

✓
1
4/13

NATIONAL PARK SERVICE

RESEARCH/RESOURCES MANAGEMENT REPORT SER-85

Vegetation Changes on Bodie Island, Cape Hatteras National Seashore, North Carolina



United States Department of the Interior

National Park Service
Southeast Region

VEGETATION CHANGES ON BODIE ISLAND,
CAPE HATTERAS NATIONAL SEASHORE, NORTH CAROLINA

by Ian Firth
School of Environmental Design
University of Georgia
Athens, Georgia 30602

NATIONAL PARK SERVICE – Southeast Region
Research/Resources Management Report SER-85

Produced under Cooperative Agreement No. CA-5000-4-8005 (Amendment no. 7)
between the U.S. Department of the Interior, National Park Service, and the
University of Georgia Research Foundation, Inc.

U.S. Department of the Interior
National Park Service
Science and Natural Resources Division
75 Spring Street, S.W.
Atlanta, Georgia 30303

June 1987

UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE



Firth, Ian. 1987. Vegetation Changes on Bodie Island, Cape Hatteras National Seashore, North Carolina. U.S. Department of the Interior, National Park Service, Research/Resources Management Report SER-85. Southeast Regional Office, Atlanta, Georgia. 42 pp.

Abstract

This is a study of vegetation changes on the Bodie Island section of Cape Hatteras National Seashore (CHNS). The marshes on Bodie Island, which are an important wintering home for waterfowl, have been invaded by shrubs and trees during the past 50 years. This invasion has reduced the habitat for waterfowl and obscured views into the wetlands. The objectives of this study were to (1) analyze the changing distribution of shrubs and trees during the period for which surveys are available, (2) catalog anthropogenic disturbances within this period, and (3) examine the connections between vegetation changes and the disturbance history of the island. Vegetation, characteristics and anthropogenic disturbances were analyzed from the evidence of historical maps, written descriptions, old photographs, interviews with local people, and aerial photographs, reports and records in the files of Cape Hatteras National Seashore.

In the vegetation history of Bodie Island since 1849, the 1930s were a turning point. Before that time woody species failed to reach a significant size and went largely unnoticed in the windswept expanses of sand and marsh. Since then shrubs have spread to form dense thickets, and, above these, stands of trees now rise to punctuate views across the island. An analysis of the rate of invasion in two sections of the island shows that this expansion of the shrub zone has generally slowed since 1974 and in some places stopped.

Before the 1930s the major anthropogenic disturbances to the vegetation on Bodie Island were grazing stock, burning marshes, and impounding ponds. Since that time disturbances have included dune building and reforestation programs, construction and drainage projects and attempts to control "weed" species in the wetlands.

Before the 1930s the cumulative impact of natural and anthropogenic disturbances prevented the development of shrub and tree communities on Bodie Island. It is not possible to clearly distinguish the impact of grazing and burning from that of natural disturbances, as no areas were protected from grazing for a significant period. In two areas the construction of impoundments converted areas of sand flats and high marsh to freshwater ponds.

In the 1930s the building of barrier dunes and the prohibition of grazing initiated a period of recovery and vegetation succession. The development of shrub and tree communities behind the dunes may have been accelerated by reforestation, but it is difficult to evaluate the success of that program. Various construction and drainage projects undertaken by the National Seashore staff encouraged the invasion of the marshes by woody species. Subsequent attempts to negate this were ineffective.

Since the early 1970s the National Park Service has abandoned the maintenance of the artificial barrier dunes. The island is now in transition to a more dynamic natural condition. The colonization of new areas by woody plant communities will probably be reversed. As the barrier dunes erode, salt spray, sand movement and overwash should cause the replacement of shrub communities by grassy dune and marsh communities. Woody plant communities on the slopes of the sound side sand hills are the best protected, while those between the high marsh and the barrier dunes are the most vulnerable.

TABLE OF CONTENTS

	Page
LIST OF ILLUSTRATIONS	iv
STUDY AREA	1
RESOURCE MANAGEMENT ISSUES	1
OBJECTIVES	2
METHODS	2
PREVIOUS STUDIES	3
FINDINGS	5
DISCUSSION	20
CONCLUSIONS	25
ACKNOWLEDGEMENTS	27
REFERENCES	28
ILLUSTRATIONS	Following 33

LIST OF ILLUSTRATIONS

Illustrations are located at the end of the report following page number 33.

Figure 1. Bodie Island, Cape Hatteras National Seashore

Location of places referred to in this report.

Figure 2. Vegetation 1849

Interpreted from the U.S. Coast Survey 1849.

Figure 3. Stock Grazing on Bodie Island c. 1934

In the collection of Cape Hatteras National Seashore.

Figure 4. Lighthouse Pond, November 13, 1934

Interpreted from B & W aerial photographs.

Figure 5. Lighthouse Pond, December 15, 1952

Interpreted from B & W aerial photographs.

Figure 6. Lighthouse Pond, December 1974

Interpreted from B & W aerial photographs.

Figure 7. North Dike to Tommy Hammock, December 5, 1952

Interpreted from B & W aerial photographs.

Figure 8. North Dike to Tommy Hammock, December 1974

Interpreted from B & W aerial photographs.

Figure 9. The Distribution of Woody Plant Communities in 1982

Interpreted from false color infra-red photographs flown by N.A.S.A.,
December 12, 1982.

STUDY AREA

This is a study of vegetation changes on the Bodie Island section of Cape Hatteras National Seashore, North Carolina (Figure 1). The portion of the Outer Banks known as Bodie Island lies south of the old Roanoke Inlet near Nags Head. Since the closure of that inlet at the beginning of the 19th century (Dunbar 1958), Bodie is no longer an island. Its length has varied with the opening and closing of inlets to the south; its present outline dates from the opening of Oregon Inlet in 1846. That inlet has moved 3.5 kilometers southwards since 1846 and Bodie Island has grown at the expense of Pea Island. In this report, Bodie Island is considered to be the area between Whalebone Junction, at the end of the causeway from Roanoke Island, and Oregon Inlet. This stretch is now some 15.5 kilometers long and is 2.5 kilometers across at its widest point.

RESOURCE MANAGEMENT ISSUES

Bodie Island has some of the most important natural areas within the Cape Hatteras National Seashore. The marshes on the sound side of Bodie Island, together with those on Pea Island and Ocracoke Island, provide a wintering home for over half of North America's greater snow geese on the Atlantic flyway, as well as significant numbers of other waterfowl. Resource management is guided by the enabling legislation for the park, which calls for both recreational use and protection of these natural resources. The northern half of the marshes on Bodie Island is managed as a

public hunting area (see Figure 1). Overlooks are provided along the main park road, North Carolina 12, to enable motorists to observe and photograph waterfowl in the marshes. Beside the historic Bodie Island Lighthouse, a boardwalk has been built into the wetlands, and a visitor center provides information on the natural history of the marshes.

Within the past 50 years, shrubs and trees have invaded the marshes, reducing the habitat for waterfowl and obscuring views into the wetlands. The growth of shrubs and trees across the island followed the construction of a line of artificial barrier dunes in the 1930s. The 1984 General Management Plan for the National Seashore calls for an investigation of methods to counter this invasion of woody shrubs in the marshes (National Park Service 1984).

OBJECTIVES

The objectives of this study were:

1. To analyze the changing distribution of shrubs and trees during the period for which surveys are available;
2. To catalog anthropogenic disturbances within this period; and
3. To examine the connections between vegetation changes and the disturbance history of the island.

METHODS

Vegetation characteristics and anthropogenic disturbances in the period before the construction of the artificial dunes in the 1930s were analyzed from the evidence of historical maps, written descriptions, old photographs and interviews with local people. A vegetation map of the island in 1849 was produced based on an interpretation of the first U.S. Coast Survey. Few people have first-hand knowledge of the condition of the

island before the 1930s, as there were few permanent residents. Nine people were interviewed who had lived in the area for brief periods, or had visited it in connection with its use for stock raising or hunting. These interviews were conducted in July 1984, October 1985 and June 1986.

Changes since the construction of the artificial dunes were analyzed from aerial photographs and reports and records in Cape Hatteras National Seashore files. The aerial photographs were black and white prints at various scales taken in 1932, 1934, 1945, 1952, 1955, 1962, 1965, 1974 and 1978. Maps showing the distribution of shrubs and trees were compiled for two sections of the island: around Lighthouse Pond and between North Dike and Tommy Hammock. These areas are of particular interest to park management; Lighthouse Pond is adjacent to the Bodie Island Visitor Center, and the North Dike to Tommy Hammock section is part of the public hunting area. The maps were compiled to show the distribution of shrubs and trees at intervals of approximately 20 years -- in 1934 before the construction of the artificial dunes, in 1952 before the National Seashore was established, and in 1974 after a series of major construction and drainage projects were completed. These maps were quantitatively analyzed using a planimeter. Finally, false color infra-red photographs flown by N.A.S.A. in 1982 were used to compile a map showing the distribution of woody plant communities along the whole island.

PREVIOUS STUDIES

Differing views have been offered on the natural distribution of trees and shrubs on the Outer Banks.

Plant ecologists have identified the role of natural factors in limiting biotic succession towards shrub and tree communities -- in particular, the significance of salt spray and sand movement from the ocean and tidal inundation from the sound (Wells 1928, Oosting 1945 and 1954, Martin 1959, Adams 1963, Au 1974).

Proponents of the dune building program argued that tree cover was formerly greater and emphasized the role of anthropogenic disturbances (timbering and grazing) in the development of live dunes (Bond 1908, Stratton and Hollowell 1940).

More recently, critics of the dune building program have pointed out the dynamic nature of these barrier islands, emphasizing the rise in sea level, the effects of storms and overwash on the retreating islands, and the vulnerability of woody communities to these natural disturbances (Dolan, Godfrey and Odum 1973, Godfrey and Godfrey 1974 and 1976, Riggs 1976). This chronological shift of views reflects an improved understanding of coastal processes in the past 20 years. But questions remain as to the natural distribution of shrubs and trees on these islands.

Bodie Island has been included in a number of botanical descriptions of the Outer Banks (Brown 1959, Burke 1962, Bellis 1980), and the Bodie Island marshes have been used to examine marsh productivity (Cooper and Waits 1967) and vegetation response to goose grazing (Smith and Odum 1981).

This study is the first detailed analysis of changes over time in the distribution of woody plant communities on Bodie Island.

FINDINGS

The Distribution of Shrubs and Trees

In 1849 the U.S. Coast Survey made its first detailed topographic survey of Bodie Island. There is no key to the topographic symbols used in the survey, so our interpretation in Figure 2 is based on a comparison with other areas and later surveys (Sholowitz 1964). The original survey could not be clearly reproduced so it was redrawn for this report. The northern half of the island was bare sand flats, except for a broken line of marshes along the sound. The southern half had more vegetation; behind a broad beach were extensive grassy sand flats with interior pockets of wetland, and marshes beside the sound. Trees are shown in three locations: Billy's Woods, Tommy's Hammock and an unnamed area to the north. (The area referred to as Tommy's Hammock in 1849 is not the same as the present day Tommy Hammock; the latter has arisen in the large area of overwash in Roanoke Sound shown in Figure 2.) In Billy's Woods -- now the site of the water tank -- the trees are noted as being "dead cedars." The death of the trees may have been the result of the 1846 storms which inundated the island (U.S. Coast Survey 1847).

In 1893 a survey was made of the Bodie Island Light Station. This provides the earliest photographs of the island. The area around the Light Station compound was a grassy sandflat with no vegetation rising above knee height (Holland 1967).

In 1915 the U.S. Coast and Geodetic Survey resurveyed the topography of Bodie Island. The mapping of vegetation was far less detailed than in 1849. Bare sand flats are not differentiated from grassy areas. No trees or shrubs are indicated. The survey is chiefly remarkable for the changes in the outline of the island -- the movement of Oregon Inlet southwards and

the build up of sand on the sound side (Everts, Battley and Gibson 1983).

The condition of the island in the 1920s can be pieced together from interviews with people who lived on or visited the island at that time. All of them remember sparse vegetation and low shifting dunes, but some also recall seeing myrtle bushes on sand hills and in the vicinity of the lighthouse (NPS CPSU Univ. Ga. CHNS interviews nos. 3, 4, 5 and 9). These shrubs, however, were not high enough to obstruct views across the island. The only trees were inside the gardens of the Light Station and Life Saving Station (NPS CPSU Univ. Ga. CHNS interview no. 9). All those interviewed emphasized the open windswept character of the landscape (Figure 3).

Aerial photographs of Bodie Island are available from the early 1930s. A comparison of these early photographs with more recent ones shows a remarkable increase in shrub and tree cover from 1934 to 1974. Figures 4 to 8 were produced to facilitate this comparison; they identify the shrub zones and any stands of trees in two areas -- around Lighthouse Pond and between North Dike and Tommy Hammock. The division of the shrub zone into over 1/3 and 2/3 cover is based on a visual estimate. Stands of trees are identified where they clearly overtop adjacent shrubs. Ponds are indicated, but their boundaries are difficult to identify and should be regarded as approximations.

Around Lighthouse Pond in 1934, shrub savanna occupied the slopes of the sand hills on the sound side of the lighthouse. By 1952 the shrub zone had surrounded the pond and became dense along the tracks between the lighthouse and Hatteras Road. In 1934, shrub savanna occupied 25.9 hectares within the area shown in Figure 4; by 1952 the shrub zone extended over 105.9 hectares within this same area. (Areal distortion at the edges of each aerial photograph makes these figures subject to a small margin of

error.) According to a 1945 aerial photograph, much of this fourfold increase in the extent of the shrub zone had taken place by that time. Between 1952 and 1974 the shrub zone further expanded. Within the area shown in Figures 5 and 6, excluding Off Island which is outside the National Seashore, the shrub zone covered 129.1 hectares, or 30% of the land, in 1952. By 1974 woody species dominated 151.7 hectares, or 35% of the total area. Trees had grown up in several locations and the density of the shrub zone had increased on all sides of the pond. The occurrence of major storms in 1955, 1958 and 1962 did not affect the spread of the shrub zone, except around the southeastern corner of Lighthouse Pond, where overwash entered the pond in the 1962 Ash Wednesday storm.

No shrubs can be detected in the early aerial photographs of the area between North Dike and Tommy Hammock. Most of the flats south of the dikes had little or no vegetation (1932 photographs are in the collection of the U.S. Army Corps of Engineers Coastal Engineering Research Center at Duck, N.C. and are reproduced in Birkemeier, Dolan and Fisher 1984). By 1952, patches of shrub savanna were present on elevations in the marsh and alongside Hatteras Road, becoming denser to the south and on the inland slopes of sand hills near the sound. Altogether the shrub zone covered 107.8 hectares, or 13% of the area shown in Figure 7. The 1962 aerial photographs show that storm overwash crossed the Hatteras Road near the North and South Dikes, but this provided only a temporary setback to the expansion of the shrub zone. By 1974, woody species dominated 231.5 hectares or 30% of the total area in Figure 8. Shrubs now formed a dense thicket between Hatteras Road and the new Route 12. In the wetlands there had been an increase in the number and size of the clumps of shrubs around the ponds, but on the sound side sand hills the changes were mainly limited

to increases in density and height within existing thickets.

Figure 9 shows the distribution of woody plant communities throughout the study area in 1982. On the sound side of the island, shrubs and trees form dense thickets on the slopes of the sand hills, which stand between the salt marshes and the interior wetlands. Woods were recorded in the 1849 Survey on the summits of three of these hills, but today the tops of the higher hills are bare and the woody plant communities are found on the slopes. Within the interior wetlands, clumps of shrubs and trees occupy the many small mounds and narrow ridges which rise above the ponds. On the ocean side of the island, there is a band of shrub thickets, in places over 400 meters wide, between the high marsh and the barrier dunes. The main park road -- N.C. Route 12 -- runs within this band from Whalebone Junction to the campground near Oregon inlet.

There is evidence, however, that the expansion of the shrub zone has generally slowed and in some places stopped. In the vicinity of Lighthouse Pond, the shrub zone expanded between 1934 and 1952 at a rate equivalent to 4.4 hectares per year, and between 1952 and 1974 at a rate equivalent to 1.0 hectare per year. Since 1974 there has been no further expansion in this area, although some increases in density can be detected on the sound side sand hills. The most noticeable change since 1974 is an increase in the height of the trees, particularly those beside the road leading to the lighthouse. Between North Dike and Tommy Hammock, the shrub zone expanded between 1932 and 1952 at a rate equivalent to 5.4 hectares per year and from 1952 to 1974 at a rate equivalent to 5.6 hectares per year. But between 1974 and 1982 the increase has been about 0.6 hectares per year. In the shrub thickets beside Route 12, areas that were open in 1974 had become part of the thickets in 1982, and in the wetlands some small ridges had become

overgrown within this period. But the total area involved in these additions to the shrub zone is less than 5.0 hectares.

Anthropogenic Disturbances

This catalog of anthropogenic disturbances to the vegetation on Bodie Island is divided into two sections: disturbances before the construction of the barrier dunes in the mid-1930s and those which have occurred since that time.

1. Disturbances Before the mid-1930s

Settlement. There was probably no permanent settlement on the island in the 19th century except for the Light and Life Saving Stations. In the 20th century, hunting clubs established clubhouses with small permanent staffs. But essentially Bodie Island has been used by people who lived elsewhere.

Grazing Stock. By 1846, livestock had been grazing the Banks for at least 150 years (Ruffin 1861, Newsome 1929, Dunbar 1958, Stick 1958). One of the other names of Bodie Island in the 18th century was Cow Island (Stick 1958), but no early descriptions of stock raising in the study area have been found. According to Dunbar, (1958), the number of livestock on the Banks declined after the Civil War as mainland owners became conscious of the value of selective breeding, but in the 1920s there were still a large number of cattle, sheep and horses on Bodie Island. Louis Midgett, who lived on the island in the late 1920s, estimates there were between 500 and 700 cattle, a somewhat smaller number of sheep, and around 400 ponies (others interviewed could not provide any more precise estimates). These were owned by six or seven residents of Roanoke Island. Hogs had gone from the study area by the late 1920s but could still be seen in the woods at

Nags Head and Kitty Hawk. "Hog holes" formed by hogs rooting in the sand still made horse riding hazardous on Bodie Island in the late 1920s (NPS CPSU Univ. Ga. CHNS interviews nos. 5 and 6).

The best grazing on Bodie Island was found in the marshes, especially those near Oregon Inlet. The stock would gather there particularly in the summer if the wind was from the southwest, for then insects would be less troublesome at the south end of the island (NPS CPSU Univ. Ga. CHNS interview no. 5). The concentration of stock on the south end of the island kept them well separated from the stock around Nags Head, and there was little mixing between separate herds (NPS CPSU Univ. Ga. CHNS interviews nos. 4, 5 and 6). Within the marshes the various types of stock had particular grazing preferences; for example, in the spring cattle grazed on threesquare (Scirpus spp.), "wild oats" (identity unknown) and "corn sage" (Spartina spp.) (NPS CPSU Univ. Ga. CHNS interview no. 6). But at other seasons this selectivity was limited as stock was obliged to graze on everything to survive. That included shrubs such as myrtle (Myrica spp.) and yaupon (Ilex vomitoria) (NPS CPSU Univ. Ga. CHNS interview no. 5). Hogs when present were omnivorous, and were known to scavenge dead fish on the beach (NPS CPSU Univ. Ga. CHNS interview no. 6).

Two areas of the island were fenced by hunting clubs to exclude stock, but this only lasted a few years. The Bodie Island Club fenced the area around Lighthouse Pond after 1904, but conflict with the stock owners meant the club had great difficulty in maintaining its fences (Stratton and Hollowell 1940). None of those interviewed could recall which areas, if any, were still fenced in the 1920s. The Goosewing Club fenced the area between North Dike and Tommy Hammock from 1928 to the mid-1930s (NPS CPSU Univ. Ga. CHNS interviews nos. 5 and 7). Louis Midgett remembers some

livestock getting tangled in those fences and drowning in the 1933 hurricane. The only parts of the island from which stock were excluded for a long period of time were the Light Station compound and the Life Saving Station garden.

Several times a year, stock would be driven north to be penned. Pennings were required for marking and dipping stock and shearing sheep. The main pennings were in the spring and fall, but stock might be rounded up at other times for special sales (NPS CPSU Univ. Ga. CHNS interview no. 5). Stock that was sold was usually taken to Roanoke Island by shad boat or barge. The pens were located just north of the study area. One pen near the Nags Head Life Saving Station kept filling with sand, so in later years another pen near Whalebone Junction was used (NPS CPSU Univ. Ga. CHNS interviews nos. 5 and 9).

The numbers of cattle, sheep and ponies declined in the early 1930s (NPS CPSU Univ. Ga. CHNS interviews nos. 5 and 6). In anticipation of the passage of a Stock Law, adults as well as young were sold and shipped off the island. The 1935 North Carolina Stock Law banned the free range of any stock on the Banks, between Caffey's Inlet, about 40 kilometers north of Whalebone Junction, and Hatteras Inlet. This law, which was closely tied to the construction of artificial dunes in the North Carolina Beach Erosion Control Project, became effective on February 1, 1937 (Dunbar 1958).

Burning marshes. The burning of coastal marshes associated with hunting and grazing is an old practice. Lawson's History of North Carolina (Lawson 1714) refers to the firing of marshes to facilitate the hunting of rabbits. Many of the people interviewed remember the marshes on Bodie Island being burnt in the 1920s and early 30s (NPS CPSU Univ. Ga. CHNS interviews nos. 1, 2, 4, 5, 6, 7 and 9). The burns were initiated in the

late winter or early spring of each year, both to improve the grazing for stock (NPS CPSU Univ. Ga. CHNS interviews nos. 1, 5 and 6) and to improve conditions for muskrats (NPS CPSU Univ. Ga. CHNS interviews nos. 2, 7, and 9). Fires were usually short-lived and were not particularly organized; and the hunting clubs which owned much of the area did not authorize the burns (NPS CPSU Univ. Ga. CHNS interviews nos. 4, 5, 6, and 9). The practice ceased with the removal of the stock in the late 1930s and a period of fire suppression began. Nevin Wescott remembers fighting fires associated with a naval bombing range on the island during the Second World War (NPS CPSU Univ. Ga. CHNS interview no. 9).

Impounding ponds. Throughout the 19th century, the northern Banks especially along Currituck Sound were famous for waterfowl hunting (Ruffin 1861, Dunbar 1958, Stick 1958, Baum 1968). Commercial hunting was an important source of income for some Bankers until outlawed by the Migratory Bird Treaty Act of 1918. Sport hunting developed in the latter part of the 19th century when sportsmen from states to the north began to establish clubs along Currituck and Pamlico Sounds. Large parts of Bodie Island were acquired by three hunting clubs after the turn of the century. The Bodie Island Club acquired the sound end of the island in 1904 and built a clubhouse near the lighthouse (Figure 5) (Stratton & Hollowell 1940). The Goosewing Club acquired nearly 700 hectares north of Tommy Hammock in the 1920s and built a clubhouse beside the sound (Figure 7) (NPS CPSU Univ. Ga. CHNS interviews nos. 4, 5, and 7). The Lone Cedar Club owned land north of this. Its clubhouse was on Cedar Island, which is now crossed by the causeway from Roanoke Island (Figure 1).

Each club built freshwater impoundments to improve the habitat for waterfowl. The Bodie Island Club, soon after its establishment in 1904, impounded an area of almost 150 hectares beside the lighthouse. The dikes on the south side are clearly visible today, but there was probably construction work on the north side also. The ridge of sand that is now followed by the road to the lighthouse may have been built to impound the pond. (The 1849 Coast Survey -- Figure 2 -- shows the wetland on the site of Lighthouse Pond linked to the salt marsh to the north.) This construction work was done by manual labor under the direction of Club superintendent Nathaniel Gould (NPS CPSU Univ. Ga. CHNS interview no. 3). The Goosewing Club dikes were built by dragline under the direction of Harry Lawrence, an engineer, in 1927-28 (NPS CPSU Univ. Ga. CHNS interviews nos. 4, 5, and 7). These dikes enclosed two areas, a large rectangle of approximately 140 hectares and a smaller triangle beside the Clubhouse on the sound side sand hill. The Lone Cedar Club built a small impoundment beside its clubhouse on Cedar Island, but this lies outside the National Seashore boundary.

The ponds were separated from the sound by floodgates constructed on inlets near the clubhouses. The water level in the ponds fluctuated with the seasons and in some years the ponds could become dry in late summer. In dry seasons, brackish sound water was admitted to the Goosewing impoundments (NPS CPSU Univ. Ga. CHNS interviews nos. 4 and 5). This may also have been the practice at Lighthouse Pond, but none of those interviewed could recall details on the management of that pond and no records have been found.

Various aquatic plants, such as widgeongrass (Ruppia maritima), eelgrass (Zostera marina) and wildcelery (Vallisneria americana) were planted in the Goosewing Club's ponds to attract waterfowl (NPS CPSU Univ. Ga. CHNS interviews no. 4 and 5). The area was also sometimes baited by

spreading corn (NPS CPSU Univ. Ga. CHNS interview no. 9). No information is available on whether Lighthouse Pond was planted with aquatic species.

A hurricane in 1933 damaged the floodgates at both clubs. The Lighthouse Pond gates were not repaired (NPS CPSU Univ. Ga. CHNS interview no. 1), but the Goosewing Club restored its gates only to have them washed out again in 1935 (NPS CPSU Univ. Ga. CHNS interview no. 5). Hunting clubs on the Banks were in decline by the 1930s, after the passage of laws shortening the shooting season, lowering the bag limit, and restricting the types of batteries, guns and decoys that could be used (Dunbar 1958, Stick 1958). The Bodie Island Club was little used in the 1930s, and the owner of the Goosewing Club, Jule Day, suffered a financial crisis and closed the club in 1935 (NPS CPSU Univ. Ga. CHNS interview no. 5).

The condition of the ponds in the late 1930s was probably similar to that on Pea Island. In 1937 the manager of the newly established Migratory Waterfowl Refuge on Pea Island reported:

With the dikes all broken we have no means of controlling the water. The refuge may be dry one week and flooded the next week. North and northeast winds blow the water away, draining the ponds and marshes, and cause them to go dry, that is, if the winds blow from this direction for several days. On the other hand, if the winds blow southwest or west, water is blown to the refuge filling the ponds and marshes. Therefore we have been entirely dependent upon the winds for water on the refuge, which of course makes very poor conditions.

(Walker 1937).

Building and Planting Dunes. Nathaniel Gould, superintendent of the Bodie Island Club between 1904 and 1924, tried to prevent sand moving into Lighthouse Pond by erecting sand fences made from young pine trees (Stratton and Hollowell 1940). The dunes that formed over the fences were planted with what Gould called Cape Cod grass (probably Ammophila breviligulata).

This work was cited by Stratton and Hollowell (1940) as a successful precedent for the Beach Erosion Control Project of the 1930s.

2. Disturbances since the mid 1930s

Dune building and reforestation programs. In 1934 a dune building program using transient laborers started at Nags Head (Stick 1958). This was the beginning of the North Carolina Beach Erosion Control Project, the objective of which was to build a line of dunes from the Virginia line to Ocracoke Inlet using Works Progress Administration (W.P.A.), Civilian Conservation Corps (C.C.C.) and National Youth Administration (N.Y.A.) labor. The ideas underlying this project included the relief of unemployment, the reforestation of the Banks, and the establishment of a coastal park made accessible by an Outer Banks Highway (Weatherwax 1937, Dunbar 1958, Stick 1958). In 1936 the project came under the direction of the National Park Service, though it was to be another 17 years before the National Seashore was established.

By November 1938, work on Bodie Island was nearly completed (National Park Service 1938). Between Nags Head and Oregon Inlet, a line of barrier dunes had been raised by the use of sand fences to a height of around 4 meters. At Oregon Inlet, multiple lines of fences had been erected "to raise the beach in general and to keep water from covering the entire point" (National Park Service 1938 p. 4). Additional fencing had also been erected on the ocean side of Lighthouse Pond. The dunes had been planted with American beach grass (Ammophila breviligulata) and it was intended to add sand to the foredune and plant it with sea oats (Uniola paniculata). Behind the dunes reforestation work had begun with the planting of approximately 20,000 seedlings of loblolly pine (Pinus taeda), black locust (Robinia

pseudoacacia) and dogwood (Cornus florida), between Whalebone Junction and Lighthouse Pond. It was planned to add another 30,000 seedlings between the pond and Oregon Inlet. In the sandflats south of the Goosewing Club impoundments, the plan called for the sand to be stabilized using brush mattresses and strips of Bermuda grass (Cynodon dactylon).

In 1940, Stratton and Hollowell presented a general report on the accomplishments of the project. They evaluated the effectiveness of different types of sand fences and planting methods and gave a list of some 20 species of trees and shrubs which had been planted. The species planted were considered indigenous to coastal North Carolina.

Work was suspended in 1941, when the U.S. entered the war, and for the next 13 years the barrier dunes were neglected (Brown 1959). Repair work began in November 1954 after the establishment of the Cape Hatteras National Seashore (National Park Service 1954). The objective was to restore a continuous dune line the length of the Seashore to an average height of 2.5 to 3.0 meters. Sand fences were employed as in the 1930s, but bulldozers were now used to obtain immediate dune mass and height in critical areas (Nash 1962). The dunes and flats were planted with six types of grass: American beach grass, sea oats, running beach grass (Panicum amarum), silver beach grass (Panicum amarulum), salt meadow grass (Spartina patens) and smooth cordgrass (Spartina alterniflora). The establishment of the grasses was promoted by periodic fertilization (Nash 1962). In the shelter of the dunes the National Seashore recommenced the tree planting program. Between 1956 and 1961, 21,000 pine seedlings were planted within the park (Nash 1962). In 1961 the Superintendent reported the receipt of 100,000 loblolly and slash pines (Pinus taeda and Pinus elliottii). In the same year, 11,500 eastern redcedar (Juniperus virginiana) and bald cypress (Taxodium

distichum) were planted on Bodie Island (National Park Service 1961).

In 1962 the Ash Wednesday Storm damaged 75% of the dunes along the Seashore (National Park Service 1962). On Bodie Island the erosion of the beach in that storm was estimated to be equivalent to the total erosion sustained during the previous 25 years (Nash 1962). Reconstruction work was begun and continued for the next year, but this was to be the last major work undertaken within the study area. (Work continued in other parts of the Seashore for several more years.) A reevaluation of the program was prompted by increasing costs and by criticism of its effectiveness by coastal geologists and ecologists. This criticism is summarized in Dolan, Godfrey and Odum (1973). The National Seashore began to develop a new management policy. "In the early 1970s the NPS recognized the futility of any further long term shoreline stabilization attempts" (National Park Service 1978, p. 15). The process of reevaluation and policy change is described in Behn and Clark (1979).

The 1984 General Management Plan for the National Seashore proposes: "Allowing natural seashore dynamics to occur except in instances where life, health, significant cultural resources, or the transportation link along North Carolina 12 would be jeopardized" (National Park Service 1984, p. iii).

No major storm has hit Bodie Island since the adoption of this policy.

Construction and Drainage Projects. A series of projects undertaken after the establishment of the National Seashore in 1954 affected the drainage of the marshes.

In 1958-59, Route 12 was constructed, bypassing the ocean front development south of Whalebone Junction. The construction of the road required the excavation of a series of borrow pits, which now form a line of

ponds over 1 meter deep in places. Around the edges, stands of widgeon-grass, muskgrasses (Nitella and Chara spp.) and other aquatic plants had developed by the mid-1960s (Florschutz 1964, Dow 1965). For several years the highway acted as a dam impounding fresh water on the ocean side, until the culverts were made effective by a drainage system in 1963 (Dow 1965).

In 1960 a mosquito control program was developed for the National Seashore. This called for the construction of a series of impoundments and drainage systems plus the filling of small areas in the salt marshes to reduce mosquito production (Bogue and Tinker 1960). Only parts of this program were implemented on Bodie Island because of concerns over the effect on the ecology of the marshes. In 1962 a small area of salt marsh adjacent to the new marina near Oregon Inlet was filled with excavated spoil (National Park Service 1962). In 1963, drainage ditches were dug in three areas: the flats between Route 12 and Hatteras Road, the high marsh north of the Goosewing Club dikes, and the low marshes beside the sound near the lighthouse. In the same year the Lighthouse Pond impoundment was restored and new ditches dug to drain the margins of the area towards the pond. A dike was built to create a new impoundment in the marsh between the road to the lighthouse and the water tank hill to the north. However, storms washed out the floodgates in this dike and these were not replaced (McDairmid 1965, Cooper and Waits 1967).

Controlling "weed" species. While stopping short of the construction of new impoundments, the National Seashore staff has periodically attempted to control the invasion of the marshes by shrubs and other vegetation of low value as waterfowl habitat.

In the late 1950s, mats of saltgrass (Distichlis spicata) were bulldozed away from the blinds in the hunting area (Florschutz 1964). The shallow ponds thus created were maintained each year until the mid-1970s. The use of heavy equipment was then discontinued because of the trails left in the marsh (NPS CPSU Univ. Ga. CHNS interview no. 8).

A number of recommendations were made for the chemical control of "weed" species (Watson 1958, Dow 1965), but it is not known if these recommendations were followed. There is a record of a 1970 application of Dalapon to control cattails in the hunting area (Tipton 1971).

In March 1970 the National Seashore burned several sections of the marshes: the main Goosewing Club impoundment, a two-mile strip along Route 12, and some small areas around four hunting blinds (Tipton 1970). The objective of these prescribed burns was to eliminate woody plants such as myrtle and groundsel tree (Baccharis halimifolia), and reduce stands of undesirable grasses, rushes and sedges. There was another burn in 1975, but there is no record of the exact areas affected. Apart from these prescribed burns, the National Seashore has practiced a policy of fire suppression for the past 32 years. However, the 1984 General Management Plan called for further investigation of the application of fire to counter the invasion of woody shrubs in the wetlands (National Park Service 1984).

Settlement. The residential development that has occurred along Hatteras Road since the early 1950s is outside the boundary of the National Seashore. However, together with developments in the park -- at the campground, Coquina Beach and the Rangers' Quarters -- this ocean front development is significant for its damaging impact on the barrier dunes. The removal of vegetation from the dunes has left them more exposed to erosion.

DISCUSSION

Vegetation changes on Bodie Island have resulted from both natural and anthropogenic disturbances.

On barrier islands, vegetation succession to shrub thicket and maritime forest occurs only in locations with access to fresh groundwater which are protected from damage from ocean and sound. On the ocean side the grassy communities of the dunes and flats are maintained by the action of salt spray and sand movement. On the sound side the marsh communities are maintained by tidal inundation (Oosting 1954, Martin 1959). But the resultant physiographic vegetation zones are subject to frequent natural disturbances. Even in protected locations, such as the hollows of interior sand flats and the slopes of sound side hammocks, succession may suffer periodic reversal by storm damage. Rhizomatous grasses adapt to overwash, but shrub and tree communities are vulnerable to salt spray and inundation (Dolan, Godfrey and Odum 1973, Au 1974, Travis 1976).

Anthropogenic disturbances have both reinforced and modified these natural processes on Bodie Island. Before the 1930s most disturbances prevented or reversed vegetation succession. Since the 1930s human activities have tended to encourage and accelerate the development of shrub and tree communities.

The Impacts of Anthropogenic Disturbances Before the mid-1930s

The uncontrolled grazing of stock was blamed for the "deforestation" of the Banks by the advocates of a dune building program. Grazing was observed to have two damaging effects: it destabilized the dunes, allowing sand to blow across the islands; and it prevented regeneration in woodlands already depleted by cutting (Bond 1908, Stratton and Hollowell 1940). Hogs

were regarded as the most destructive livestock, particularly on the dunes. Goats and sheep were the main browsers of woody species, but all stock entered the woods to root, graze or browse at various seasons (Bratton and Davison 1985, NPS CPSU Univ. Ga. CHNS interview no. 6). However, livestock was probably blamed unduly for "deforestation," since the original extent of woodland on the Banks had been exaggerated (Dolan, Godfrey and Odum 1973). This overestimate was based on a misinterpretation of historical maps and oral traditions (Porter 1938, Dunbar 1958), and a misunderstanding of the significance of tree stumps exposed by beach erosion (Bellis 1980). On comparatively narrow Bodie Island, there is no evidence there were ever woods comparable to those at Nags Head and Kitty Hawk. Certainly by 1849 there were only small wooded areas and these had probably been damaged in the 1846 storm. The effect of grazing was, no doubt, to compound the effect of such natural disturbances by retarding regrowth. It is not possible to clearly distinguish the impact of grazing from that of natural disturbances, as no areas were protected from grazing for a significant period. The two hunting clubs introduced fencing to exclude stock from their lands, but these fences were not maintained long enough to provide a useful comparison between grazed and ungrazed areas.

In the marshes, burning was an important ancillary to grazing. Most fires were probably light cover burns with little effect on marsh structure. However, by preventing the accumulation of organic matter, they would have delayed succession to high marsh and upland communities (Daiber 1974). Burns probably reached the sand flats and the slopes of the sand hills, but a lack of fuel in these locations must have limited the spread of fire (NPS CPSU Univ. Ga. CHNS interview no. 2).

The construction of impoundments converted areas of sand flats and high marsh into freshwater ponds. Aquatic plants were introduced, but the ponds were shallow and tended to dry out in late summer. This could have allowed the return of high marsh and the invasion of woody species, but the periodic admittance of brackish sound water would have negated this. Shrub invasion, therefore, probably did not begin until the neglect of the ponds in the 1930s. From the beginning, however, dikes provided elevated sites for the development of shrub communities.

The early attempts to revegetate the dunes by Lighthouse Pond were short-lived. They were probably abandoned after Gould's death in 1924. There is no evidence of vegetation on the dunes in the 1934 aerial photograph, which shows bare sand and overwash from the beach into the pond.

The Impacts of Anthropogenic Disturbances Since the mid 1930s

The artificial barrier dunes, although periodically breached, have lasted for fifty years on Bodie Island. These barriers have protected the interior of the island from the impacts of salt spray, sand movement and overwash, and thereby encouraged succession towards shrub and tree communities. Schroeder, Dolan and Hayden (1976) studied vegetation changes associated with barrier dune construction on Ocracoke Island. They measured the large increases which had occurred in prairie and woody vegetation and the decreases in the areas of bare sand and marsh over a sixteen year period. The expansion of the shrub community was primarily at the expense of the cordgrass communities of the sand flats and marshes. Similar changes have occurred on Bodie Island since the 1930s, but these cannot be attributed solely to the construction and maintenance of the barrier dunes. The end of grazing would have initiated a period of recovery and vegetation

succession even without the protection of the dunes. In addition, the reforestation program and the various National Seashore construction and drainage projects all encouraged the development of shrub and tree communities.

The planting of grasses was an essential part of the dune building program, and a number of studies have analyzed the effects of variables such as species selection, planting methods, diseases, sand supply and fencing systems on the success of the program (Woodhouse, Seneca and Broome 1976). In contrast, no follow-up studies have been done on the reforestation program behind the dunes. As exact planting locations were unrecorded and mostly indigenous species were used, it is difficult to evaluate the success of this program. Stratton and Hollowell (1940) reported some initial mortality rates, but the long-term survival rates, through the 1940s, are unknown. It is impossible to say how much of the 1934 to 1952 development of the shrub zone (shown in Figures 4 and 5) should be attributed to the planting program and how much to natural regeneration.

Most of the stands of pines that now rise above the shrubs on Bodie Island are the result of the planting program undertaken by the National Seashore staff in the late 1950s and early 1960s. In the stand of loblolly pines alongside Lighthouse Road, the planting lines can be clearly seen. (These trees were probably planted in 1963 or '64 as they cannot be seen in the 1962 aerial photographs, but they are clearly visible in 1965 photographs.) Elsewhere, the monospecific character of the stands and their association with construction sites along Route 12 suggest that most are the result of planting rather than natural regeneration.

The various construction and drainage projects undertaken after the establishment of the National Seashore have played a significant part in the spread of woody species. The embankment carrying Route 12 provides a prime site for the growth of woody species, but this growth is largely prevented by a mowing program. The road does, however, provide a barrier to natural drainage across the island. At first this barrier impounded fresh water on its ocean side and this impeded the growth of woody species. Once drained, the area between Route 12 and the old Hatteras Road became a dense thicket of shrubs. The excavation of the mosquito control ditches left spoil heaps that were soon colonized by shrubs, but the rate of spread from these centers has varied. In the needle rush (Juncus roemerianus) marsh, north of the Goosewing Club dikes, the spread of woody species beyond the spoil heaps has been slow and mainly confined to the margins of the area. In the low marshes along the sound the aerial photographs reveal no further invasion of woody vegetation in the past twenty years.

The problem of the loss of waterfowl habitat on Bodie Island was recognized in the 1950s (Watson 1958), but attempts to control weed species have been intermittent and ineffective. In the hunting area the creation of ponds around the blinds had the unfortunate effect of leaving peripheral ridges that have been colonized by woody species. A preliminary report on the prescribed burn in 1970 indicated considerable success in eliminating undesirable species (Tipton 1971). Eighty percent of the myrtles and groundsel tree, 60% of the sea oxeye (Borrichia frutescens) and 40% of the needle rush had been killed. However, these observations were made in the winter before regrowth had time to appear and may have been overestimates. The 1974 aerial photographs show considerable areas of shrub savanna within the zones burned in 1970. The experiment was repeated in 1975 but there is no record of its effect.

CONCLUSIONS

A high point in the spread of shrub thickets may have now been reached. Just as the 1930s were a turning point in the vegetation history of Bodie Island, so the 1980s may prove to be another. There have been only minor extensions to the areas occupied by woody species since 1974. Natural limiting factors appear to be operating. In the marshes, inundation by brackish water from the sound is probably the principal factor. On the summits of the sand hills, the xeric and exposed conditions are probably restricting the development of woody plant communities. Now, as the barrier dunes are allowed to erode, salt spray, sand movement and overwash should cause the replacement of vulnerable shrub communities by grassy dune and marsh communities. The pace at which this happens will depend upon the incidence of storms. The woody plant communities on the slopes of the sound side sand hills are the best protected and these should survive, but the extent to which a mature maritime forest community can develop remains to be seen. The shrub thickets alongside Route 12 are the most vulnerable to storm damage if the barrier dunes are breached. The kind of measures the National Seashore staff take to safeguard the transportation link along Bodie Island to the rest of the Outer Banks may determine which parts of this shrub community survive.

Several research projects concerning the vegetation of Bodie Island are in progress. A vegetation survey of the island has been made with an analysis of the species composition of the woody plant communities (Davison and Bratton in prep.). A program of prescribed burning is being developed and the effectiveness of fire in reversing shrub encroachment into marsh areas will be monitored (National Park Service 1987). The staff of the

National Seashore is preparing a vegetation management plan for Bodie Island. The plan will specify which areas are to be cleared of shrub thickets in order to protect wetland habitats for waterfowl and to provide views into the marshes for visitors to the park. The clearance program will have to take into account the natural disturbances to the woody plant communities which are likely to occur as the island changes from an artificially stabilized system to a more dynamic natural condition.

ACKNOWLEDGEMENTS

I wish to thank the following for their cooperation in the preparation of this report:

Kent Turner of Cape Hatteras National Seashore;
Susan Bratton and Kathryn Davison of the NPS CPSU, Institute of Ecology, University of Georgia; Jim Wood of the NPS Science Publications Office, Atlanta, Georgia; and those who granted interviews and shared their personal knowledge of the history of Bodie Island.

List of persons interviewed:

1. Balfour Baum, Manteo, NC
2. John Foreman (interviewed by Susan Bratton), Elizabeth City, NC
3. Phoebe Hayman, Nags Head, NC
4. David Lawrence, Kitty Hawk, NC
5. Louis Midgett, Manteo, NC
6. Hallett Perry, Kitty Hawk, NC
7. David Stick, South Shores, N.C.
8. Ralph Umphlett, Manteo, NC
9. Nevin Wescott, Manteo, NC

Copies of CHNS interview transcripts or notes are on file at the NPS CPSU, Institute of Ecology, University of Georgia, Athens, GA.

REFERENCES

- . Adams, D.A., 1963. Factors influencing vascular plant zonation in North Carolina salt marshes. Ecology 44(3): 445-456.
- . Au, S., 1974. Vegetation and ecological processes on Shackleford Bank, North Carolina. National Park Service Scientific Monograph Series no. 6, 87 pp.
- . Baum, J., 1968. A History of Market Hunting in the Currituck Sound Area. Wildlife in North Carolina, November: 13-15 and December: 4-8.
- . Bellis, V., 1980. The Vegetative Cover on the Barrier Islands of North Carolina. Contributions to the Knowledge of Flora and Vegetation in the Carolinas. Proceedings of the 16th International Phytogeographical Excursion (IPE), 1978 through the SE United States (2): 121-144.
- . Behn, R.D. and M.A. Clark, 1979. The Termination of Beach Erosion Control at Cape Hatteras. Public Policy 27(1): 99-127.
- . Birkemeier, W., R. Dolan, and N. Fisher, 1984. The Evolution of a Barrier Island: 1930-1980. Shore and Beach April 1984: 3-12.
- . Bogue, M.D. and M.E. Tinker, 1960. Mosquito Control for the Cape Hatteras National Seashore Recreational Area. (CHNS technical resource files.)
- . Bond, J.F., 1980. Report on an Examination of the Sand Banks along the North Carolina Coast. Biennial Report of the State Geologist, 1907-1908. North Carolina Geological and Economic Survey, Raleigh, NC: 42-48.
- . Bratton, S.B. and K. Davison, 1985. The Disturbance History of Buxton

- Woods, Cape Hatteras National Seashore, North Carolina. NPS CPSU Univ. Ga. Technical Report no. 16, Athens, GA, 36 pp.
- . Brown, C.A., 1959. Vegetation of the Outer Banks of North Carolina. LSU Press, Baton Rouge, LA, 179 pp.
 - . Burke, C.J., 1962. The North Carolina Outer Banks: a floristic interpretation. Journal of the Elisha Mitchell Scientific Society 78: 21-28.
 - . Cooper, A.W. and E.D. Waits, 1967. Net Primary Productivity of an Irregularly-Flooded North Carolina Salt Marsh. (CHNS technical resource files.)
 - . Daiber, F.C., 1974. Salt marsh plants and future coastal salt marshes in relation to animals. Ecology of Halophytes, Reimold, R.J. and W.H. Queen ed. Academic Press, New York: 475-508.
 - . Davison, K. and S. Bratton, in prep. Vegetation Patterns on Bodie Island, Cape Hatteras National Seashore. NPS CPSU Univ. Ga. Technical Report, Athens, GA.
 - . Dolan, R., P.J. Godfrey, and W.E. Odum, 1973. Mans impact on the Outer Banks of North Carolina. Am. Scientist 61: 152-162.
 - . Dow, S., 1965. A report of a field trip to Bodie Island in August, 1965. (CHNS technical resource files.)
 - . Dunbar, G.S., 1958. Historical Geography of the North Carolina Outer Banks. LSU Press, Baton Rouge, LA, 234 pp.
 - . Everts, C.H., J.P. Battley, and P.N. Gibson, 1983. Shoreline Movements Report 1 Cape Henry VA to Cape Hatteras NC 1849-1980. U.S. Army Corps of Engineers and NOAA, 111 pp.

- . Florschutz, O., 1964. Investigation of Bodie Island Marsh May 1964.
North Carolina Wildlife Resources Commission, Raleigh, NC, 7 pp.
- . Godfrey, P.J. and M.M. Godfrey, 1974. The role of overwash and inlet dynamics in the formation of salt marshes on North Carolina barrier islands. Ecology of Halophytes, Reimold, R.J. and W.H. Queen, ed. Academic Press, New York: 407-427.
- . Godfrey, P.J. and M.M. Godfrey, 1976. Barrier Island Ecology of Cape Lookout National Seashore and Vicinity, North Carolina. National Park Service Scientific Monograph Series no. 9, 160 pp.
- . Holland, F.R., 1967. A History of the Bodie Island Light Station.
National Park Service Division of History, 71 pp.
- . Lawson, J., 1714. Lawson's History of North Carolina. 1937 edition, Garrett and Massie, Richmond, VA, 259 pp.
- . Martin, W.E., 1959. The Vegetation of Island Beach State Park, New Jersey. Ecological Monographs 29(1): 1-46.
- . McDairmid, J.M., 1965. Operational Survey Report for the Cape Hatteras National Seashore September 1965. (CHNS technical resource files.)
- . Nash, E., 1962. Beach and Sand Dune Erosion Control at Cape Hatteras National Seashore A Five Year Review 1956-1961. NPS CHNS Manteo, NC, 15 pp.
- . National Park Service, 1938. Period Plan and Progress Map, showing work done or contemplated by the Beach Erosion Control Project from the Virginia-North Carolina boundary line to Ocracoke Inlet. Work Accomplished to November 30, 1938. (CHNS technical resource files.)
- . National Park Service, 1954. Cape Hatteras National Seashore,

- Superintendent's Monthly Narrative Reports. (CHNS technical resource files.)
- . National Park Service, 1961. Cape Hatteras National Seashore, Superintendent's Monthly Narrative Reports. (CHNS technical resource files.)
 - . National Park Service, 1962. Cape Hatteras National Seashore, Superintendent's Monthly Narrative Reports. (CHNS technical resource files.)
 - . National Park Service, 1978. Seashore Management Strategy, Cape Hatteras National Seashore, Status Report. U.S. Department of Interior, 25 pp.
 - . National Park Service, 1984. Cape Hatteras National Seashore, General Management Plan, Development Concept Plan, Amended Environmental Assessment. U.S. Department of Interior, 123 pp.
 - . National Park Service, 1987. Natural Resource Management Plan, Cape Hatteras National Seashore. (CHNS technical resource files.)
 - . Newsome, A.R., 1929. A Miscellany from the Thomas Henderson Letter Book, 1810-11. North Carolina Historical Review 6(4): 398-410.
 - . Oosting, H.J., 1945. Tolerance to salt spray of plants of coastal dunes. Ecology 26: 85-89.
 - . Oosting, H.J., 1954. Ecological processes and vegetation of the maritime strand in the southeastern United States. Botanical Review 20: 226-262.
 - . Porter, C.W., 1938. Forest Cover of the Cape Hatteras Seashore Area in Historical Times. (CHNS technical resource files.)
 - . Riggs, S.R., 1976. Barrier Islands - Natural Storm Dependent System.

- Barrier Islands and Beaches. Technical Proceedings of the 1976 Barrier Island Workshop, Annapolis, MD, 25 pp.
- . Ruffin, E., 1861. Agricultural, Geological and Descriptive Sketches of Lower North Carolina and the Similar Adjacent Lands. Raleigh, NC.
 - . Schroeder, P.M., R. Dolan, and B.P. Hayden, 1976. Vegetation Changes Associated with Barrier-dune Construction on the Outer Banks of North Carolina. Environmental Management 1(2): 103-114.
 - . Shalowitz, A.L., 1964. Shore and Sea Boundaries, with special reference to the interpretation and use of Coast and Geodetic Survey data. U.S. Department of Commerce, vol. 2, 749 pp.
 - . Smith, T.J. and W.E. Odum, 1981. The Effects of Grazing by Snow Geese on Coastal Salt Marshes. Ecology 67: 98-106.
 - . Stick, E., 1958. The Outer Banks of North Carolina 1584-1958. UNC Press, Chapel Hill, NC, 352 pp.
 - . Stratton, A.C. and J.R. Hollowell, 1940. Sand Fixation and Beach Erosion Control. U.S. Department of Interior, National Park Service, 102 pp.
 - . Tipton, P.F., 1970. Prescribed Burning Operations on Bodie Island. Draft. (CHNS technical resource files.)
 - . Tipton, P.F., 1971. Results of Prescribed Burning Operations on Bodie Island. (CHNS technical resource files.)
 - . Travis, R.W., 1976. Interactions of Plant Communities and Oceanic Overwash on the Manipulated Barrier Islands of Cape Hatteras National Seashore, North Carolina. PhD dissertation, University of Massachusetts, 133 pp.
 - . United States Coast Survey, 1847. Report of the Superintendent of the

Coast Survey showing the progress of that work December 15, 1847.

Department of the Treasury.

- . Walker, S.A., 1937. Letter to Chief Bureau of Biological Survey,
Department of Agriculture. September 7, 1937. (Pea Island National
Wildlife Refuge files.)
- . Watson, W.V., 1958. Management of Bodie Island Lighthouse Freshwater
Pond: Memorandum. (CHNS technical resource files.)
- . Weatherwax, H.E., 1937. Seashore Park Construction in North Carolina.
Shore and Beach 5(1): 12-17.
- . Wells, B.W., 1928. Plant Communities of the Coastal Plain of North
Carolina and their successional relations. Ecology 9: 230-242.
- . Woodhouse, W.W., E.D. Seneca, and S.W. Broome, 1976. Ten Years of
Development of Man-Initiated Coastal Barrier Dunes in North Carolina.
Bulletin 453, Agricultural Experiment Station, NCSU, Raleigh, NC,
53 pp.

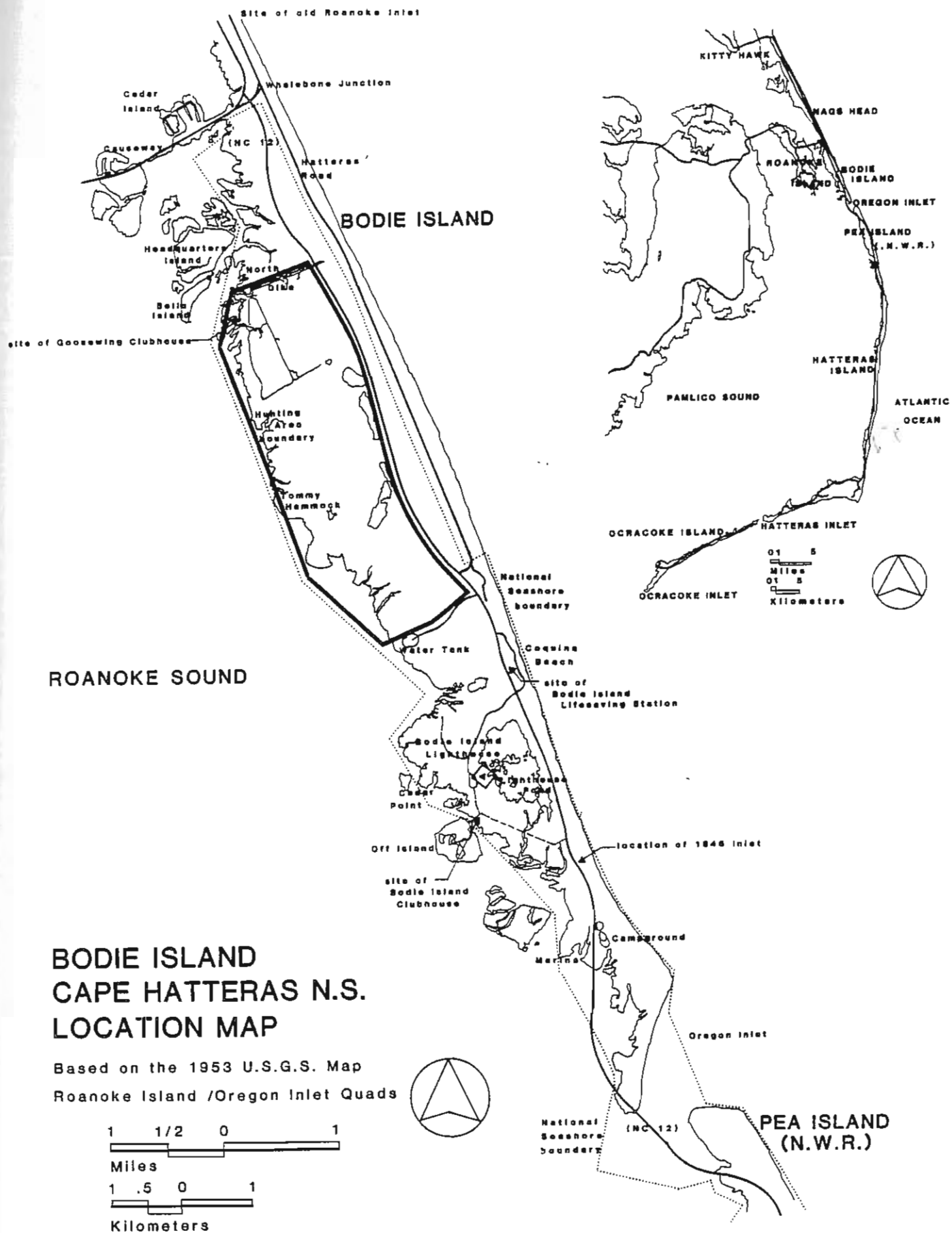


Figure 1.

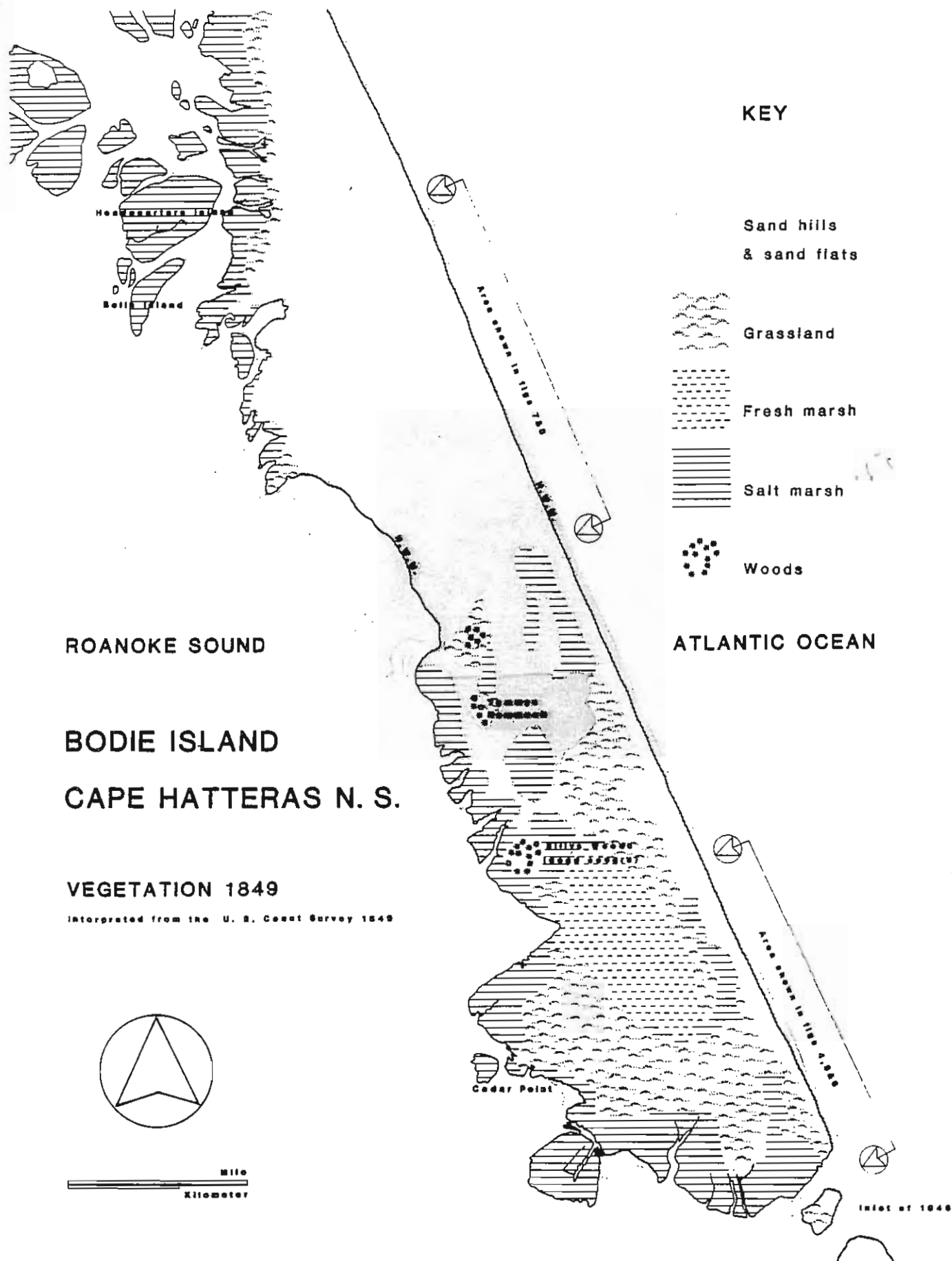
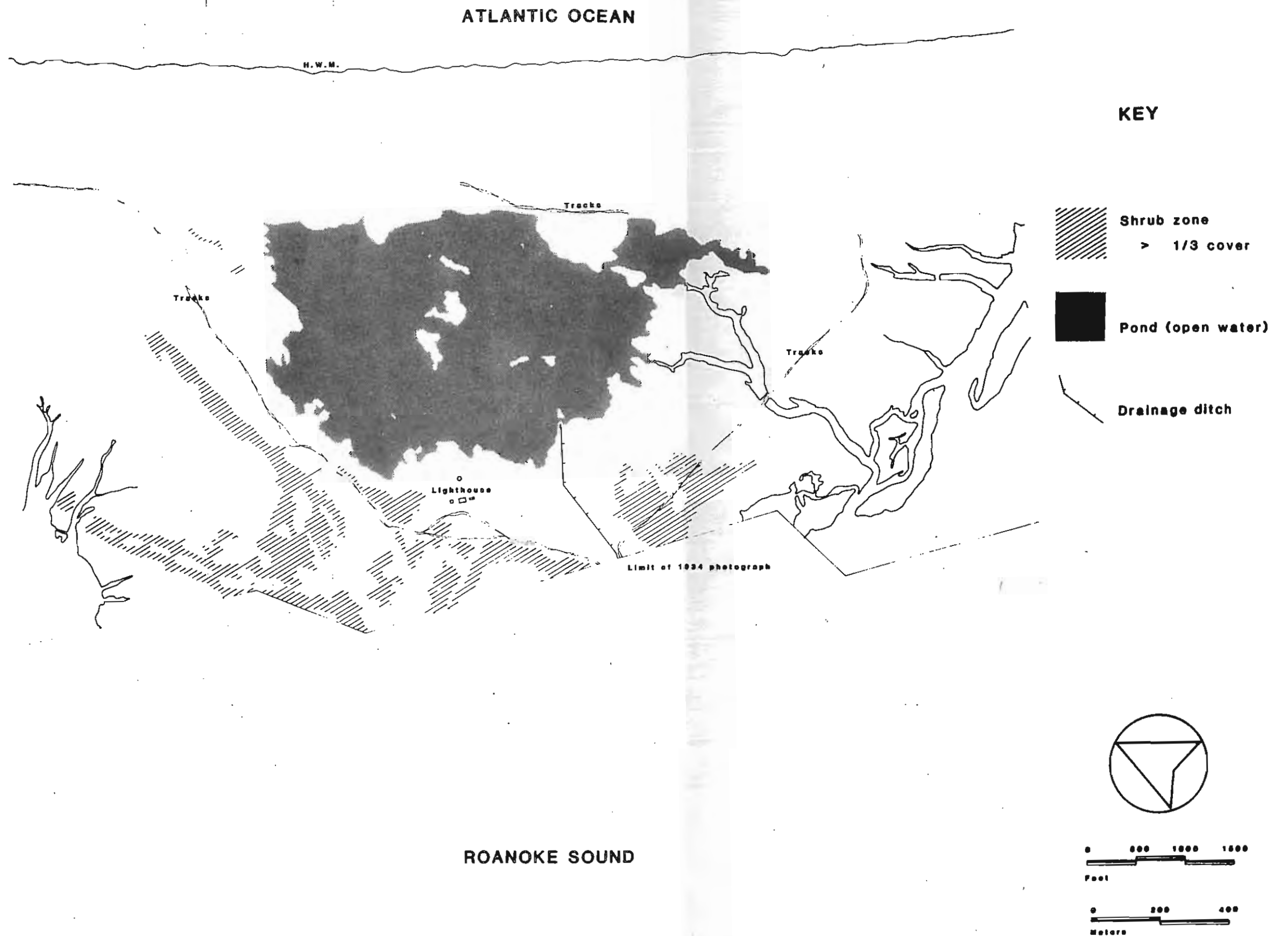


Figure 2.



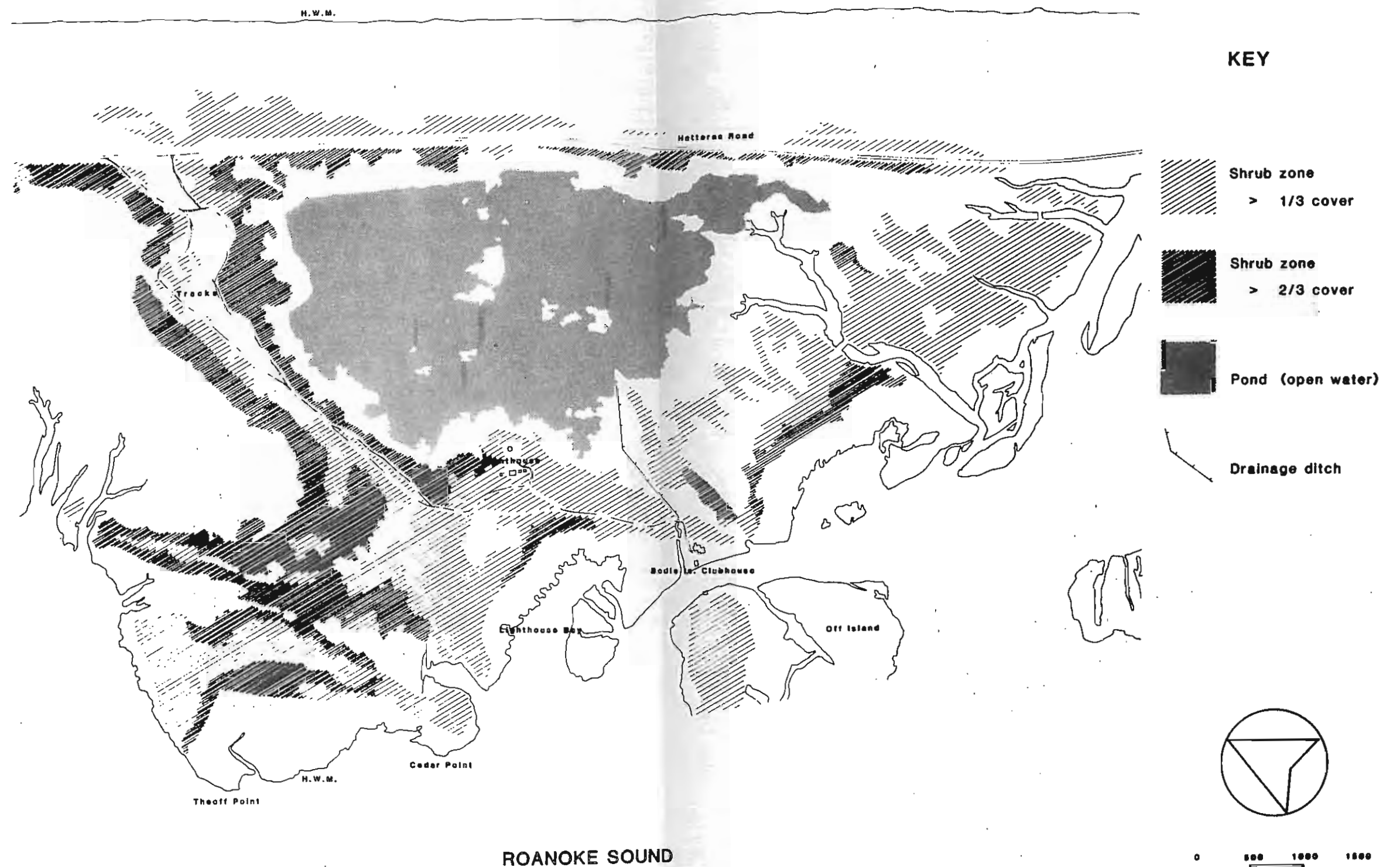
Figure 3. Stock Grazing on Bodie Island c. 1934.



Interpreted from S&W aerial photographs by I.J.W. Fifth October 1965

Figure 4.

ATLANTIC OCEAN



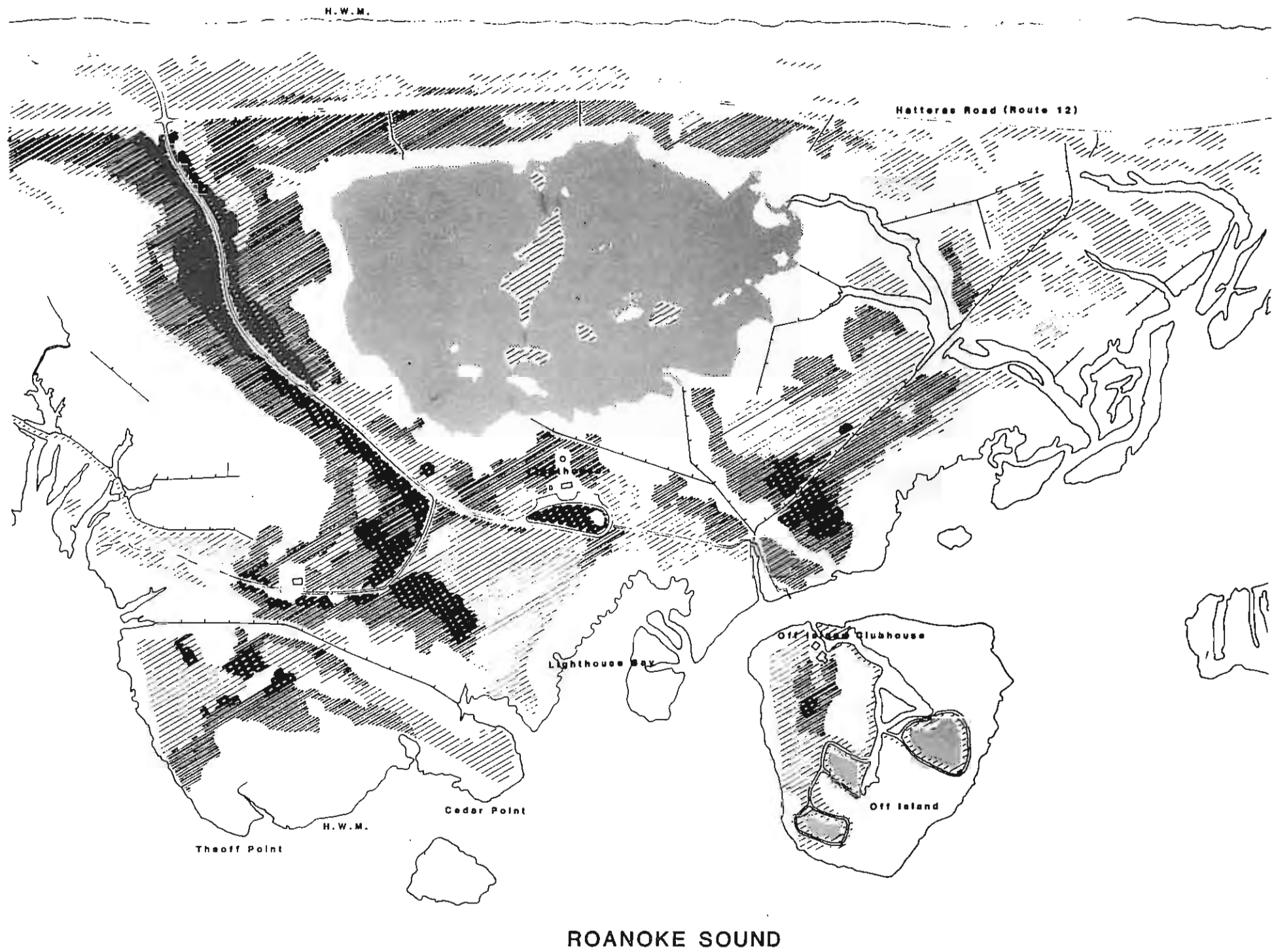
BODIE ISLAND CAPE HATTERAS N. S.

LIGHTHOUSE POND December 15 1952

Interpreted from BW aerial photographs by I.J.W. Fifth October 1955

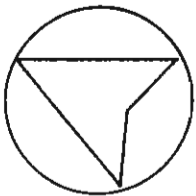
Figure 5.

ATLANTIC OCEAN



KEY

- Shrub zone
> 1/3 cover
- Shrub zone
> 2/3 cover
- Trees
- Pond (open water)
- Drainage ditch



0 500 1000 1500
Feet

0 200 400
Meters

BODIE ISLAND CAPE HATTERAS N. S.

LIGHTHOUSE POND December 1974

Interpreted from B&W aerial photographs by I.J.W. Firth October 1985

Figure 6.

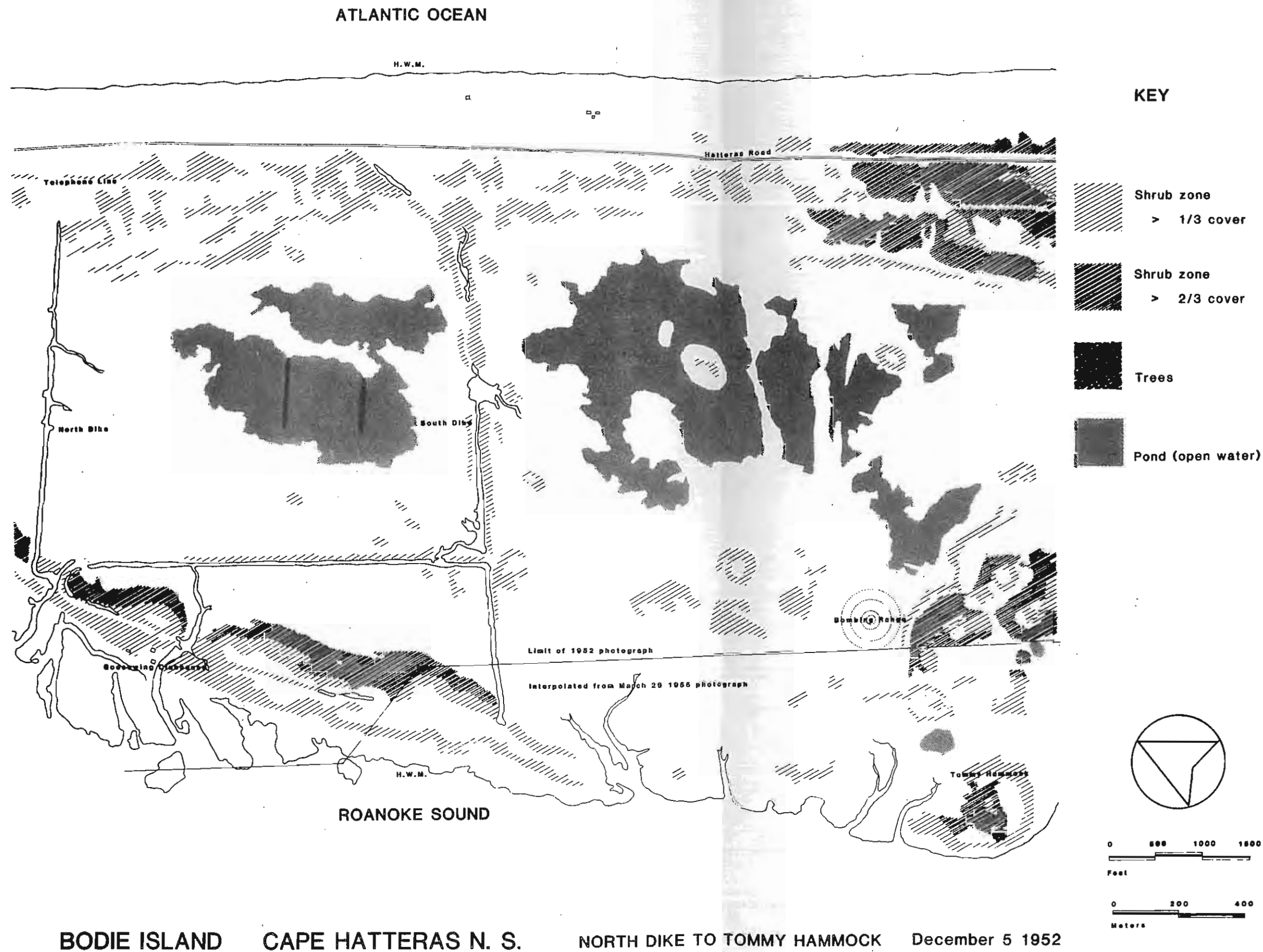
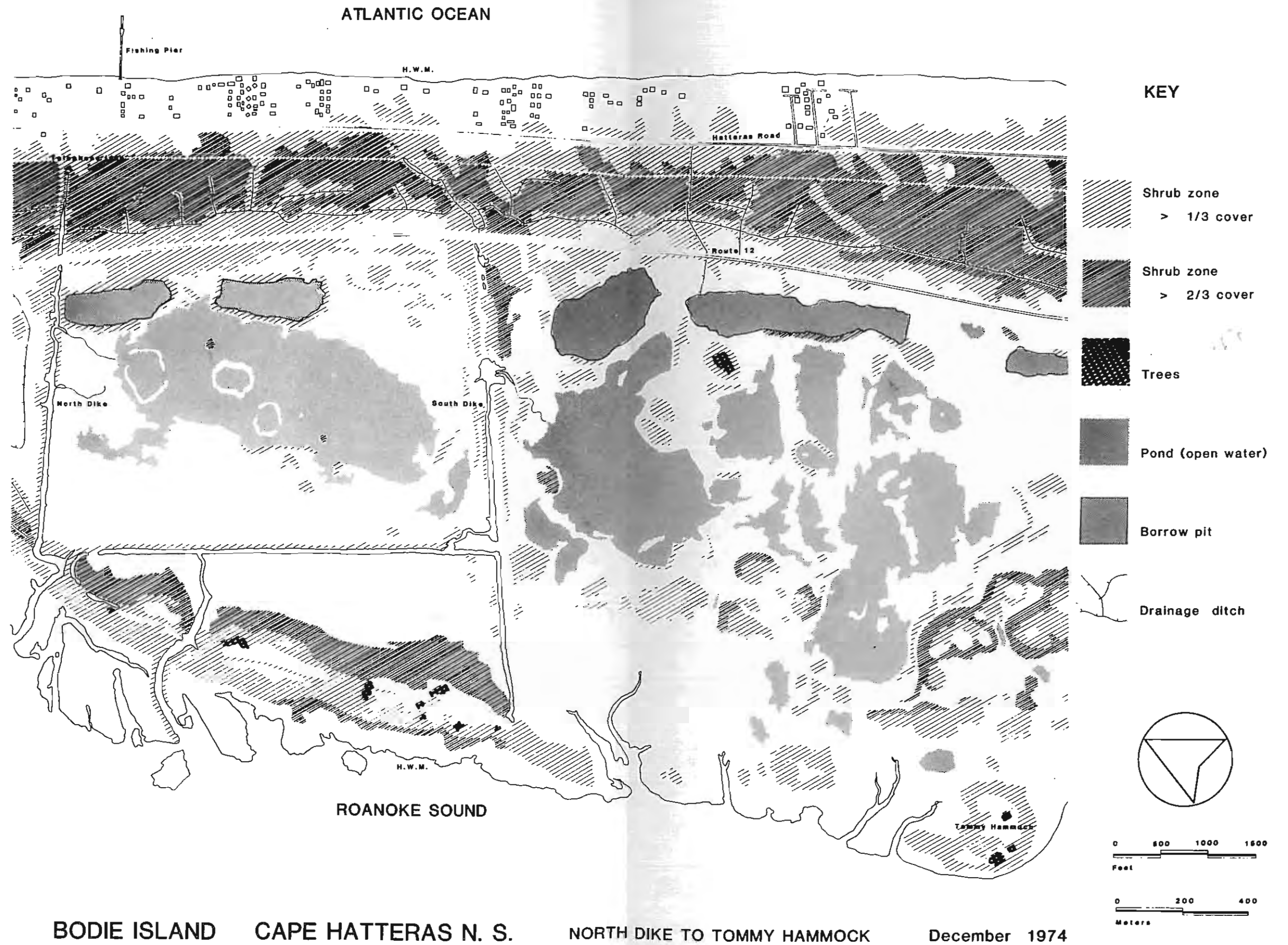


Figure 7.



BODIE ISLAND CAPE HATTERAS N. S. NORTH DIKE TO TOMMY HAMMOCK December 1974

Interpreted from B & W aerial photographs I.J.W. Firth Oct. 1985

Figure 8.

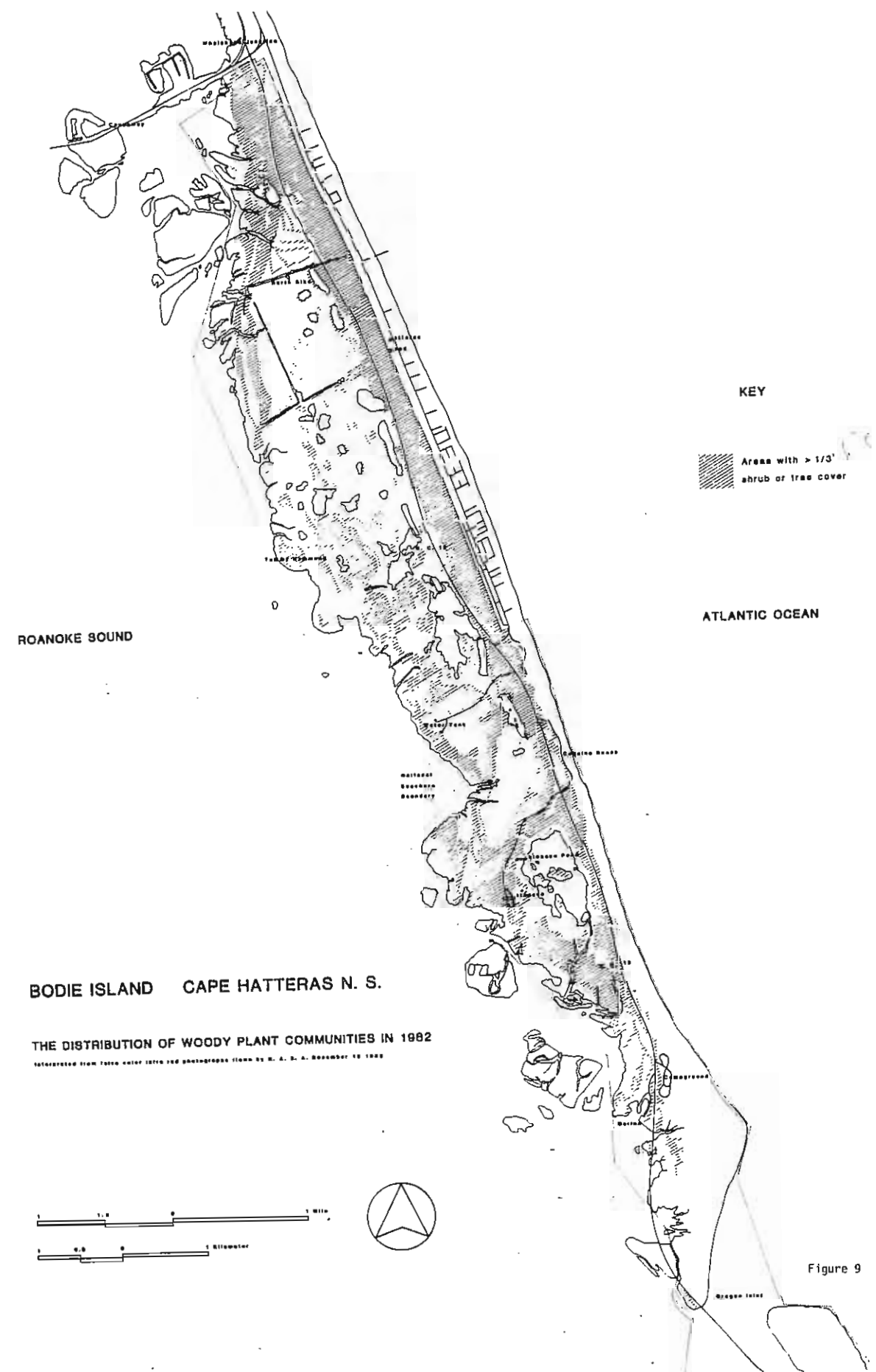


Figure 9