, that was six miles from Ocracoke.

Grazing

Although it is probably impossible to determine exactly when livestock grazing began on the various islands of the Outer Banks, it was

certainly initiated early in the colonial period. Stick (1958) writes that when Sir William Berkley sold a half interest in Roanoake Island in 1676, it was provided that the buyer receive half of "all the cattle, hoggs and other stock... thereon." Dunbar (1958) suggests livestock from coastal North Carolina were driven to Virginia for sale and settlers from Virginia were looking for necks and islands to "free range" stock as early as 1657. There were sales of cattle on Colington Island and Roanoke Island in 1698 and 1701 respectively. A petition to settle stock near Ocracoke Inlet was filed in 1710. As early as 1673, the North Carolina General Assembly "passed a law regulation the killing of unowned livestock." By 1700 theft and crop damage had become problems and owners were required to mark stock (Parker 1971, vols. III and V).

In 1733 a man named Sanderson owned all of Ocracoke with its "stock of horses, cattle, sheep and hoggs" (Stick 1958). In 1741-1742 and 1747-1748 Spanish privateers killed part of the animals on Ocracoke (Dunbar 1958). By 1776, all of the banks were covered with cattle, sheep and hogs, although the settlers tried to remove them to protect them from war related activities. A letter of about 1810-1811 (Newsome 1929) documented that about 1800 a resident of Portsmouth Island had... "sheared 700 head of sheep--had between two hundred & fifty, & three hundred head of cattle & near as many horses." In the letter writer's opinion, Portsmouth was overstocked at this time and could do with one-third the number of animals. Although no specific colonial or early 19th century references to Buxton Woods were located, stock grazing patterns on Hatteras Island presumably followed those of the rest of the Outer Banks.

Interviewees reported that livestock were common in Buxton Woods until after the passage of a North Carolina law prohibiting free range grazing. All stock were supposed to be penned by February 1, 1937 (Green 1937, Desch 1979). Stocking densities were high. Rany Jennette (interview) estimated at least 200 ponies and five to six-hundred cattle. Curtis Gray also estimated the cattle and horses to be in the hundreds, and Green (1937) reports several hundred head as previously being present. There were also numerous sheep and hogs, and goats were so common in the Buxton area that children from nearby Avon called Buxton "Goat Town" (Maude White, interview). Almost everyone had at least two or three milk cows and a few horses. Kendric Gray (interview) reported his family had 25 to 30 hogs, and a number of other families maintained herds of cattle and horses for commercial sale. The ponies and sheep preferred to stay out in the open interdune grasslands, whereas goats frequently grazed in the woods and hogs preferred the marshes (Rany Jennette, interview). Cattle preferred the beach and the marsh, but did have established trails in the woods (Rany Jennette, Curtis Gray, interview). Photographs in Settel's (1937) report and other early park sources show understories clear of small shrubs. Bond (1908) observed hogs, cattle and sheep disturbing sand-binding grasses. All informants aggreed that livestock had kept the woods open, and after the cessation of free range grazing, the "brush" had greatly increased. By the late 1930s, almost all domestic grazing stock had been removed from the island.

Logging

Although no reference could be found to the initiation of commercial logging in the Buxton area, live oak (Quercus virginiana) timber was harvested along the southeastern coast at a relatively early date and used for ship building, both locally and in New England. By 1700, American shipyards were well established and supplying craft for fishermen and traders. (Wood 1981). By 1732-33, Captain Barrington reported there were several saw mills on the North Carolina mainland and these were milling pine (Saunders 1886, vol. 3 and Lefler 1934). By 1770, the state was a major exporter of wood products including barrel staves and other items of oak, and pine and cypress planks for Europe and the West Indies. It seems unlikely that pine was cut in any great quantities on the Outer Banks, however, because it would have been so difficult to transport to a mill or load onto ships.

Live oak was, at that time, more valuable. "Large quantities" of live oak and red cedar were carried across the Albemarle Sound from places like Portsmouth Island to towns such as Beaufort where there were boat works. With the demand from ship wrights, it is reported that.... "As early as 1810,... the supply of live oak and cedar on nearby Shackleford Banks was 'by no means so abundant as it has been'" (William Tatham cited in Stick 1958). By 1826, over half the accessible live oak on the southeastern coast had disappeared, and even in swampy Florida forests had been stripped up to fifteen miles inland (Wood 1981). An Outer Banks resident, Pharoah Farrow, supposedly cut live oaks at Kinnakeet (just north of Buxton) using slave labor. They "trimmed the branches and took the limbs that were suitable for framing to muddy glades and immersed them in the muddy waters for preservation and sold

this oak timber to the shipbuilders of New England" (Williams 1975). Presumably, the same market was available for Buxton timber although supplies were probably depleted by 1830. Cobb (1906) reports an area of moving sand "was started just after the Civil War by the cutting of trees next to the shore for ships timbers, and the section is still known as The Great Woods, though not a stick of timber stands upon it today". Cedar cutting continued after the Civil War, but informants could not remember any great amount of logging for boat building in the present century. Lumber for boats has, in recent years, been brought from the mainland.

No evidence was found for other commercial logging, except the possible continued cutting of cedar and oak, until almost the beginning of the 20th century. According to the Deed Books, Dare County Court House, Manteo, N.C., in 1899, 1900, and 1901, Hornthal Lumber Company bought land on the north side of Hatteras Island and purchased a number of options to cut timber on various properties in Buxton Woods (these records are probably not complete). The options were for five, eight or ten years. An option with the Basnight family mentions "all the pine timber of and above the size of (10) ten inches at the base when cut," and an option with Maggie E. Davies concerns "all the pine, oak, holly, buck, & dogwood timber of and above the size of eight inches in diameter." An option with V.E. Foster provides for "building tramways and railroads across the said lands and for equipping and operating the said railroad and locomotive, and also for the purpose of rafting and removing said timber".

In 1907, Hornthal Lumber Co. sold their operation to J.W. Dennickson et al. for $6,050, who in turn sold it to Foreman-Blades Lumber Company for $10,800. The former transfer included buildings, boilers,

circular saws, a 2½ mile railroad and a wharf 3/4 mile long. The latter transfer included "the lands and timber, saw mill, dry kiln, railroad iron, options, four mules, one horse, three yoke of oxen, wagons, harness and all other property... also one lighter now at Hatteras". This agreement reserved "the sawed lumber on the grounds or at the mill" for the previous owners indicating some cutting had already been completed. Foreman-Blades acquired additional options in 1907, and began cutting. The logs were hauled by tram to the wharf at Brigand's Bay. Originally, the logs were rafted to Elizabeth City for milling but losses to storms, and damage from the rafting techniques encouraged the use of barges (John Wood Foreman, interview). In order to use the Hornthal options, much of the logging would have to have been completed by 1911.

Foreman-Blades was primarily interested in cutting pine, but were disappointed with the quality of the timber from Buxton much of which was infected with "red heart". Settle (1937) reports that local residents told him larger trees (probably greater than 4 feet in diameter) were not taken by the turn of the century operation, but died due to insect infestations following the cutting. Cobb (1906) reports "vetern pines" to 3 feet in diameter. Kendric Gray (interview) could remember pines 4 feet in diameter growing in Buxton Woods, in about 1915-20.

Several informants reported dogwood cutting in the early part of the century (1920s). Local people would cut dogwood and sell it to outside buyers for cotton mill spindles (Cutis Gray, Kendric Gray, John Wood Foreman, Mosley Meekins, Ruth Quidley, interviews). Dogwood cutting on the Outer Banks, probably stopped in the late 1940s (John Wood Foreman, interview). Buxton residents cut firewood for themselves

and hauled it out of the woods with horses and carts. Pines in the ten to fourteen inch size classes were preferred for splitting and larger trees were generally left in the woods. (Curtis Gray, Ruth Quidley, Rany Jennett, interviews). The U.S. Coast Guard Stations would contract for wood for heating and cooking, and local residents would cut it and haul it to the stations. Flanner's Ridge Road was used regularly for cutting wood and for taking it to the coast guard station (Curtis Gray, interview). Firewood cutting continued as common practice until after World War II.

After the establishment of the park (about 1937), the Civilian Conservation Corp cut brush from the southern half of Buxton Woods to use for sand fences. This cutting was practiced away from the beach and included primarily small hardwood understory species (Curtis Gray, Rany Jennette, interviews).

From 1953 to 1956, Leighton Gibbs and Harold Holton cut in the north-eastern quarter of Buxton, south to the park boundary. They removed pine and trucked the timber to Norfolk, although a horse was still occassionally used for snaking logs, (Evelyn Gibbs, interview). None of the informants could remember any fires related to burning slash or other aspects of logging either in the early 1900s or 1950s cuts.

Fire

One of the earliest accounts of the Outer Banks, John White's narrative (Quinn 1955), reports three fires between the 15th and 17th of August, 1590. The first was on Roanoke Island, and the second at "Kind-rikers mountes" now at Wimble Shoals north of Roadanthe. White and his crew investigated the second fire, which was some distance from their

landing point, and found no one present. White described the third blaze as "a great fire thorow the woods..." and on a day-break inspection he found "the grass & sundry rotten trees burning about the place." (Quinn 1955). Since there were no European settlers resident at the time, the fires were presumably ignited by either lightning or by Indians.

Burney and Burney (1984) in their study of Nags Head Wood ponds found charred plant fragments at 40 cm in a core of pond sediment. They suggest this area burned more frequently a few centuries ago when the water table was lower (it has risen with sea level rise). Previously the area around the ponds was more xeric and there were more pines present and fewer hardwoods, although pollen from upland hardwoods is found in the lowest section of the cores indicating they predate the ponds. Fire can thus be assumed to be at least an occassional disturbance on the Outer Banks in pre-Colonial times, although nothing is known of ignition sources. No information was located on Colonial to late 19th century burning in the Buxton area.

Older informants indicated that fire had always been common in Buxton Woods, but that in the early part of the 20th century the fires were not serious and attracted little attention. (Maude White, Ruth Quidley, Kendric Gray, interview). Kendric Gray (interview) said that a couple of fires a week was not unusual. After removal of grazing animals, the forest understory increased, causing higher fuel loading. Several informants recalled large fires in the 1940s. Raymond Basnight (pers. comm) described a fire begun by a Buxton resident who was clearing his garden in October, 1946. The fire, driven by 40 knot winds, swept south over Jeanette Sedge and Open Pond and burned out onto grassy areas at the beach. This fire burned for two days and several inform-

ants remembered this specific fire as being one of the most intense. Park records indicate a second fire burning across Jennette Sedge in 1954. Mosley Meekins and Ruth Quidley (interview) recalled a fire in the 1940s that burned up into treetops near Doctor's Road, and threatened their residences.

Photos included in Sager (1937) shows an area of Buxton that appears to have been burned. Although the defoliation may also have resulted from storm damage, the marsh edge is clear and the oaks leafless. Whatever the combination of events at the site in the photograph, a disturbance intense enough to completely open the canopy happened sometime prior to 1937.

Informants indicated most of the fires were human-caused and many of them were intentionally set. Reasons for the ignitions were varied, although none of the Buxton residents associated burning with range improvement, indicating little or no use of fire on green marshes or grasslands for grazing. John Wood Foreman (interview), suggested that under grazing, fuels were too low to burn in the interdune meadows. Photographs from the 1930s confirm the close cropping of the grass and forbs.

In the first half of the present century, marsh burning was common. Residents around Currituck purposefully burned in the spring to improve the grass for muskrats, and increase populations for commercial trapping (John Wood Foreman, interview). Although no Buxton residents mentioned this (Foreman lives in Nags Head), it may have been practiced in the area. Mosley Meekins and Ruth Quidley (interview), mentioned fire in association with hunting and with removal of snakes and brush. Some ignitions during hunting may have been accidental since the hunters

frequently had campfires and also "firelighted" at night. Edward Scarbouro (cited in Hooper 1975) reports:

> People would sometimes fire-light for yellow birds. They would get an old rag and dip it in kerosene and tie it around the end of a stick and light it up. They would go under the trees and hunt for them.

Mosley Meekins recalled burning used in conjunction with clearing "duck holes" for hunting in the marshes, and reported that during her childhood (1930s-40s) the men set the woods afire every year. She also remembered an incident where a hunting companion of her brother's started a fire that nearly trapped her brother at his "duck hole." Informants suggested some fires were arson, set by mischievious boys or by people who "did not care for the park." With the arrival of the Civilian Conservation Corp., fire supression was initiated and since the mid 1950s, there have been no major fires in Buxton Woods.

Superintendent's Monthly Reports for 1957 through 1962 (National Seashore Library, Mantao, N.C.), which are probably incomplete, indicate 36 fires, most of which began outside the park. Hunter caused fires are noted in 1958 and 1959 (outside the park) including possible "burning off dead material to create open pond" and "abandoned a warming fire." Debris burning and ignitions from power lines or transformers caused several blazes.

From 1963 to 1984 (Kent Turner, 1985), there were 186 fires on park lands or 8.4 fires per year. The largest fire was 50 acres (9-27-83) and only 5 were larger than 9 acres. Ninety percent occurred between March and October. Sixty-four fires had probable causes identified, and of these only 3 were thought to be lightning ignited. Two of these occurred on the same day and both were extinguished by rain. Of the recent fires, smoking, powerlines, campfires and fireworks are the

most important sources of ignition. As Turner (1985) notes, park visitors prefer to use beach and dune grass areas, thus visitor caused ignitions are limited in woods and shrub thickets.

A search for surface charcoal and charred trunks produced evidence of past fires throughout the woods. The charcoal in the western most stands was largely on old stumps, however. South of Jeannette Sedge, there was frequent charcoal and numerous scarred trees (some showing evidence of at least two fires). No evidence was found of scarring of small trees (indicating recent hot fire).

Other disturbances

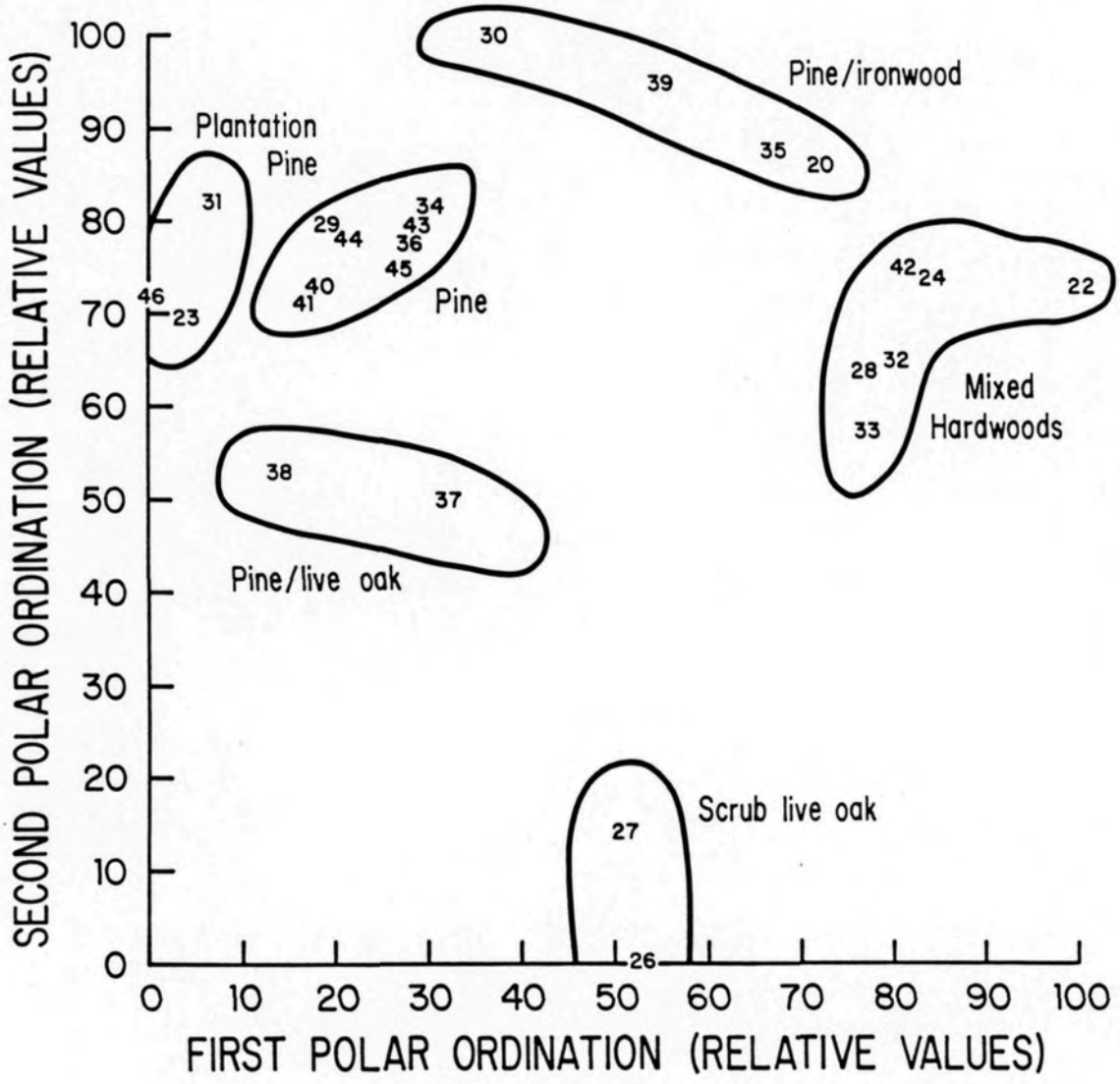
Hurricanes are frequent on the Outer Banks, and informants could remember several serious storms that toppled trees. This appears to be a continuing process, however, and no single storm was identified by several informants as being the most serious. Settel (1937) reports that the hurricanes of 1933 and 1936 caused flooding that killed numerous loblolly pines. This was followed by insect outbreaks including terpentine bettle (*Dendroctenous terebrans*) and engraver bettles (*Ips*. spp.) which further damaged mature trees. There are no recent park records of similar outbreaks.

The contemporary vegetation

Forest types

Canopy basal area data were initially subjected to Principal Components Ordination in an attempt to objectively order plots into community types. Loblolly pine was so dominant that it determined the axes of the ordination giving unsatisfactory results. A polar ordination was then applied and clearly separated six major stand types (Fig. 2).

FIGURE 2. A polar ordination of the canopy data by basal area. Note pine/ironwood and pine/live oak types, which are transitional between pine and mixed hardwoods and are probably successional to hardwood forest.


SECOND POLAR ORDINATION (RELATIVE VALUES)
FIRST POLAR ORDINATION (RELATIVE VALUES)
0
10
20
30
40
50
60
70
80
90
100
Plantation Pine
Pine
Pine/ironwood
Mixed Hardwoods
Pine/live oak
Scrub live oak
30
39
35
20
31
34
29
44
43
36
45
40
41
46
23
42
24
22
28
32
33
38
37
27
26

Live Oak Scrub formed the naturally regenerating primary successional forest established on former dune areas. Live oak (Quercus virginiana) was dominant (7.4 m^2/ha) followed by (Q. laurifolia) 3.0 m^2/ha). Loblolly and a number of the species common in more developed hardwood forest, were present. Red cedar (Juniperus virginiana) was of variable importance (1.2 m^2/ha). In the two stands sampled, 85% of the basal area was oak.

Pine plantations have been established in some of the open sand flats and dune areas. There was little in the canopy besides loblolly (27.1 m^2/ha) which comprised 87% of the basal area. Live oak was consistently present and there were scattered immature hardwoods.

The loblolly/live oak type included one poorly drained and one ridge top plot dominated by pine (16.1 m^2/ha), live oak (4.4 m^2/ha). Ironwood (Carpinus caroliniana), American holly (Ilex opaca) dogwood (Cornus florida) and yaupon (Ilex vomitoria) were present in both sites at low densities.

The pine/ironwood type also included a poorly drained plot as well as three from ridge locations. Loblolly (8.3 m^2/ha) averaged 34% of the total basal area. Thus, hardwoods as a group were dominant. Laurel oak (2.4 m^2/ha), ironwood (6.5 m^2/ha), American holly (1.9 m^2/ha), and yaupon (.4 m^2/ha) were consistently present. Red bay (Persea borbonia) (1.6 m^2/ha) and dogwood (1.8 m^2/ha) were important on drier sites.

The Mature Pine type occupied both dry and wet sites, and was dominated by loblolly (27.0 m^2/ha) or 74% of the total basal area (average total 35.28 m^2/.08 ha). Red bay (.7 m^2/ha), laurel oak (4.1 m^2/ha), ironwood (1.5 m^2/ha), dogwood (2.2 m^2/ha), American holly (.2 m^2/ha) and yaupon (.3 m^2/ha) were present in all stands and bayberry (Myrica cerifera) was present in five stands of eight.

The Hardwood type had pine in three of six stands but the basal areas of pine were low (1.0 m^2/ha, or 4% of an average total basal area of 24.3 m^2/ha). Ironwood (8.1 m^2/ha), laurel oak (4.3 m^2/ha), dogwood (3.5 m^2/ha), red bay (3.2 m^2/ha), American holly (.5 m^2/ha) and yaupon (1.4 m^2/ha) were present in all six stands sampled. Red mulberry (Morus rubra) was present in four stands and live oak was present in three. Large vines including poison ivy, (Rhus radicans), and grapes, (Vitis spp.), were more common in the Hardwood type (.05 m^2/ha) than in the mature pine type (.0025 m^2/ha).

The understory compositions of the plots had many similarities. Young red bay was present in all 25 plots, yaupon was present in 20. The average percent understory cover for the two oak species was 1.63% in pine plantation, 1.35% in mature pine, 3.78% in hardwood and 2.53% in pine/ironwood (Table 1). Pine cover was, in comparison, .77%, 0%, .12% and .03% respectively. Red bay was 3.37 %, 9.91%, 6.00%, and 10.38% and yaupon was .53%, 3.63%, 28.35% and 6.48% respectively. Scrub stands had a high cover of oaks, averaging 27.10%. Pine seedlings were most common in the pine plantation type (1.69/m^2), but were rare under mature pine (.12/m^2) and very rare under hardwoods (.03/m^2) and pine/ironwood (.01/m^2). Oak seedlings and small saplings were rarest in the pine plantations (.33/m^2), but were common under mature pine (1.52/m^2) and were most common under hardwoods (2.54/m^2) and pine/live oak (2.18/m^2).

Changes since 1937

In 1937, Sylvan Settel completed a timber cruise of Buxton Woods and developed a system of forest types. Settel (1937) estimated 2,432 acres of loblolly pine types, 153 acres of which were in reproductive

Table 1. The cover of understory species in 1937 and 1984.

PERCENT COVER

	PINE TYPES				HARDWOOD TYPES			SCRUB	
	1937		1984		1937	1984		1937	1984
	Pine Pole	Pine Sawlog	Pine Plantation	Mature Pine	Hardwood Sapling	Hardwood	Pine/ Ironwood	Live Oak Scrub	Live Oak Scrub
Pinus taeda	20	19.08	.77	.19	11.67	.12	.03	-	.25
Callicarpa americana	17	11.48	-	.41	7.00	.50	.38	-	-
Diospyros virginiana	3	8.59	-	-	6.67	-	-	34.5	-
Myrica cerifera	2.5	3.83	4.97	-	12.67	.03	.03	-	11.0
Smilax spp.	3	6.75	1.03	.76	12.66	1.87	2.68	4.0	1.35
Quercus spp.	5	1.91	1.63	1.35	5.57	3.78	1.28	6.0	27.1
Persea spp.	3.5	2.50	3.37	9.91	8.00	6.00	9.35	-	5.5
Cornus florida	1.5	3.41	.03	1.35	2.33	.82	.50	1.0	1.0
Ilex opaca	3	1.08	.03	.25	2.33	1.27	1.98	1.0	.10
Carpinus caroliniana	-	2.50	.60	2.34	1.00	1.68	1.90	-	3.75
Vitis spp.	5.5	5.25	6.50	.56	1.67	.97	.58	.5	1.00
Ilex vomitoria	17	19.08	.53	3.63	12.66	28.35	6.95	38.5	.65
Total vines	8.5	12.00	16.65	4.94	16.67	23.18	14.63	4.5	4.75

through "pole" (most trees 12 to 20 cm in dbh) size classes. Settel (1937) estimated 339 acres of mixed hardwood sapling type (diameters largely less than 20 cm, the 2 to 4 cm size class predominant). He also identified a yaupon, live oak, persimmon type, occupying 351 acres. This type is similar to live oak scrub.

Although Settel's (1937) understory cover measurements are not strictly comparable to measurements in the present study, they may be compared to 1984 data to indicate proportional shifts in species dominance. In 1937, loblolly had 10 times the understory cover in pine saw log stands as did the oaks. In 1984, in mature pine, oaks had seven times the cover of loblolly. In 1937, loblolly had 1.75 times the cover of oaks in the hardwood sapling type. In 1984, oak had 31.5 times the cover of loblolly in hardwood stands. Table 1 shows several other interesting trends. In 1937, beauty-berry (Callicarpa americana) and persimmon (Diospyros virginiana) were important understory dominants in both pine and hardwood stands and persimmon was important enough in oak scrub to be considered characteristic of the type. In 1984, persimmon was absent from the plots sampled and was an occasional species in scattered locations. Beauty-berry was present at many sites but is proportionately much reduced in cover. Cat brier (Smilax spp.) was probably more common in 1937, although total vine cover relative to total hardwood cover is probably little changed. Some vine species, such as poison ivy, (Rhus radicans) have probably increased in importance.

Settel (1937) reports a maximum diameter for trees in his "Saw log" type as about 70 cm, although trees above 40 cm were rare. In 1984, pine trees above 40 cm were common, although no tree (except one

dead live oak) measured exceeded 70 cm. Settel reported the average diameter of loblolly in saw log stands as about 9 cm and as 24 cm in "swamp saw log." Today, diameter in pines stands varies but average stands have diameters of 16 to 20 cm and more mature stands have average diameters of 30 to 40 cm. Stand # 40 had an average diameter of 37.1 cm, for example. Settel (1937) hardwood stands had a maximum diameter of 54 cm although trees over 22 cm were uncommon. The average diameter (for all species) was 7 cm. In 1984, hardwoods over 50 cm diameter were still uncommon, although oaks often exceeded 30 cm. A typical hardwood stand near Open Pond had an average diameter of 7.6 cm, but a better developed stand nearby had several large oaks (over 40 cm dbh) including a 65.5 cm laurel oak. The average diameter was 13.6 cm. The predominance of understory species such as dogwood and ironwood in the hardwood stands will probably continue to keep the average diameter in these stands low although the basal area of the canopy dominants should slowly increase. There are far fewer small pines in the pine types than formerly, so trends in the two types of forest are probably not comparable.

Stand Age

The oldest tree cored was a loblolly with 91 rings at breast height. This was the only individual cored, that pre-dated the period of commercial logging at the turn of the century. The oldest stands were mature pine or mature pine with laurel oak and other hardwoods. The oldest mature pines stands (Table 2) had ring counts varying from 77 to 45 indicating ages from about 80-85 years to about 50-55 years. These stands had thus largely regenerated between 1910 and 1935. Some

Table 2. Ring counts for pine stands of various ages.
Sites may be approximately located on the map in Fig. 2

MATURE PINE			YOUNGER PINE		
Stand	diameter in cm	Rings	Stand	diameter in cm	Rings
#1 Well Field	53	91	#6 East of Park	37	22
Rd - mature	37	57	Maintance	32	20
near plot 34	52	57	(plantation)	238	20
			just E of NPS maintenance		
#3 Well field	49	68	#9 on Open Pond	40	34
Rd. - mature	40	62	Rd. (plantation)	35	25
west of plot 35	44	77	just west of	33	30
			entrance to Open Pond Rd.; W of Coast Guard Station		
#18 (with ever-	51	45	On Open Pond	26	42
green hardwood	56	60	Rd. (plantation)	27	35
NW of shooting	45	50	just west of	26	45
range; near plot 33			entrance to Open Pond Rd.; west of Coast Guard Station		
#20 NE of Open	49	47	Natural South	32	41
Pond (poor	43	48	of Jeanette	35	45
drainage; near plot 44			Sedge; near plot 44		

of the mixed pine-hardwoods also regenerated prior to the cessation of grazing in 1937. Table 3 shows a stand south of Jeanette Sedge where the oldest trees are about 80 years old (regeneration just after 1900). In three stands, the largest sound laurel oaks and pines were cored and these are about the same age, indicating simultaneous regeneration of pines and oaks. A stand of mature hardwoods near Open Pond provided ring counts up to 45 and to 47 for mature laurel oaks (the largest individual in the stand had heart rot and gave an incomplete count). Most of these trees probably either sprouted or were released sometime during the 1930s. The largest live oak stem in adjoining oak scrub was 50 + years old, but a laurel oak at the same site was only 22 years.

Pines of an expanding population in the dunes ranged from 8 rings at the edge to 22 at the center. Pines in scrub at the east edge of the woods gave counts from 22 to 29 at one site, and 12 to 26 rings at another. Two red cedars and a laurel oak at the same location gave (basal) counts from 28 to 29. Trees in an older pine plantation along Open Pond Road gave counts from 45 to 35, indicating the stand was probably the work of the Civilian Conservation Corp (Table 3). A younger stand near the Park Maintenance Garage dated from about 1960.

Ring width for most larger loblollies have declined for the past 20 years or more, but ring widths for larger laurel oaks in mixed stands are also declining.

Table 3. Ring counts for Stands with pines and oaks of similar diameters
Sites are near plots shown by numbers in Fig. 2.

Stand	Loblolly Pine		Laurel Oak	
	Diameter in cm	Rings	Diameter in cm	Rings
#4 Well-field	23	44	42	45
road; just E of	41	45	30	37
plot 35	50	35	43	48
#5 Well-field	23	26	31	30
road; S of	34	30	23	27
plot 34	30	27	23	28
#16 Ridge South	57	75	37	70
of Jeanette Sedge;	45	58	29	70 + fragments
near plot 24	47	73	42	60 (heart rot)

DISCUSSION

Through the last three centuries, the vegetation of Buxton Woods has been heavily modified by anthropogenic disturbances. Although palynological work by Brown (1983) indicates that tree pollen in Jeannette Sedge has always been primarily oak and pine, at 895 ± 155 years before present it was 51% oak and 30% pine. In the most recent sediments pollen was 6% oak and 80% pine, therefore the dominance of pine has greatly increased. Brown (1983) dates the decline in oak as beginning about 1700 AD.

Brown's (1983), dates for oak decline corresponds well to a possible date for early logging efforts (although there is no concrete documentation). Both live and laurel oak can regenerate from root sprouts, however, so even selective cutting of oak and cedar does not by itself explain the long-term loss of oaks. Oaks will replace pines after logging and this has happened in several Buxton stands outside the park boundary, which have been cut since 1953. Since livestock grazing was probably initiated prior to 1700, and the logging efforts of the 18th and early 19th century, it is likely that livestock originally suppressed hardwood regeneration after cutting. Changes in the fire regime may also have favored pines, although prior to 1937, Settel (1937) notes that grazing gave the forest an open "park-like appearance." Informants agree that in the early 20th century grazing reduced fuels and hot fires were rare. Grazing, logging, and to a lesser extent fire, were probably the primary forces accomplishing a conversion from oaks to pines.

Fire regimes have changed through Buxton's history. During this century there has been a shift from frequent low intensity fires,

probably of small size, to larger high intensity fires (late 1930s to early 1950s), to small fires that are quickly suppressed under NPS management. In pre-colonial times the higher percentage of oak in the canopy would have retarded crown fires (live oak leaves and litter do not burn as readily as pine needles), but it is possible the Indians burned the marshes and/or forest understories. Natural ignition is presently rare at Cape Hatteras National Seashore, and historically many lightning fires were probably extinguished by rain. In recent years, hunting and purposeful brush clearing have probably declined as sources of anthropogenic fires, while power lines have become a major anthropogenic source of ignitions (in the Park as a whole). A reduction in burning by hunters may be encouraging succession around marshes and sedges and reducing the area of open water in Buxton Woods. A probable reduction in anthropogenic ignitions and improved suppression, rather than a reduction in fuel loadings, have resulted in a decline in fires in Buxton Woods.

In the vegetation samples, the canopy at Buxton was of low diversity and despite local topographic variation, many of the same species occupied both wet and dry sites. Plots purposefully sampled to represent swamp sites fell in other vegetation types in the ordinations. Much of the variation in the samples may be attributed to the age of the stands and their relative position in primary and secondary successional sequences. Since small pines are uncommon in the understories of both pine and hardwood types, hardwood succession will probably replace many of the loblolly stands. Although loblolly will probably remain the major successional species at marsh edges, rising sea level should favor hardwoods in closed canopy sites (Burney and Burney 1984).

Live oak is presently uncommmon in closed interior forest and laurel oak is most often growing up under the pines. The existence of a few old large live oak trees at scattered locations, including ridge tops as well as cemeteries and house sites, indicates live oak may have once been far more common in Buxton Woods. Extensive harvest, and perhaps intolerance of fire and grazing may have selected against live oak. Bratton (1985) has documented the greater dominance of laurel oak in old field succession in Georgia Sea Island locations where mature live oak is common on uncultivated sites. Laurel oak may be better able to establish itself in successional pine forest, and may be a better invader of secondary successional sites.

The understory at Buxton has changed radically since 1937. Former dominants such as beauty-berry and persimmon are greatly reduced in cover, probably as a result of declining disturbance and increased canopy closure. Pine seedlings similarly have declined in cover relative to hardwood seedlings and sprouts. Without severe distrubance hardwood species should eventually replace pines on many of the ridges.

Although the maritime forest at Buxton may never return to its pre-colonial state, management for hardwood succession is probably advantageous. This would serve to return the forest to a composition more similar to that of pre-colonial times, and would help to protect maritime hardwood forest, a limited resource. Replacement of pines by oaks and deciduous species would lower surface fuel loadings and reduce fire hazard. A hot fire, that removed accumulated pine litter, would kill young hardwoods and prepare the soil surface for further pine establishment. Any controlled burning, therefore, should consider its relative effects on young oaks and pines. Wind fall of larger pines, without burning, will probably favor hardwoods.

ACKNOWLEDGEMENTS

We thank Kent Turner for his help and encouragement throughout the project. We also thank Clay Gifford for his assistance with the library and finding knowledgeable informants. We thank all the interviewees who not only offered information, but provided visits to field sites, lunches, and encouragement. The kind people who put up with numerous questions included Curtis Gray, Evelyn Gibbs, John Wood Foreman, Mosley Meekins, Ruth Quidley, Rany Jennette, Kendric Grey, Maude White, Annie Hooper, Lucy Parker and Mahoney Quidley.

REFERENCES

Bond, J. F. 1908. Report on an examination of the sand banks along the North Carolina coast. Biennial Report of the State Geologist, 1907-1908: 42-46. North Carolina Geological and Economic Survey, Raleigh.

Bratton, S. P. 1985. The vegetation history of Fort Frederica, St. Simons, GA . Castanea 50:133-145.

Brown, C. W. 1983. A palynological study of peat layers from Jeanette Sedge, North Carolina, Outer Banks. M.A. Thesis, Smith College, North Hampton, MS. 56 pp.

Burk, J. C. 1962. The North Carolina Outer Banks: A floristic interpretation. J. Elisha Mitchell Sci. Soc. 78(1):21-28.

Burney, D. A. and Burney L. P. 1984. A paleoecological investigation of Nags Head Woods Ecological Preserve, Dare County, North Carolina. A Report to The Nature Conservancy. June 15, 1984. Mimeographed. 33 pp.

Cobb, C. 1906. Where the wind does the work. Nat. Geog. 17: 310-317.

Desch, M. 1979. Pony penning days. Seachest 5(2):35-39.

Dunbar, G. S. 1958. Historical Geography of the North Carolina Outer Banks. Baton Rouge, LA: Louisiana State University Press. 239 pp.

Gauch, H. 1972. Ordiflex: A flexible computer program for four ordination techniques. Ithaca, NY: Cornell University.

Manual plus computer programs.

Green, E. L. 1937. Report on the Wildlife and Park Museum at Cape Hatteras State Park, Buxton, North Carolina. Typed Carbon in the archives of Cape Hatteras National Seashore, Manteo, NC. 8 pp.

Hooper, M. 1975. Hunting on Hatteras Island in the early 1900's. Seachest 3(4):47-51.

Newsome, A. R. (ed.) 1929. A miscellany from the Thomas Henderson Letter Book 1810-1811. North Carolina Hist. Rev. 6(4):398-401.

Lefler, H. T. 1934. North Carolina History Told by Contemporaries. Chapel Hill: University of North Carolina Press. 454 pp.

Oosting, H. J. 1954. Ecological processes and vegetation of the maritime strand in the south-eastern United States. Bot. Rev. 20:226-262.

Oosting, H. J. and P. E. Bourdeau. 1959. The maritime live oak forest in North Carolina. Ecology 40:148-152.

Parker, M. E. E. 1971. North Carolina Higher Court Records, 1697-1701. Raleigh: State Dept. of Archives and History. Vols. III pp. xvi-xvii and Vol. V. p. xv.

Price, J. 1926 (originally published 1795). A description of Occacock Inlet. North Carolina Hist. Rev. 3(4):624-633.

Quinn, D. B. (ed.) 1955. The Roanoke Voyages 1584-1590. London: The Hakluyt Society. Vol. I. 469 pp. Vol. II. 492 pp.

Radford, A. E., H. E. Ahles, and C. R. Bell. 1968. Manual of the Vascular Flora of the Carolinas. Chapel Hill, NC: University of North Carolina Press. 1183 pp.

Sager, M. S. 1937. Report on Recommendations for Boundaries of the Cape Hatteras National Seashore, Cape Hatteras, North Carolina. December. National Park Service, DOI. Report in the archives of Cape Hatteras National Seashore, Manteo NC.

Saunders, W. L. (ed.) 1886. The Colonial Records of North Carolina. Raleigh: P. M. Hale, Printer to the State, Vol. III.

Settel, S. 1937. Timber Survey -- Hatteras Woods. Typed carbon, dated 9-3-37, in the archives of Cape Hatteras National Seashore, Manteo, NC. 28 pp.

Stick, D. 1958. The Outer Banks of North Carolina 1584-1958. Chapel Hill: University of North Carolina Press. 352 pp.

Turner, K. 1985. Fire History Summary, Cape Hatteras National Seashore. Manuscript dated Feb. 1985. Cape Hatteras National Seashore, Manteo, NC. 17 pp.

Wells, B. W. 1939. A new forest climax: the salt spray climax of Smith Island, N.C. Bull. Torr. Bot. Club 66:629-634.

Williams, C. T. 1975. The Kinnakeeter. New York: Vantage Press. 141 pp.

Wood, V. S. 1981. Live Oaking: Southern Timber for Tall Ships. Boston: Northeastern University Press. 206 pp.