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SHORE ZONE LAND USE AND LAND COVER: CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE

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U.S. Geological Survey
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16. Abstract

Anderson's 1972 United States Geological Survey classification in modified form was applied to the barrier-island coastline within the CARETS region. High-altitude, color-infrared photography of December, 1972, and January, 1973, served as the primary data base in this study. The CARETS shore zone studied was divided into six distinct geographical regions; area percentages for each class in the modified Anderson classification are presented. Similarities and differences between regions are discussed within the framework of man's modification of these landscapes. The results of this study are presented as a series of 19 maps of land-use categories. Recommendations are made for a remote-sensing system for monitoring the CARETS shore zone within the context of the dynamics of the landscapes studied.

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Volume 1. CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE: A PROTOTYPE REGIONAL ENVIRONMENTAL INFORMATION SYSTEM by Robert H. Alexander

2. NORFOLK AND ENVIRONS: A LAND USE PERSPECTIVE by Robert H. Alexander, Peter J. Buzzanell, Katherine A. Fitzpatrick, Harry F. Lins, Jr., and Herbert K. McGinty III

3. TOWARD A NATIONAL LAND USE INFORMATION SYSTEM by Edward A. Ackerman and Robert H. Alexander

4. GEOGRAPHIC INFORMATION SYSTEM DEVELOPMENTS ASSOCIATED WITH THE CARETS PROJECT by Robin G. Fegeas, Katherine A. Fitzpatrick Cheryl A. Hallam, and William B. Mitchell

5. INTERPRETATION, COMPILATION AND FIELD VERIFICATION PROCEDURES IN THE CARETS PROJECT by Robert H. Alexander, Peter W. DeForth, Katherine A. Fitzpatrick, Harry F. Lins, Jr., and Herbert K. McGinty III

6. COST-ACCURACY-CONSISTENCY COMPARISONS OF LAND USE MAPS MADE FROM HIGH-ALTITUDE AIRCRAFT PHOTOGRAPHY AND ERTS IMAGERY by Katherine A. Fitzpatrick

7. LAND USE INFORMATION AND AIR QUALITY PLANNING: AN EXAMPLE OF ENVIRONMENTAL ANALYSIS USING A PILOT NATIONAL LAND USE INFORMATION SYSTEM by Wallace E. Reed and John E. Lewis

8. REMOTELY-SENSED LAND USE INFORMATION APPLIED TO IMPROVED ESTIMATES OF STREAMFLOW CHARACTERISTICS by Edward J. Pluhowski

9. SHORE ZONE LAND USE AND LAND COVER: CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE by R. Dolan, B. P. Hayden, C. L. Vincent

10. ENVIRONMENTAL PROBLEMS IN THE COASTAL AND WETLANDS ECOSYSTEMS OF VIRGINIA BEACH, VIRGINIA by Peter J. Buzzanell and Herbert K. McGinty III

11. POTENTIAL USEFULNESS OF CARETS DATA FOR ENVIRONMENTAL IMPACT ASSESSMENT by Peter J. Buzzanell

12. USER EVALUATION OF EXPERIMENTAL LAND USE MAPS AND RELATED PRODUCTS FROM THE CENTRAL ATLANTIC TEST SITE by Herbert K. McGinty III

13. UTILITY OF CARETS PRODUCTS TO LOCAL PLANNERS: AN EVALUATION by Stuart W. Bendelow and Franklin F. Goodyear (Metropolitan Washington Council of Governments)

FOREWORD

The Central Atlantic Regional Ecological Test Site (CARETS) investigation is being conducted as a demonstration project for a proposed operational land-use information service in the Department of the Interior. The underlying rationale of the CARETS project is to test the feasibility of the Earth Resources Technology Satellite (ERTS) and high-altitude aircraft data as input to an environmental information system for a 73,000 square kilometer, multistate mid-Atlantic region surrounding the Chesapeake and Delaware Bays. The collected data is being integrated into a regional environmental information system including resource inventory, change detection, and determination of environmental quality. This report is part of that broad effort, specifically it provides a resource inventory and environmental assessment of land use and land cover for a substantial portion of the shore and adjacent wetlands of the CARETS study area.

CONTENTS

TABLES

FIGURES

ABSTRACT

Anderson's 1972 United States Geological Survey classification in modified form was applied to the barrier-island coastline within the CARETS region. High-altitude, color-infrared photography of December, 1972, and January, 1973, served as the primary data base in this study. The CARETS shore zone studied was divided into six distinct geographical regions; area percentages for each class in the modified Anderson classification are presented. Similarities and differences between regions are discussed within the framework of man's modification of these landscapes. The results of this study are presented as a series of 19 maps of land-use categories. Recommendations are made for a remote-sensing system for monitoring the CARETS shore zone within the context of the dynamics of the landscapes studied.

INTRODUCTION

Barrier islands and wetlands, the primary marine interfaces of the mid-Atlantic coast, are among the most dynamic landscapes utilized by man. A wide range of environmental changes occur periodically, including those associated with tides, storms, responses to long-period geophysic and climatic trends, as well as those associated with man's development of the land.

Most of the landscape changes are manifested as changes in land use and land cover. Because of the dynamic and fragile nature of this zone, both natural and man-induced changes require monitoring to quantify the biological and physical relationships and to assure intelligent planning and management. In particular, the CARETS[1] coastline was investigated to determine the environmental types that are present and have differing compositions of land use and cover. The investigation included mapping, using a modification of Anderson's land-use classification[2], and compiling aerial statistics. The applicability of the U.S.G.S. classification to land-use mapping in the coastal zone is listed using high-altitude, color-infrared photography as a data base.

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[1] Central Atlantic Regional Ecological Test Site.

[2] Anderson, J.R., E. Hardy, and J. Roach, 1972, A Land Use Classification System for Use with Remote-Sensor Data, U.S. Geological Circular 671.

Specification of different scales and frequencies of remote-sensing which phase the monitoring of the environment with time and space scales of the changes inherent in the system are also discussed.

THE TEST SITE

Land use and land cover on the barrier islands and the adjacent wetlands were mapped for most of the shore region from Cape Henlopen, Delaware, to Cape Lookout, North Carolina. All of the barrier islands and beach zones were inventoried except for a few areas in Maryland and Delaware for which imagery was not available. Most of the adjoining wetlands, within five miles (8 km) of the shoreline, were included The imagery was obtained for December, 1972, and January, 1973.

Because the primary interests in this investigation are the barrier-island environment and the fringing wetlands, riverine or estuarine areas that extended more than five miles (8 km) inland from the islands were excluded. Although it is clear that these areas are important hydrologically and ecologically, they are only rarely subjected to physical stresses related to storms or day-to-day wave action.

Physiographically, the coastal zone along the CARETS region is a flat area extending out to a generally wide continental shelf (50 miles [80 km] or more). The coastal interface usually occurs as a series of barrier islands some 1 to 20 miles (1.6 to 32 km) offshore of the mainland, however a few stretches of mainland beach also occur as coastal interfaces. The islands are 1 to 3 miles (1.6 to 4.8 km) wide and low with the highest elevations occurring as dunes usually 10 to 20 feet (3 to 6 m) above sea level. In a few areas, unvegetated dunes 10 to 100 feet (3 to 30 m) high provide maximum relief. The vegetation consists primarily of grasses or shrubs; although in older, sheltered areas, there are pine forests. On the lagoon side of the islands, marshes are usually present; the lagoons are shallow and may have large areas of tidal mud flats and marshes (Fig. 1).

Tides in the area range from 3 to 5 feet (1 to 2 m) and wave heights average from 2 to 3 feet (.9 to 1 m). Storms do generate larger waves and are, therefore, the principal natural agents of change. Extratropical storms during winter may produce deep-water waves 15 to 30 feet (5 to 10 m) high with 2- to 5-foot (.9 to 1.8 m) storm surges. Hurricanes, which occur less frequently, also cause major landscape changes.

Man's development of the CARETS shore zone is limited to Ocean City, Virginia Beach, and several areas along the Outer Banks of North Carolina.

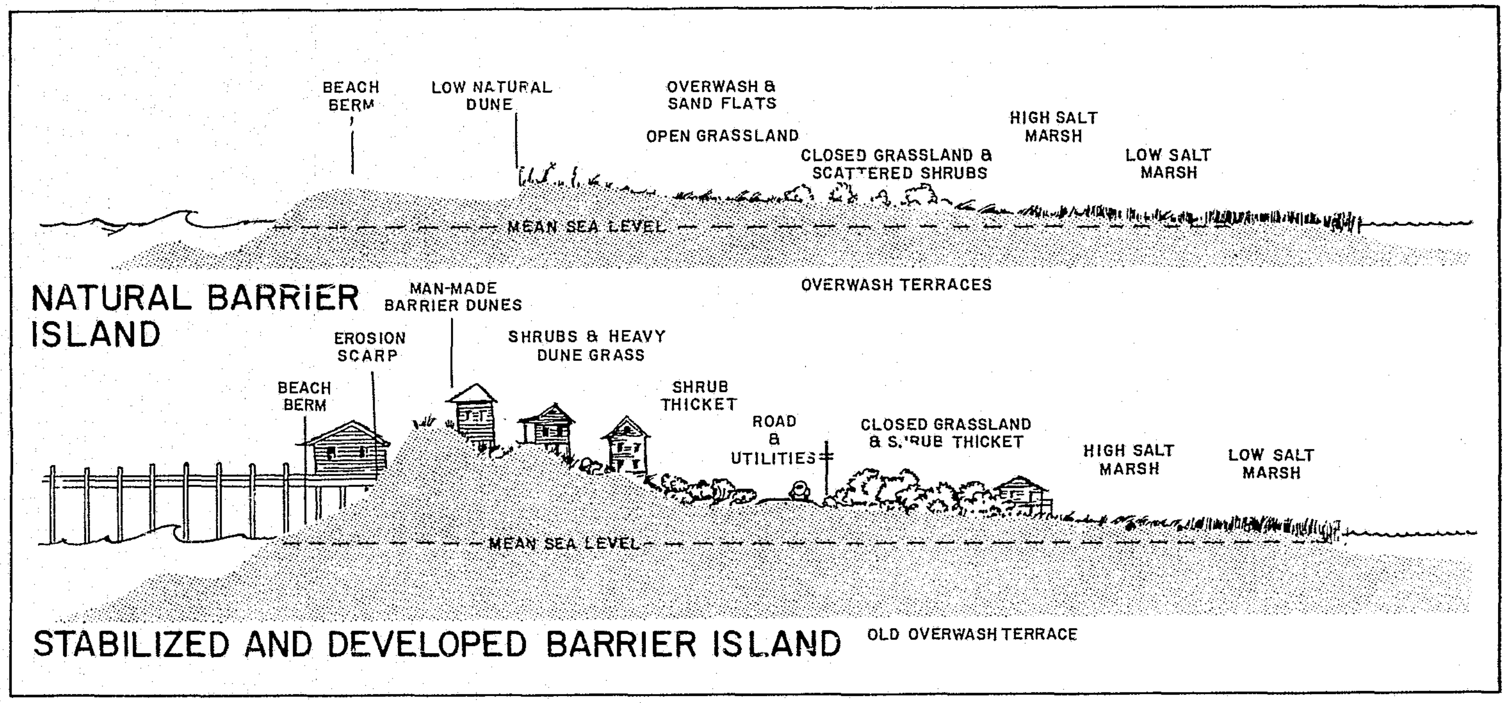

Figure 1: Natural and Man-Made Barrier-Island Environments

THE DATA

The primary data base for this mapping effort included (1) ERTS-1 imagery; (2) high-altitude (U-2), color-infrared imagery at a scale of about 1:120,000; (3) aerial photography (1:6,000) supplied by NASA Wallops Island; and (4) various sets of historical, low-level aerial photography. Because of the test-nature of the project and because the maps are not intended to be a definitive survey, ground verification was limited to only a few sites.

LAND CLASSIFICATION

Land cover and land use on the barrier islands and adjacent wetlands were mapped using the guidelines of Anderson's 1972 Circular 671, U.S. Geological Survey; the classes are given in Table 1 and illustrated in Figure 2. Because Anderson's classes were too broad in several instances, they were subdivided so that they would represent important differences in the barrier-island and wetlands environments. For example, grasslands were subdivided into classes representing vegetated sand flats and vegetated dune systems, primarily of grass and scrub growth. Other modifications of Anderson's classification are indicated on Table 1.

The geographic context in which each of the land-cover and land-use classes are found is given in Table II. The

TABLE I

Biophysical Processes of Land-Use Classification

Code	Land-Use Classification	Biophysical Processes
10	Urban	Storm surge
21	Grass and pasture lands	Surface runoff
31	Vegetated sand flats (grass)	Eolian; overwash
35	Vegetated dune systems (grass)	Eolian; wave erosion (frontal)
43	Forests	Surface runoff
53	Reservoirs	Siltation
54	Estuaries and bays	Tidal currents
55	Fresh-water ponds	Rainfall runoff
61	Marshes	Biological; tidal overwash
62	Mud flats	Tidal
72	Beaches	Waves: Tides Storm waves: Surge
731	Dunes: Unvegetated	Eolian
732	Sand flats: Unvegetated	Eolian overwash
75	Spoil banks	Tidal: Surface runoff

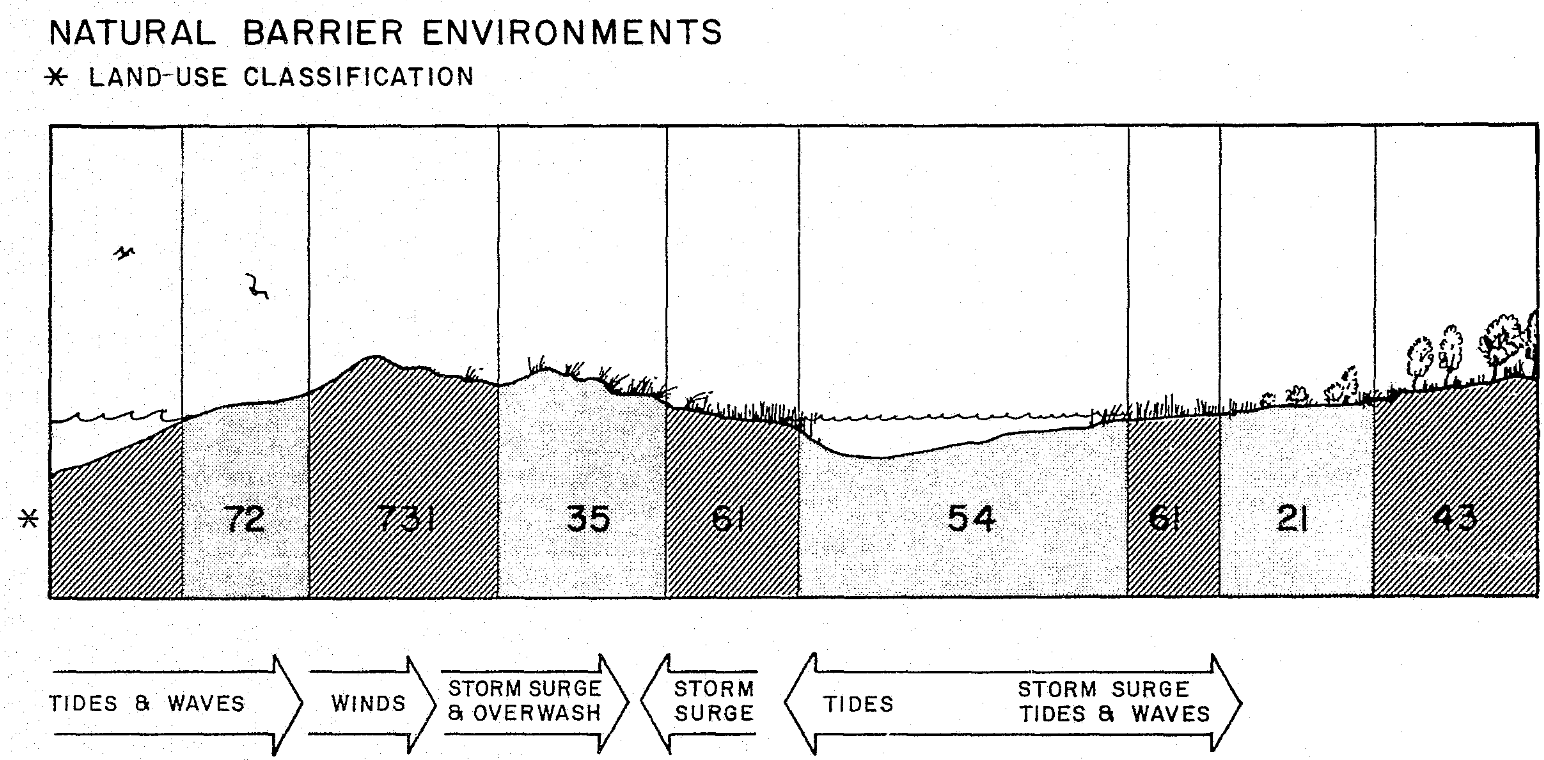

Figure 2. Natural Barrier-Island Environments, Land Classification and Associated Processes.

TABLE II

Geographic Context of Land-Use and Land-Cover Classes

Code	Primary Location*	Vulnerability	Stability
10	Barrier islands: Filled marshes	Moderate	Stable
21	Adjacent mainland: Pleistocene islands	Low	Stable
31	Barrier islands: Inland of barrier dunes	Moderate	Stable
35	Barrier dunes: Adjacent to beach on barrier islands	Low	Stable
43	High ground: Most often near sound on barrier islands	Low	Stable
53	Adjacent mainland	Low	Stable
54	Waters: Between islands and mainland	High	Unstable
55	Barrier islands: Sometimes man-made	Moderate	Stable
61	Marsh: In estuaries and bays or inland edge of barrier islands	Moderate	Unstable
62	Mud flats: Primarily in estuaries bays, more rarely in fringe islands	Moderate	Unstable
72	Beaches: Seaward edge of barrier islands, includes overwash fans if they are contingent to the beach	High	Unstable
731	Dunes: Interior of barrier islands, often denuded ancient dunes	Moderate	Stable
732	Sand flats: Interior of barrier islands or adjacent to tidal inlets	Moderate	Stable
75	Spoil banks: Along dredged channels	Moderate	Stable

Stable = relatively insensitive to activity

Unstable = easy to move out of balance.

Vulnerability high = natural changes occur frequently representing risk for development.

Moderate = danger from flood or surge.

Low = natural change low.

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*For extended explanations see Appendix II.

principal processes responsible for natural changes or for the origin and maintenance of these changes are listed on Table I and III; Table III gives the normal period of landscape response to these processes. An overriding factor for all classes responding on a daily basis is the occurrence of extreme or episodic events which may cause catastrophic land alteration. In marshes, in estuaries, and on the beaches, a major oil spill or a dump of toxic pollutants can be considered an extreme event; however, for the remainder of this report, the term will be used to indicate a storm of such magnitude that on a yearly basis it has a low expectation of recurrence.[3]

An assessment of the stability and vulnerability of land-use types is presented in Table II. Stability of the land classes is intended to provide a general indication of how moderate, developmental stresses, such as construction of buildings and roads, would change the natural landscape. Vulnerability of the classes indicates how vulnerable unprotected structures would be to natural stresses from storms. In both cases, the assessments must be taken as suggestive of the frequency

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[3] Episodic events are defined as those which occur several times a year but are clearly predictable; i.e., extratropical storms.

TABLE III

Altering Processes and Response Periods

Code	Land-Use Classification	Period of Response	Events Causing Alterations
10	Urban	Episodic	Construction; storm damage
21	Grass and pasture lands	Slow trends	
31	Vegetated sand flats	Daily; Extreme events	Storm deposition of sand; denudation
35	Vegetated dune systems	Daily; Extreme events	Storm erosion of dune mass; denudation
43	Forests	Slow trends	Denudation
53	Reservoirs	Slow trends	Siltation
54	Estuaries and bays	Daily	Pollution; alteration of flow patterns
55	Fresh-water ponds	Daily	Siltation; salt-water intrusion
61	Marshes	Slow trends; Extreme events; Daily	Overwash; deposition of sand, man-made; Land fill; restriction of water flux
62	Mud flats	Daily	Current erosion; revegetation
72	Beaches	Daily (seasonally); Extreme events	Storm-caused erosion; sea-level trend
731	Dunes: Unvegetated	Daily	Vegetation
732	Sand flats: Unvegetated	Daily	Overwash deposition; revegetation
750	Spoil banks	Daily	Revegetation; erosion

and magnitude of natural stress or the fragile nature of a particular land-use class. For each class these terms could be definitively stated, but such an attempt is beyond the scope of this initial effort.

In the mapping of land use and land cover, only a few serious problems were encountered. One problem was how to determine the boundary between marsh and mud flat areas because of the fluctuating tide; however the margin of possible error appears small. A second problem involved the inland extent of mapping; in many areas, riverine and estuary marshlands and waters extended considerably inland. The most important exclusions are the large open-water estuaries in North Carolina. These lagoons are often 20 miles (32 km) wide and have riverine arms that extend 40 miles (64 km) or more inland. Although they are important elements of the coastal interface in North Carolina, they provide little additional information about the expected nature of the barriers and beaches fringing the coast.

RESULTS

The land use and land cover of the CARETS shore zone is displayed in the maps of Appendix III. Analysis of these maps indicates that the CARETS shore zone can be divided into six clearly separate geographical regions (Fig. 3).

Aerial statistics of land use and land cover are compiled and presented in Table IV for four of these six regions (II, III, V, VI). Some care must be taken when using these statistics for comparison because they are not based upon fixed base areas; and the estuary and marsh classes do not consistently include all applicable areas because of the problems involved in defining the shore zone which have previously been described.

I. Delaware Bay, Delaware, to Ocean City, Maryland

This region is a combination of mainland beaches with few "typical" shore-zone characteristics extending inland. There are several short, narrow baymouth barriers with small estuaries, bays, and marshes. The coastline is primarily mainland beach, however; and the region is highly developed. Shoreline erosion is considered a serious problem.

II. Ocean City, Maryland, to Wallops Island, Virginia

Long, narrow barrier islands with moderately wide lagoons (2-10 miles [3 to 16 km]) are found in this

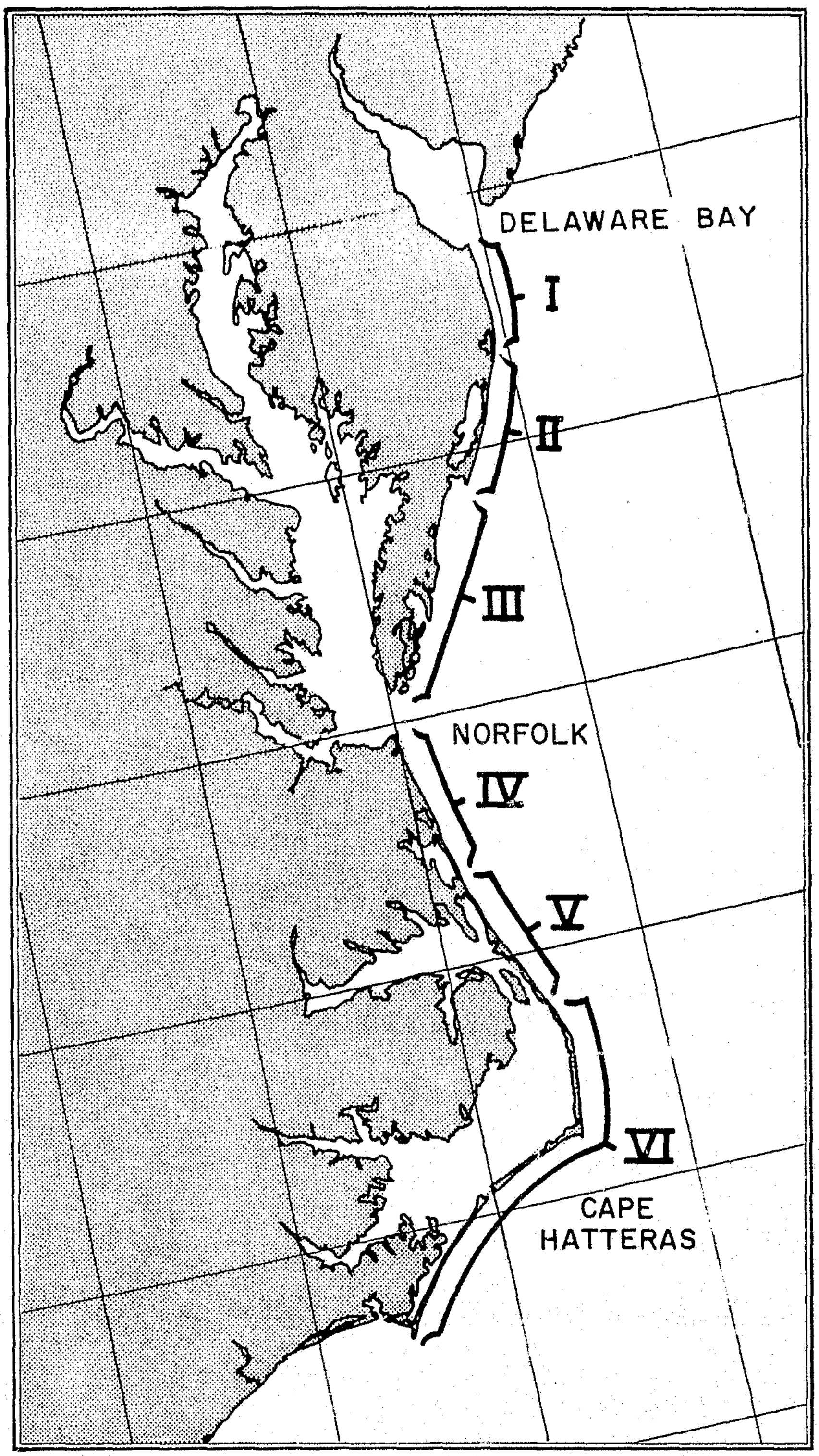

Figure 3. Location Map of Mid-Atlantic Shore Zone - CARETS. Regions of Similar Barrier-Island Environments are Indicated.

TABLE IV

Percentage of Areas in Land-Use Classes

Land-Use	(Code)	II	III	V	VI*
Urban	(10)	0.8	0.5	4.9	4.3
Grass and pasture lands	(21)	0.2	0.0	0.6	0.0
Vegetated sand flats (grass)	(31)	0.5	0.0	1.3	4.2
Vegetated dune systems (grass)	(35)	1.7	0.0	2.0	3.6
Forests	(43)	5.3	2.6	7.2	9.1
Reservoirs	(53)	0.0	0.0	0.1	0.0
Estuaries and bays	(54)	72.4	40.8	58.9	48.3
Fresh-water ponds	(55)	1.5	0.0	0.3	0.5
Marshes	(61)	14.1	52.5	19.8	19.9
Mud flats	(62)	0.1	0.0**	0.0	2.5
Beaches	(72)	1.7	3.4	1.1	0.0
Dunes: Unvegetated	(731)	0.9	0.1	3.5	4.3
Sand flats: Unvegetated	(732)	0.7	0.0	0.0	3.4
Spoil banks	(75)	0.0	0.0	0.3	0.0
Total Area Sampled	(Mi^2)	189	50	363	253

* Excludes large estuarine areas
** Present in adjacent areas not sampled

region. The islands are usually less than 2 miles (3 km) wide and very low with overwash terraces and fringing marsh areas.

Over 70 per cent of the land cover in the sampled area are estuaries and bays and 14 per cent are marshes (Table IV); however, most land-use types are represented. A large percentage of the land is in an ancient forested dune system, primarily in the Chincoteague region. The beach system is relatively narrow compared to other sand-related landforms and the shoreline is receding very rapidly. As a result, small overwash fans are present where the dune system has been breached.
Most of the area is undeveloped.

III. Wallops Island to Chesapeake Bay, Virginia

In this region there are complex islands with lagoons which are usually filled by mud flats and marshes. The islands are up to 3 miles (5 km) wide with forest and marsh areas. The beaches appear as a lens of sand pushed over the marsh. These islands are receding at a rate of several feet a year.

The areal distribution of land cover in this region is weighted heavily towards marsh and estuaries (53%

versus 41%), with few dunes or forest areas; the area not sampled because of insufficient imagery does contain large areas of mud flats which would reduce the percentage of the area in marsh and estuary classes. Again, the area is sparsely populated. At many points the deposits of sand are only a thin veneer as shown by the high ratio of beaches to other sand bodies (Table IV). Small overwash fans are numerous and contingent with the beach.

IV. Virginia Beach to Sandbridge, Virginia

This region consists of a combination of mainland beaches and small barrier islands similar to Region I. In the vicinity of Cape Henry, Virginia, there is a large, relic dune-ridge system unequalled in size throughout the CARETS region. The area is highly developed; Virginia Beach serves as the recreational center for the large, Norfolk urban complex.

V. Sandbridge, Virginia, to Oregon Inlet, North Carolina

The barrier-beach lagoon landscape of this segment of the coast is similar to Region II. Although this area is now a peninsula, at times it has been cut into islands by tidal inlets which have been opened by storms.

A large percentage of the land area is in estuaries and marshes (Table IV) but the landscape is highly diverse with forests and dunes. Large, unvegetated, active dunes, not present elsewhere in the entire test area, are common in this region. Rapid development is underway as indicated by Table IV; marsh areas are being filled and boat channels are being cut into the island from the sounds. The Kitty-Hawk-to-Nags-Head reach is a 25-mile (40 km) section of continuous development.

VI. Oregon Inlet to Cape Lookout, North Carolina

This area is similar to Region II and to Region V immediately to the north. In most places this region is separated from the mainland by a wide estuary[4] (30 miles [48 km]). The coast is receding rapidly causing extensive property damage. The segment of this region north of Ocracoke Island has been highly modified by man through an extensive dune-stabilization program initiated during the 1930's by the CCC and WPA under the direction of the National Park Service. Almost 3,000,000 feet of sand fencing were erected to create a continuous barrier dune along the Outer Banks--including Hatteras, Pea, and Bodie Islands. Most of this construction took

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[4]The estuary area is not included in Table II statistics.

place in the zone comprising the original low beach dunes and a strip 100 to 300 feet (30.5 to 91.4 m) wide behind the fore dune. This was augmented in the late 1950's by the National Park Service so that at present almost a continuous mass of vegetation blankets the barrier island from South Nags Head to the southern tip of Ocracoke Island.

This program of environmental modification is clearly evident on the imagery; the beaches are narrow and the sand flats immediately inland from the artificial barrier dune are densely vegetated. The great heights of the stabilized dunes divert salt spray from the zone directly inland and prevent flooding and overwash. Because of this protection, the shrub communities normally found well back on the sound sides of the islands have spread seaward. Overwash terraces are impossible to detect with the exception of areas where the man-made barrier dune has been breached. South of Ocracoke Island, the barrier islands are essentially in a natural state; they are undeveloped.

DISCUSSION

Of the six regions, Regions II and V are the most similar. Both have barrier islands 2 to 5 miles (3 to 8 km) from the mainland with lagoons fringed by marsh areas. The primary difference is the large area of unvegetated dunes in Region V not present in Region II. A second difference is indicated by comparison of the class "beaches" with the more unvegetated "sand flats" in Region II.

The barrier islands of Region VI are similar to those of Regions II and V; however, with the exception of the southernmost area near Cape Lookout (Core Banks, North Carolina), the islands are isolated from the mainland by 15 to 20 miles (24 to 32 km) of open water. Thus, when considering the entire interface, Region VI is unique.

Of the remaining three regions (I, II, IV), Regions I and IV are similar. Both have short barriers as well as long reaches of mainland beach. In Region IV at Cape Henry there is a large, ancient dune complex now densely vegetated. Since the shore zone in these areas is relatively compact, often less than one mile in width, no statistical compilation is provided.

The most anomalous region in CARETS is Region III, known as the Delmarva Peninsula. This landscape consists of wide (3 to 10 miles [5 to 16 km]) lagoons that are almost completely filled by marsh and mud flats. The islands are of variable width with the widest having the most complex topography (dunes, etc.). The narrow islands can best be described as narrow overwash deposits on lagoon marshland. This region has the greatest number of tidal inlets.

MAN'S USE OF THE BARRIER ISLANDS

Many of the shoreline areas along the mid-Atlantic coast have undergone intensive development and modification by man. Fresh-water supplies are taxed and waste products have changed the ecological balance of adjacent coastal areas. The interconnectivity of the waterways paralleling the intensely developed areas preclude their independence from adjacent natural or undeveloped regions.

Homes and commercial facilities constructed dangerously close to the sea, like the natural landscape, are at best ephemeral. Each year, the wide range of natural landscape changes by marine processes takes its toll in human resources with costs measurable in millions of dollars.

Historically man's occupation of shoreline areas has been inversely related to the natural stresses characteristic of the various landscape units. That is, the most intense developments are dangerously close to the sea while more stable landscape components often remain undeveloped.

This inversion stems from man's strong desire to be near the water's edge, even though this location clearly introduces a high-risk factor into development.

Land-use maps, when based upon an understanding of physical and ecological processes and landscape responses, serve as an important data base for establishing relationships between environmental dynamics and man's use of the land. In the coastal zone, land-use maps and environmental classifications can be powerful predictive tools of landscape stability and vulnerability. The establishment of regional similarities and differences permits management decisions to be made based upon the nature of the environment as a system rather than on the transient characteristics of individual sites.

Our mid-Atlantic coast shoreline resources are finite; not so much because of the attribute of consumption, but rather because barrier islands, beaches, and wetlands are among the most ephemeral of the natural landscapes. Beaches, barrier islands, and dunes are only temporary in location and form; and the dynamic nature of these systems is intimately linked to their aesthetic appeal and recreational potential. Man's development of these areas has been rapid but his understanding of the system and his ability to develop commensurate land-use strategy and policy is at best evolutionary.

Historically we have tended to the health of the shoreline areas with cures for already existing crises rather than by obviating new crises. A major step toward more intelligent management of the shoreline landscapes was the passage of the National Environment Protection Act in 1969 which required a public presentation of land use and a predicted impact analysis before construction and/or environmental modification are permitted.

CONCLUSIONS

Analysis of the land-use and land-cover maps provides a stratification of the CARETS shore areas into regions which have a similar environmental organization. In addition, analysis of the important change-forcing processes for each land-use and land-cover type (Table I) provides a basis for estimating the time period when different elements of the landscape should be monitored.

Different elements of the landscape are naturally altered less frequently as one moves inland. Thus, although the marsh environment fringing the mainland undergoes constant tidal action, major alteration in this area, such as erosion by a tidal creek, occurs very slowly. Near the beach, however, the dune system may be eroded or breached several times a year. The sand flats and marshes behind these dunes may also be stable unless dune-field erosion allows storm-surge overwash with flooding and with deposition of sand to occur in formerly stable land areas.

Man's actions when developing the landscape are by no means random; but the rate of development is likely to vary highly from region to region as well as within each region; therefore, the proper time interval for monitoring man's alterations of the environment is a function of activity.

Based upon the gradient of alteration frequency across the shoreline zone of the mid-Atlantic coast, the proper design of an environmental monitoring program should focus on the areas nearest the beach. In these areas a higher frequency of monitoring is needed than is needed in the inland areas, including the marsh and estuarine areas. In these environments, changes may only be brought about by the most severe storms; therefore, the sampling of inland areas can be independent of the sampling of beach areas. Based upon this investigation, the following recommendations are made for a remote-sensing system for monitoring the CARETS shore zone:

I. ERTS-1 satellite imagery provides a low-resolution data base for monitoring large-scale changes in the coastal zone. Although the resolution of this type of imagery is too low to allow mapping of small changes (Level II), it is the only remote-sensing system capable of providing metric imagery of the entire shore region at frequent time intervals. This type of imagery can also be used to assess the region-wide impact of major storms by indicating the distribution of overwash sites and the opening or closing of inlets. It can also be used to monitor the recovery of the system after a storm. Over broad regions, this would be otherwise impractical.

II. High-altitude overflights are required for the entire width of the shore zone at intervals of every 2 to 5 years. The objective would be to provide a high-resolution data base for determining whether or not long-term changes (trends) in the inland areas are occurring. The interval between flights could also depend, in some cases, upon the rate of man's development in the area under consideration. Satellite imagery, such as that provided by ERTS-1, may possibly fill this need except in those areas nearest the shoreline where higher resolution is needed.

III. Low-altitude overflights over the beaches, islands, and wetlands must be made more frequently. Since the primary forcing processes are generated by storms, the monitoring program might be keyed to the occurrence of storms of a particular intensity. The objective would be to determine how storm surge and overwash processes modify the more stable land-cover and land-use classes.

In both instances, the purpose would be to detect the patterns of a major change. Should either level of the program indicate that rapid or serious changes are occurring, the frequency of the monitoring would be increased. Additionally, the regionalization of the shore zone indicates that in certain areas, such as from Oregon Inlet south, low-altitude remote sensing is all that would be required because the zone is primarily water.

APPENDIX I

Key to Land-Use Maps

Code	Land-Use Classification
10	Urban
21	Grass and pasture lands
31	Vegetated sand flats
35	Vegetated dune systems
43	Forests
53	Reservoirs
54	Estuaries and bays
55	Fresh-water ponds
61	Marshes
62	Mud flats
72	Beaches
731	Dunes: Unvegetated
732	Sand flats: Unvegetated
75	Spoil banks

APPENDIX II

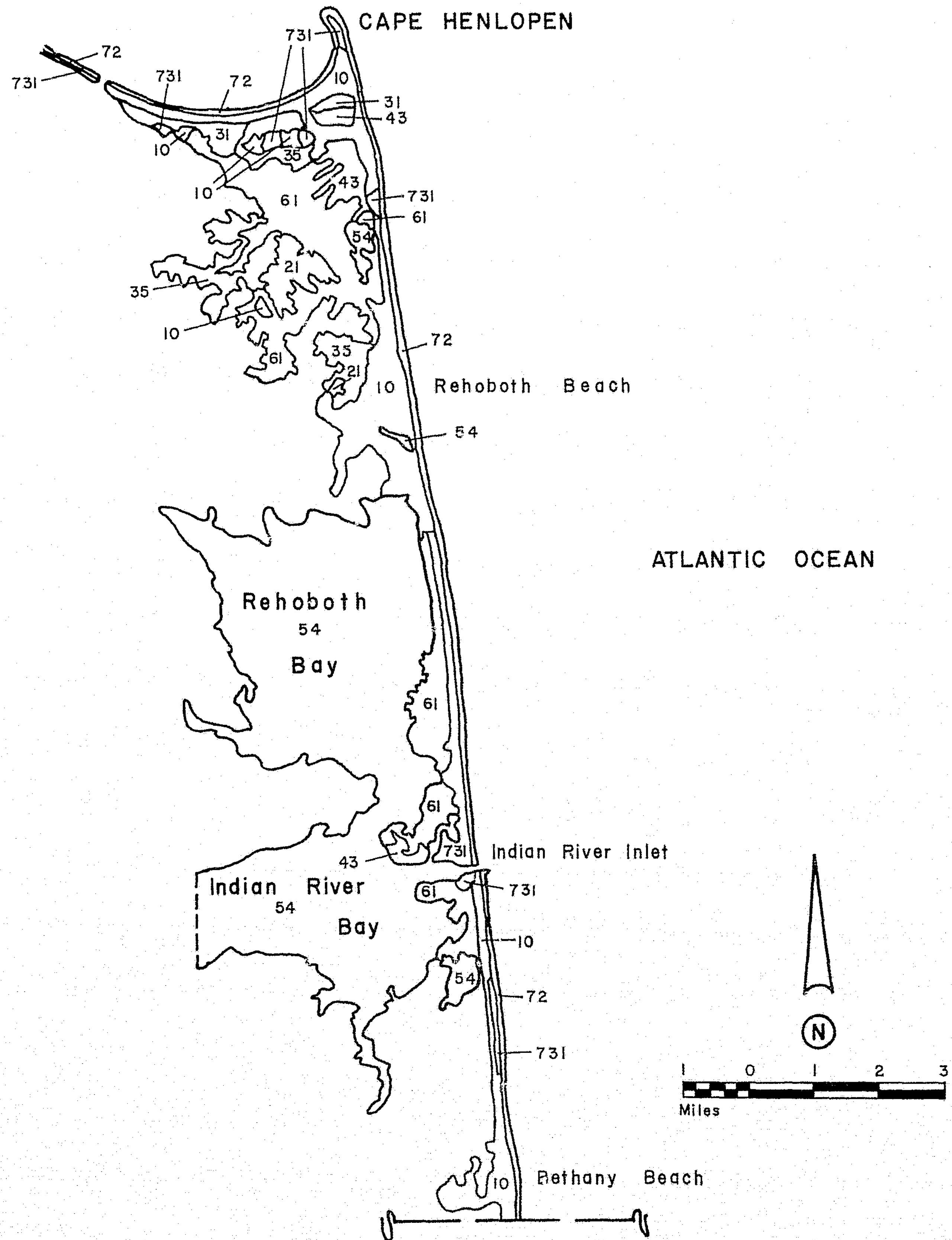
CATEGORY	FURTHER EXPLANATION
10 Urban	Along the CARETS shore, there are few densely urban areas. However, small hamlets and loosely developed recreational areas exist in many locations. For this mapping effort, all areas highly modified for urban purposes are included as urban even though this may include a considerable percentage of adjacent property.
31 Vegetated Sand Flats	These include sand flats heavily vegetated with grass or scrub growth. In future efforts some measure of percentage of coverage might be appropriate.
35 Vegetated Dunes	Dunes heavily vegetated with grass or scrub growth are included but not those with stands of trees (see 43). Stabilized barrier dunes are included often but many times are too small to be mapped.
43 Forests	Primarily includes pine woods. In most areas these are on high ground and on the barrier islands may be associated with large ancient dune ridges.
62 Mud Flats	This unit includes unvegetated tidal flats, both mud and sand. Often on the barrier islands lowlying sand flats were inundated at the time of photography and are hence classified as tidal flats. The term sand flats was reserved for those areas typically dry.
731 Dunes - Unvegetated and	Both units are primarily open sand, although sparse vegetation may be evident.
732 Sand Flats Unvegetated	As with 31 and 35, a criterion for degree of vegetation is needed.

APPENDIX III

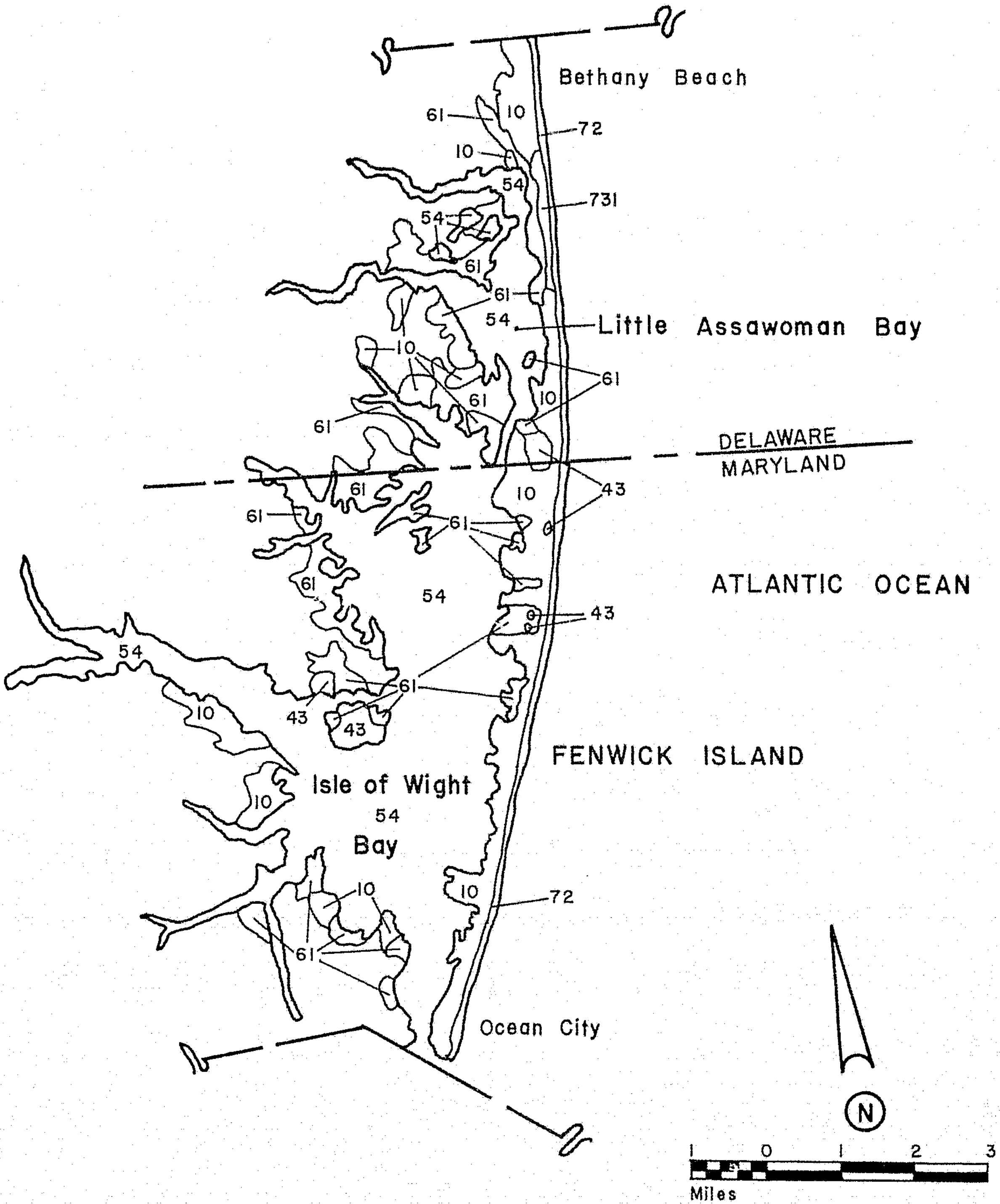
Maps of land cover and land use on barrier islands and adjacent wetlands from Cape Henlopen, Delaware, to Cape Lookout, North Carolina, using the guidelines of Anderson's 1972 Circular 671, U.S. Geological Survey.

The primary data base for these maps were: ERTS-1 imagery; high-altitude (U-2), color-infrared imagery; and various sets of aerial photography.

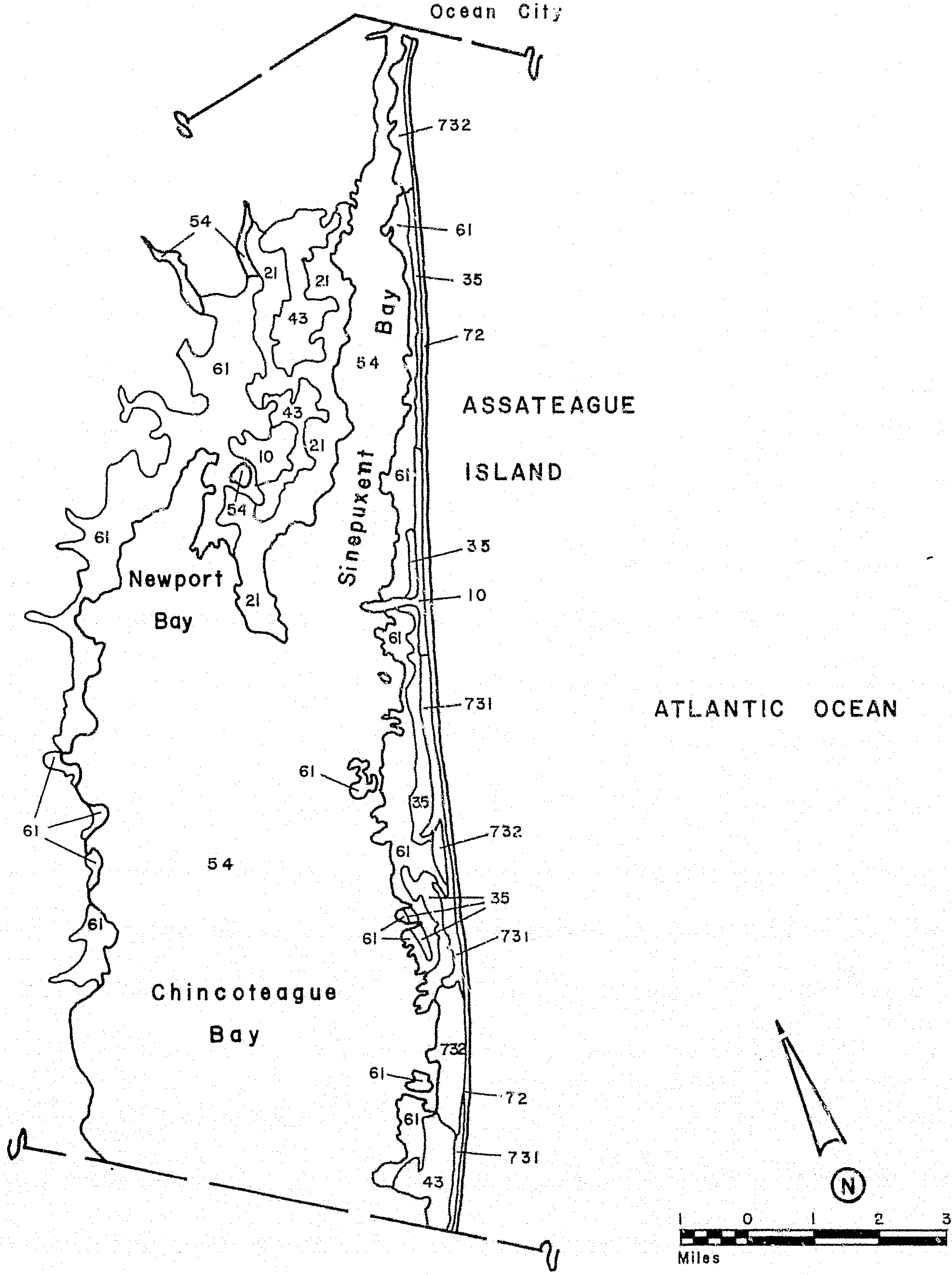
MAP No. 1 — CAPE HENLOPEN



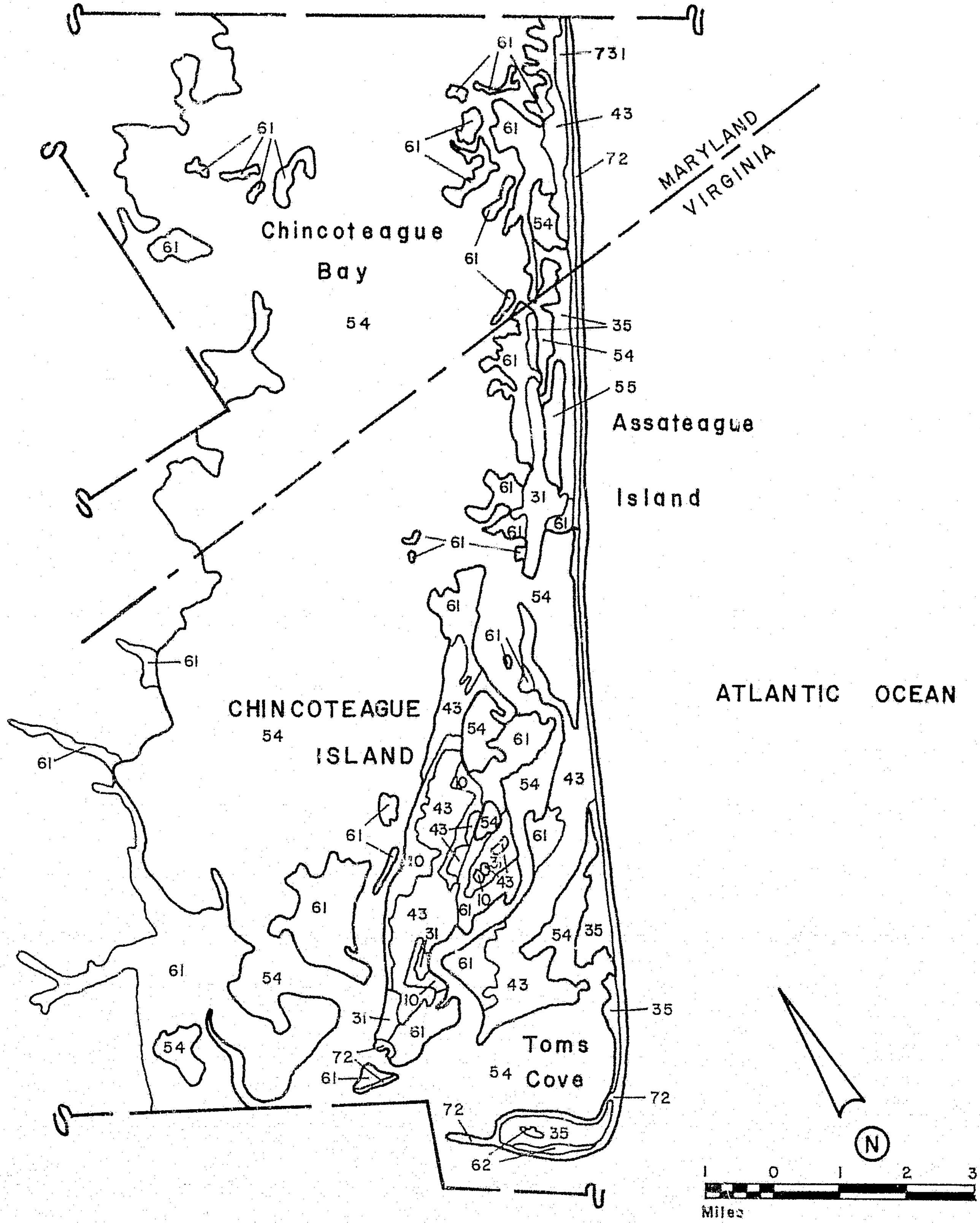
MAP No. 2 — FENWICK ISLAND



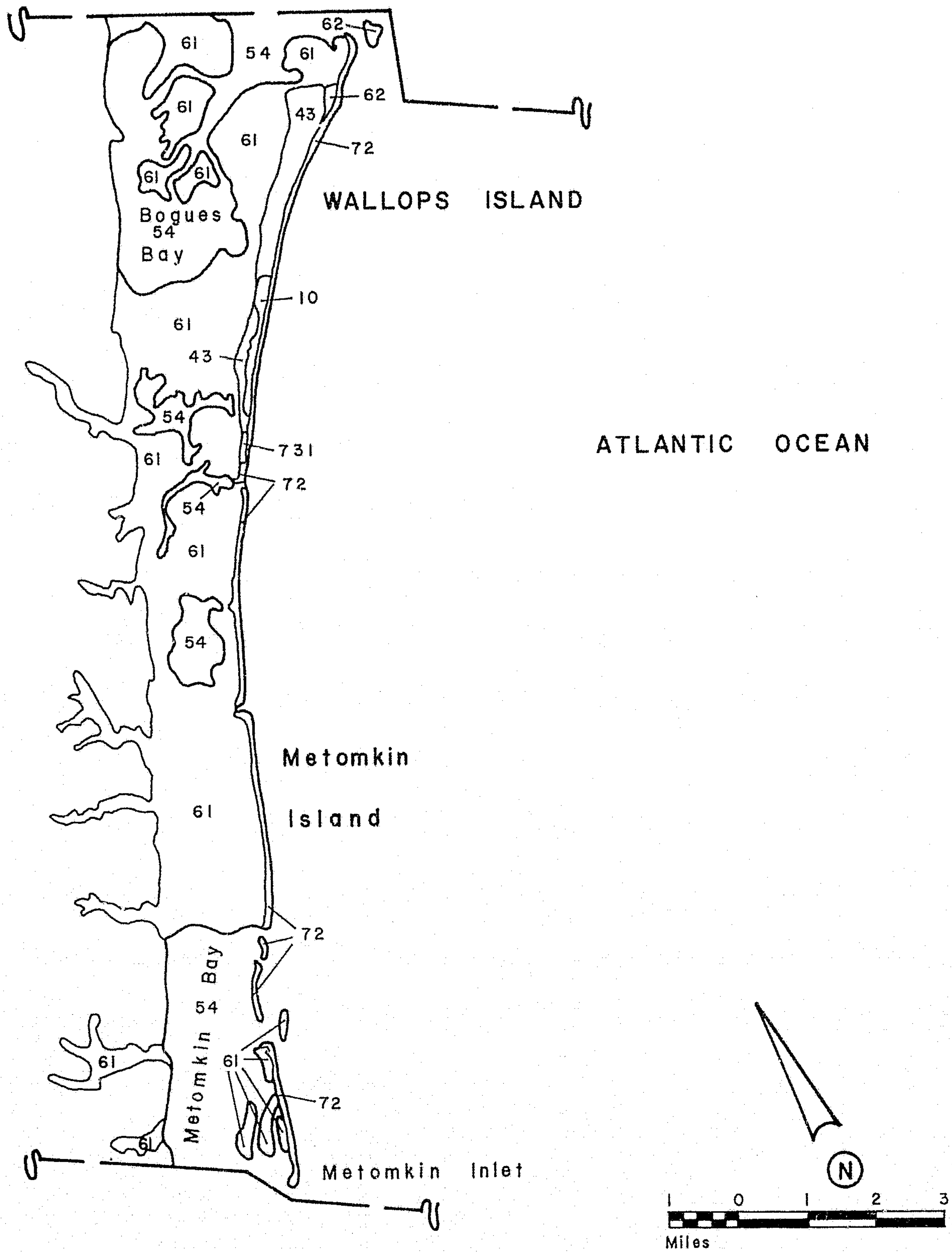
MAP No. 3 — ASSATEAGUE ISLAND



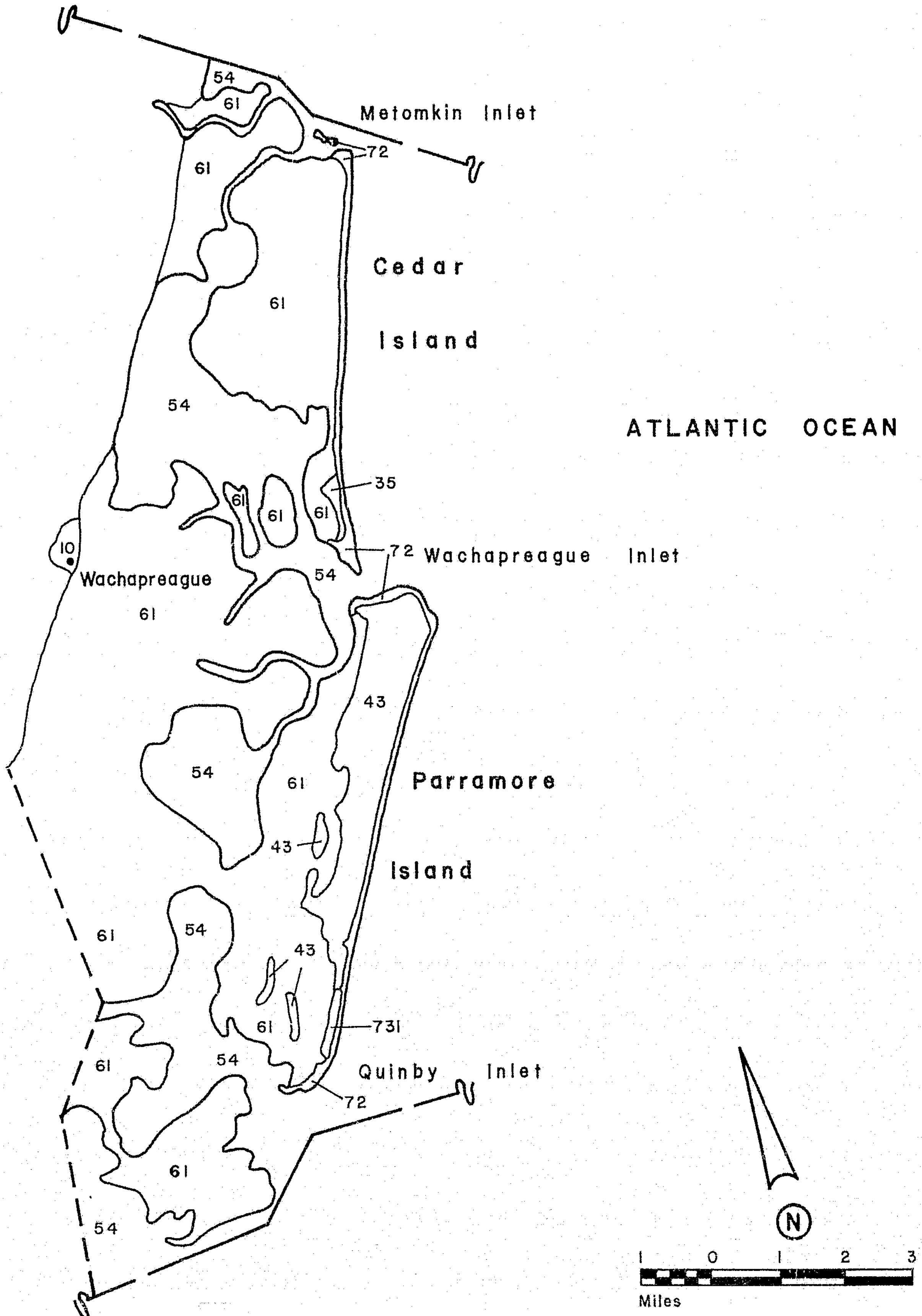
MAP No. 4 – CHINCOTEAGUE ISLAND



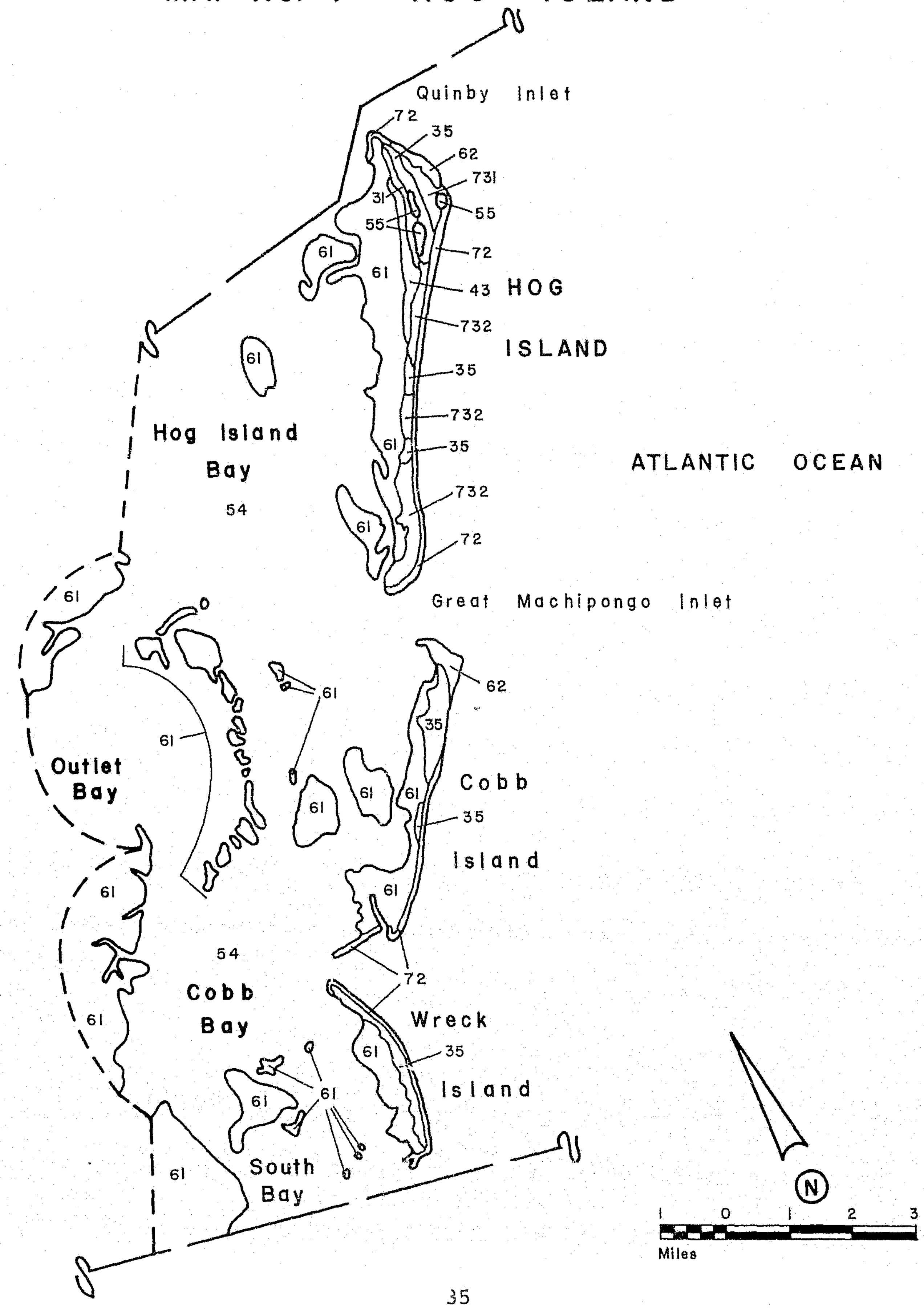
MAP No. 5 — WALLOPS ISLAND



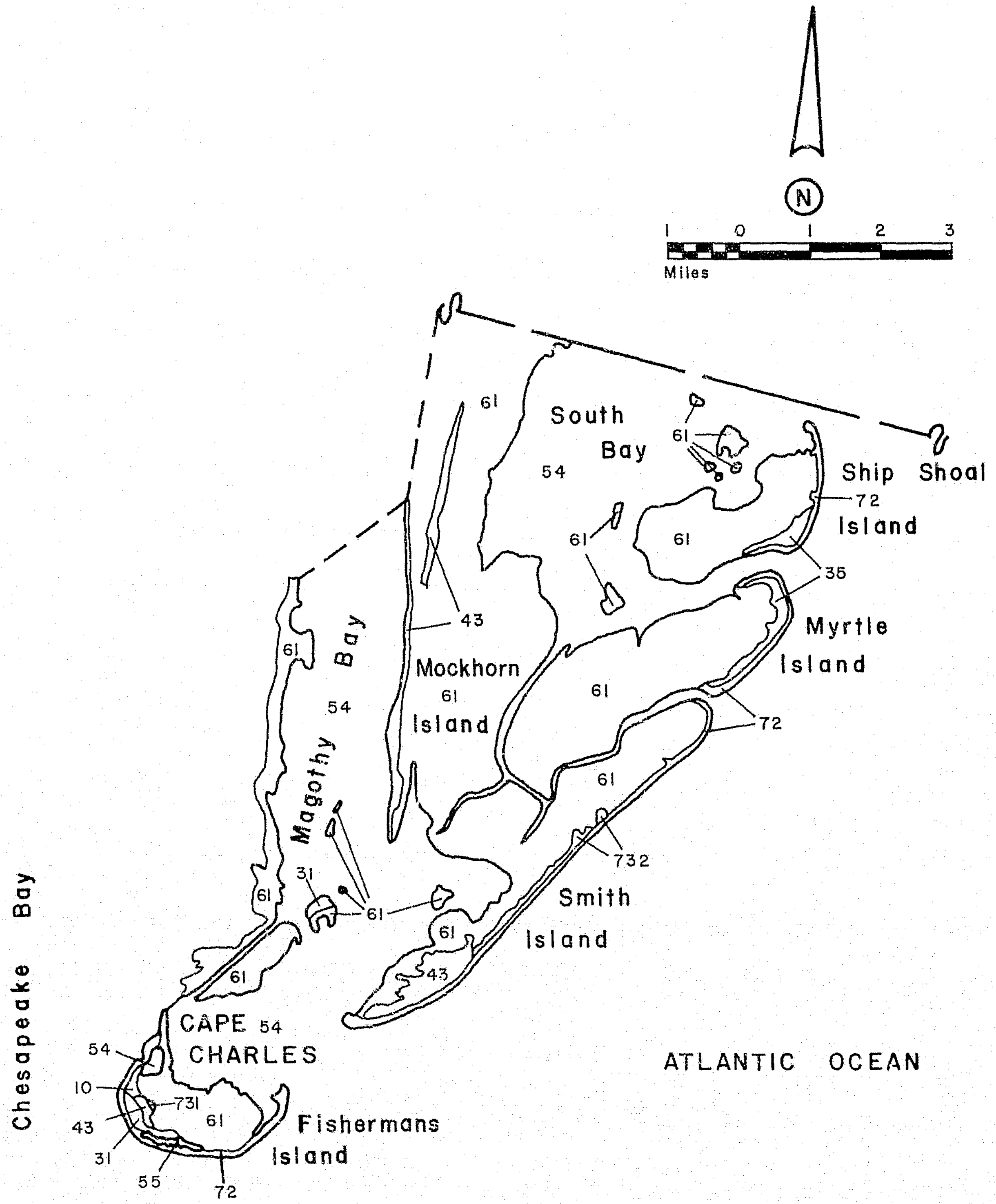
MAP No. 6 – WACHAPREAGUE



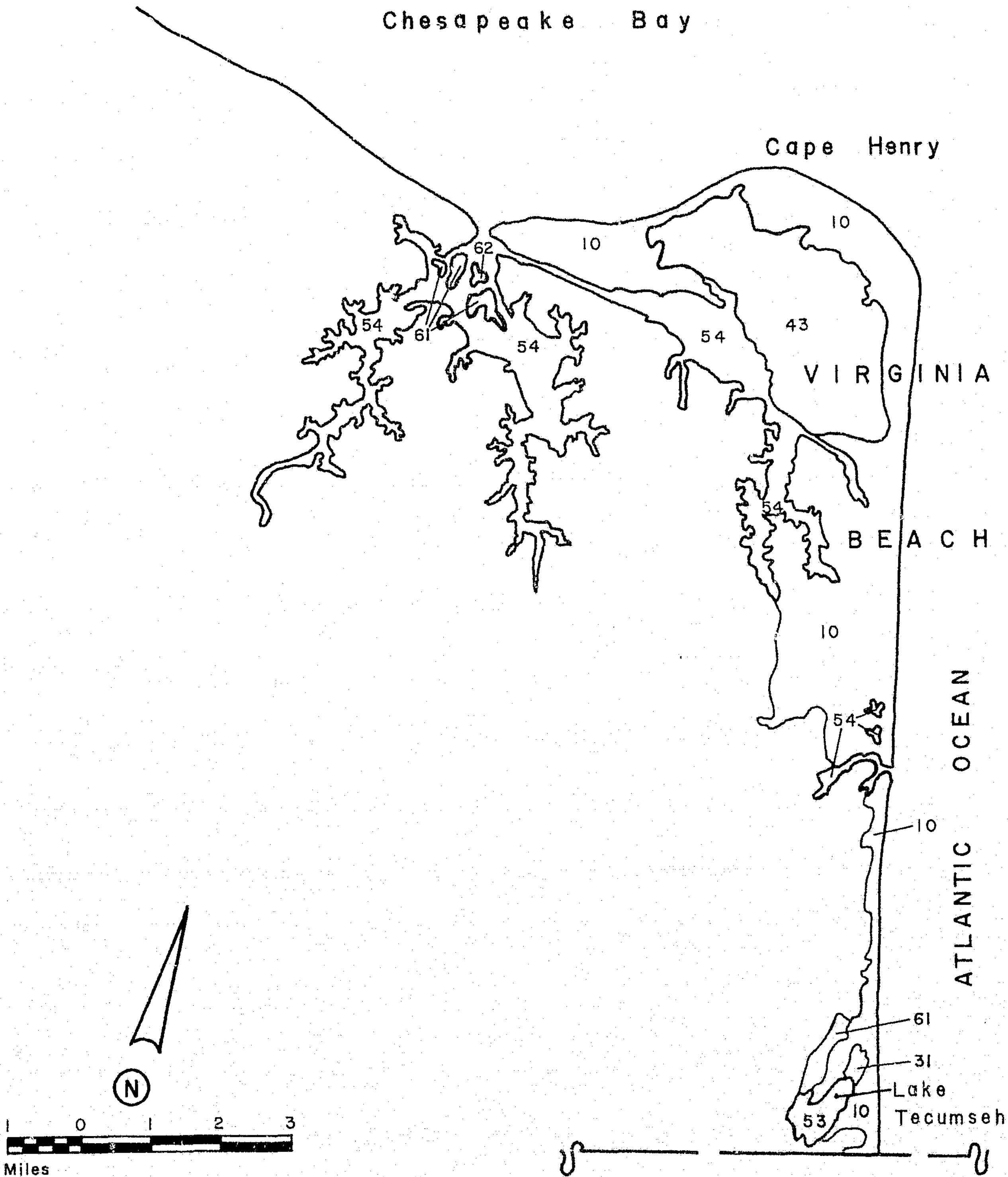
MAP No. 7 — HOG ISLAND



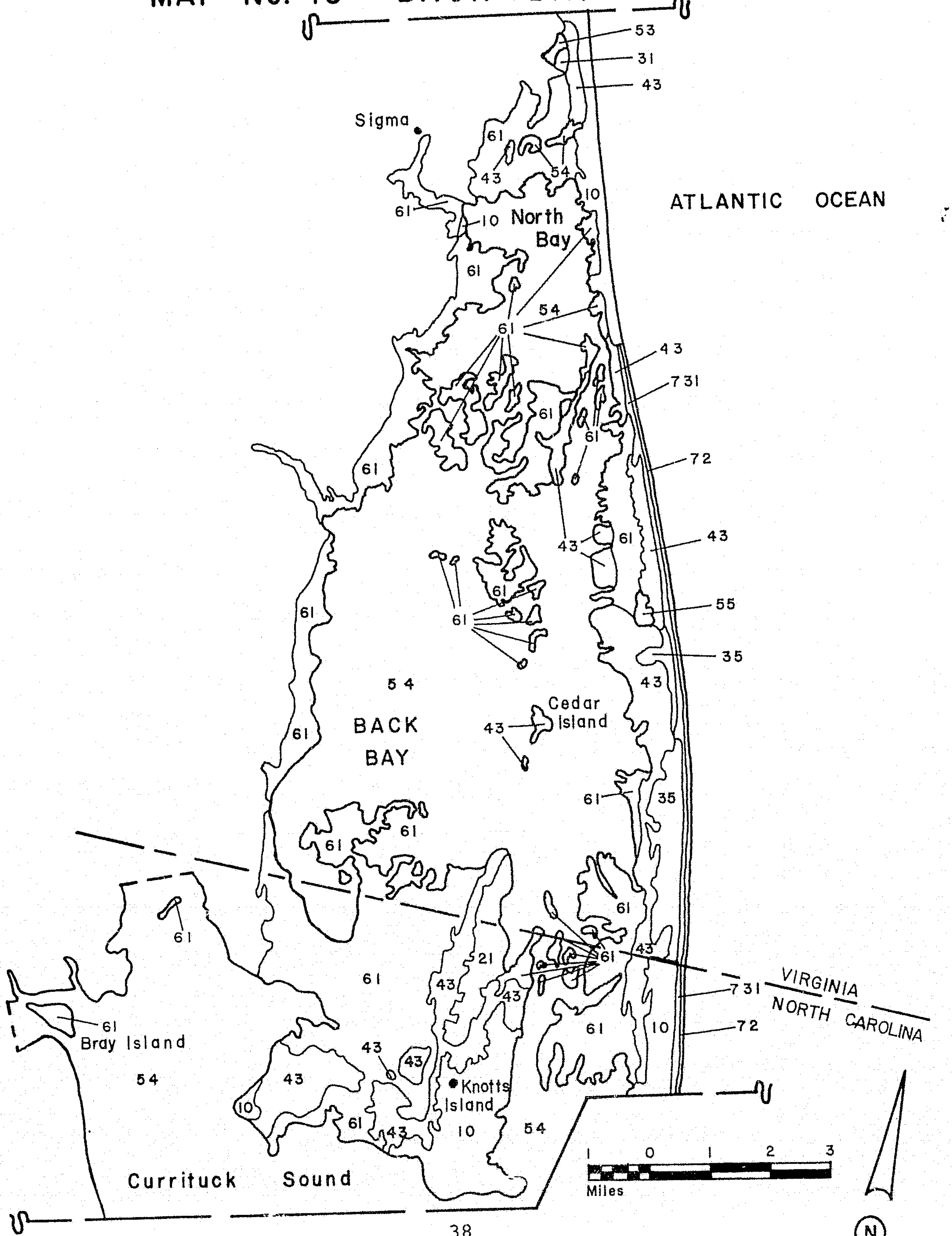
MAP No. 8 — CAPE CHARLES



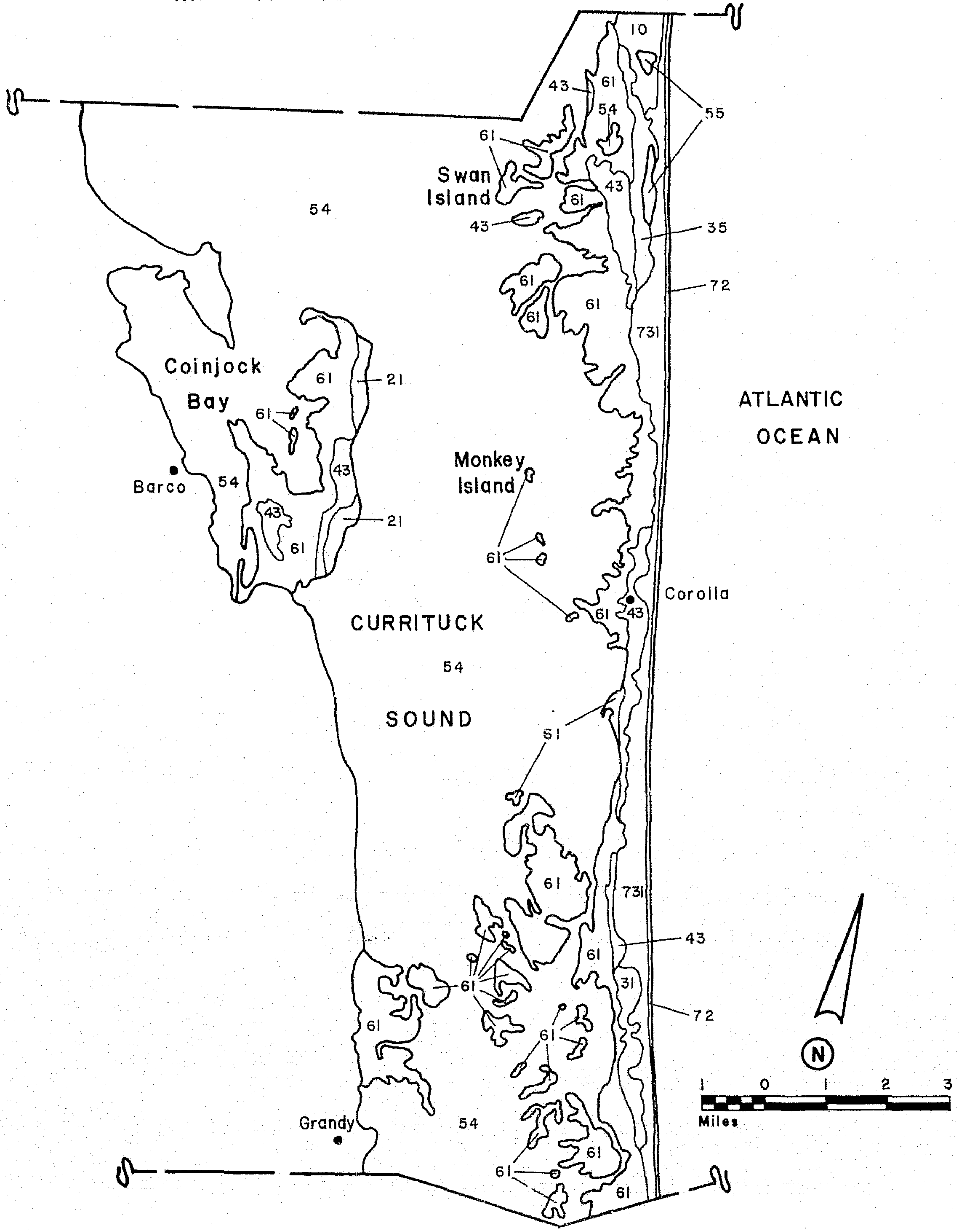
MAP No. 9 — VIRGINIA BEACH



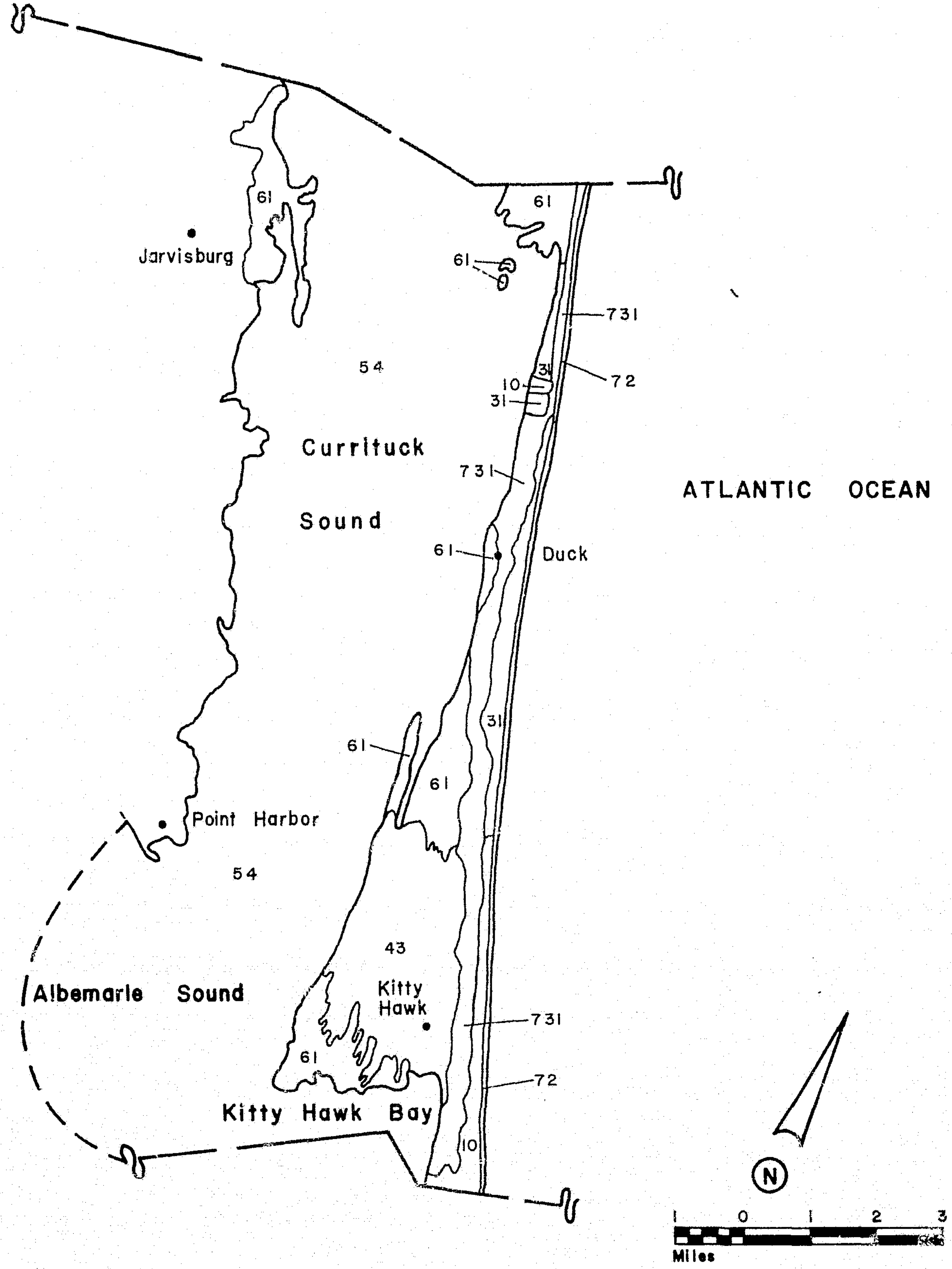
MAP No. 10 – BACK BAY



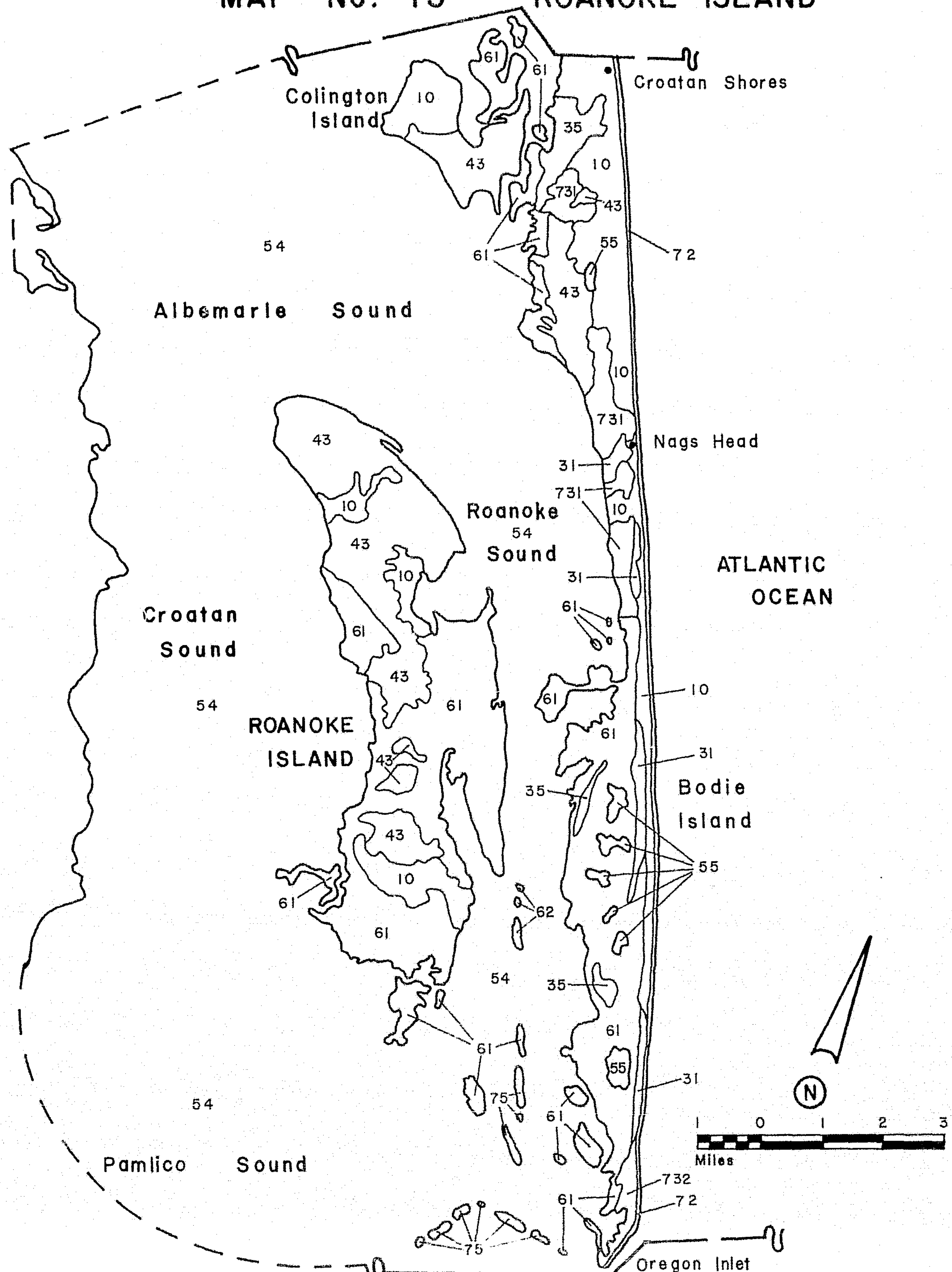
MAP No. 11 – CURRITUCK SOUND



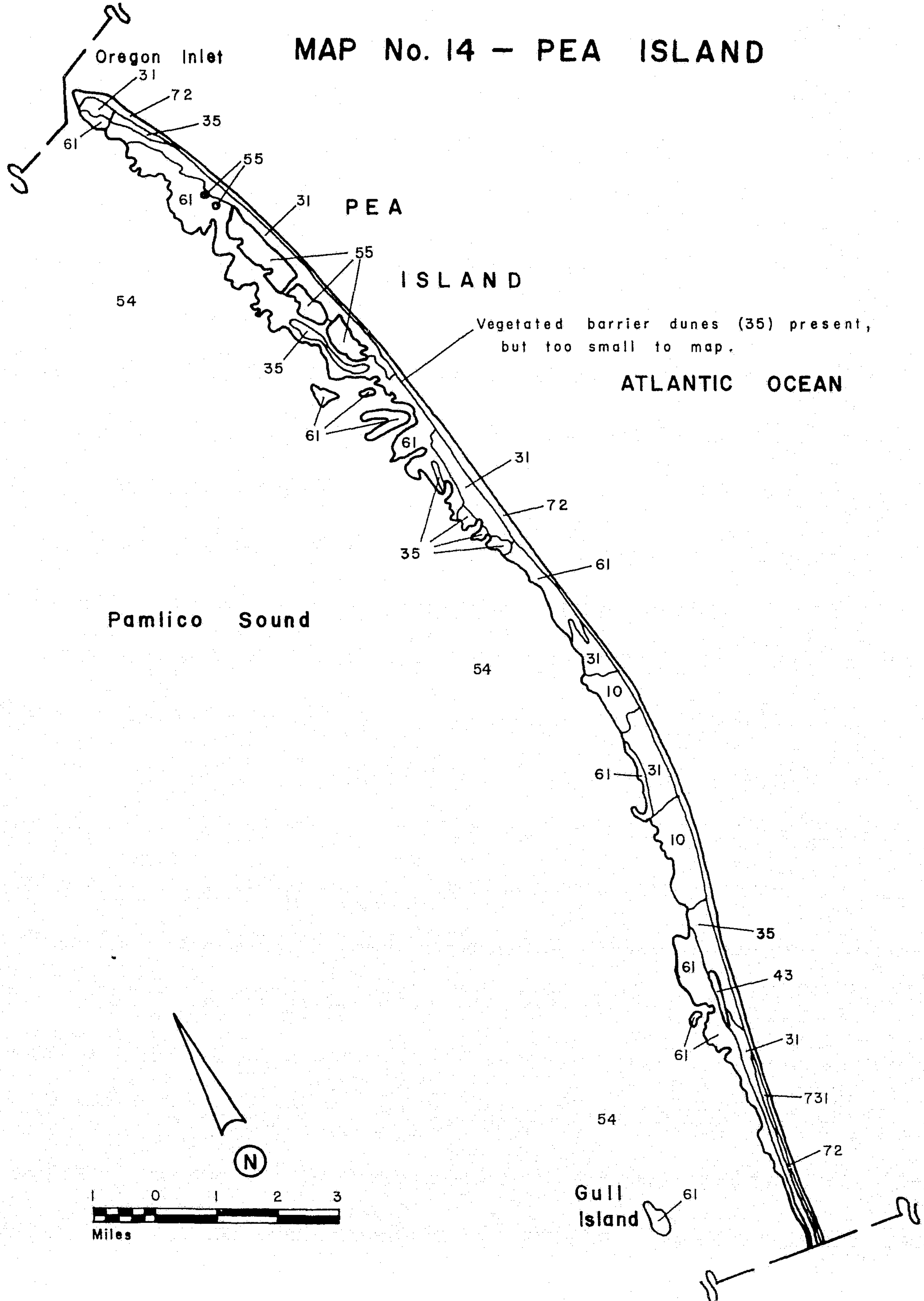
MAP No. 12 — KITTY HAWK



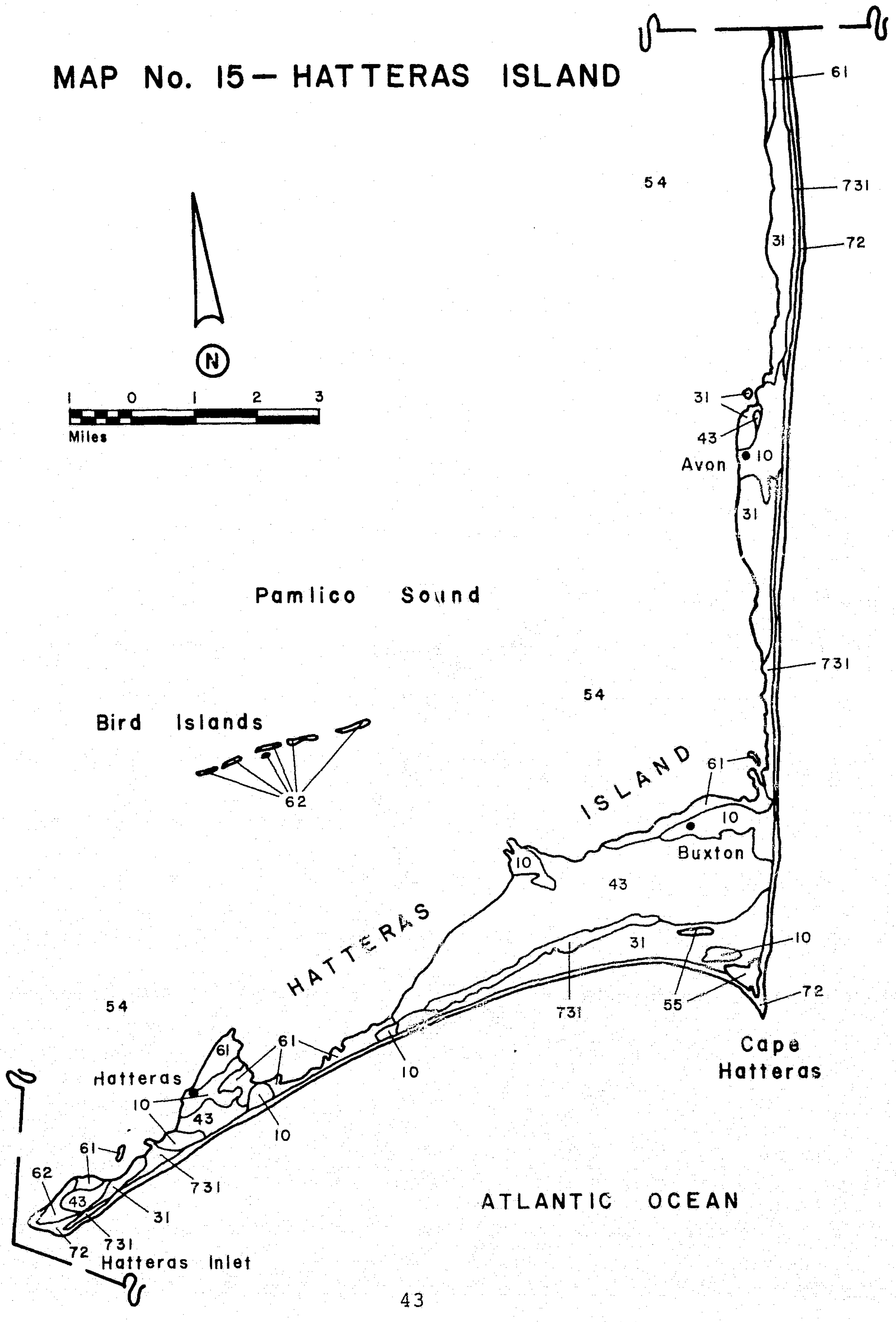
MAP No. 13 — ROANOKE ISLAND



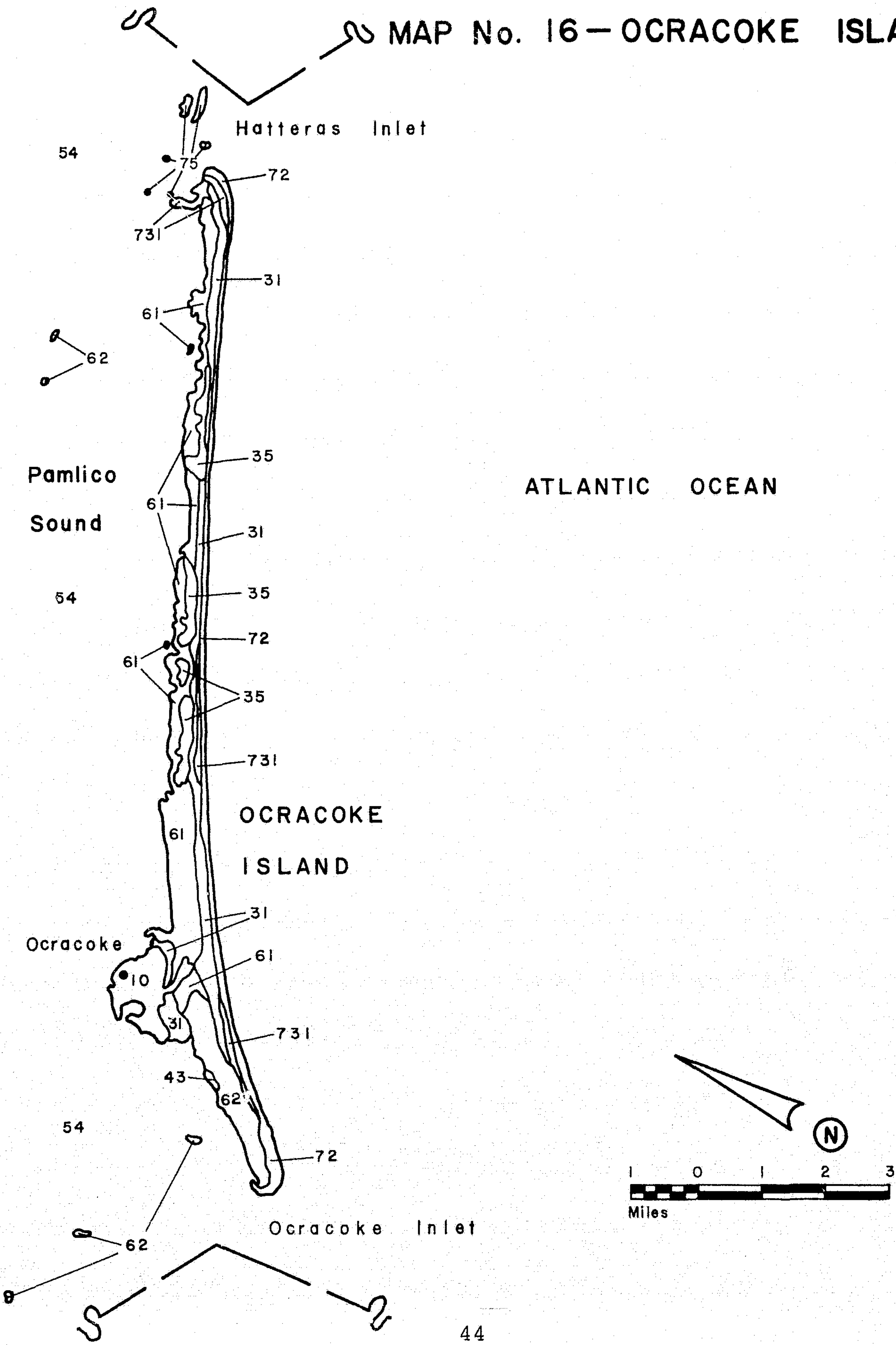
MAP No. 14 — PEA ISLAND

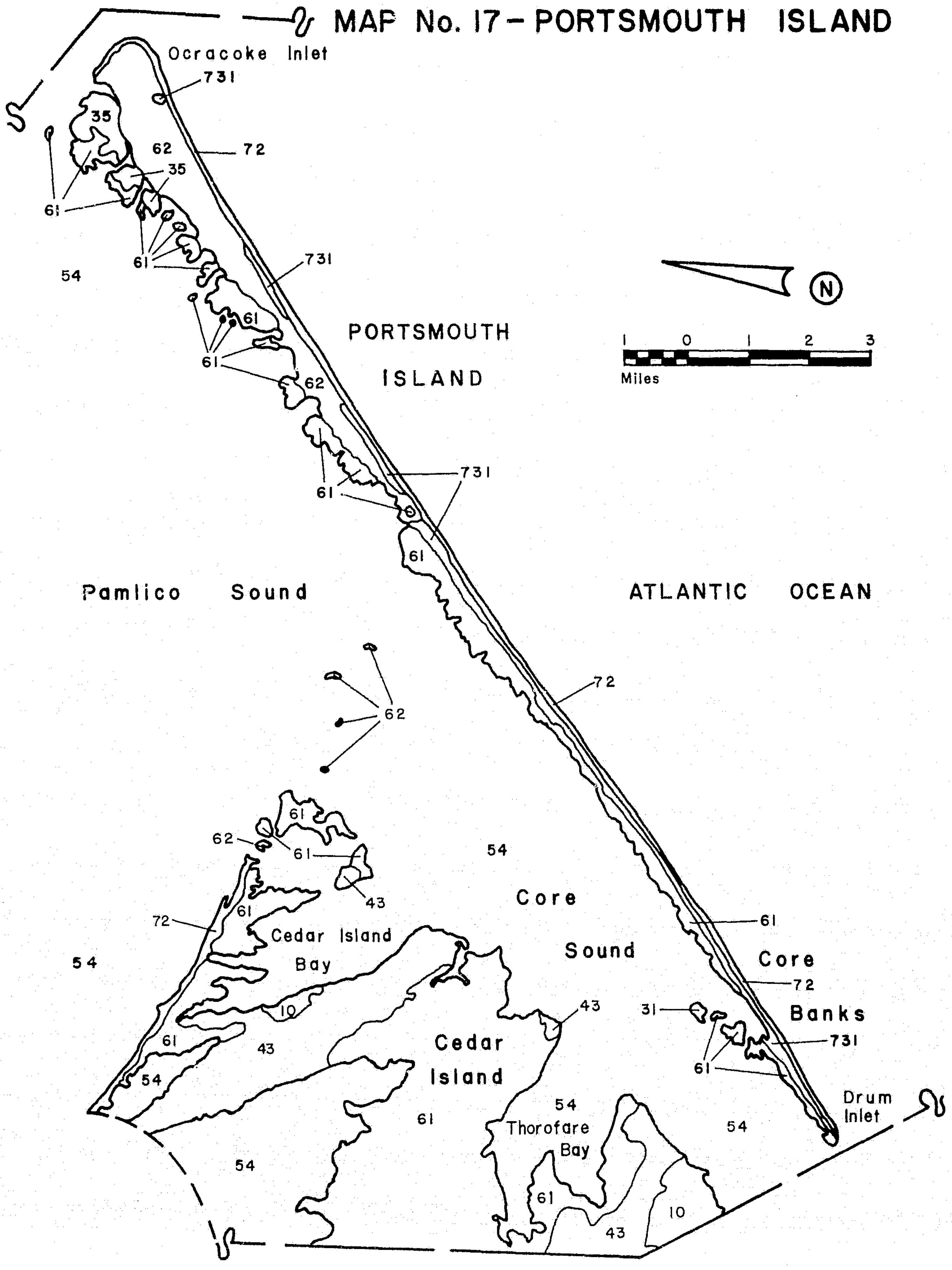


MAP No. 15 — HATTERAS ISLAND

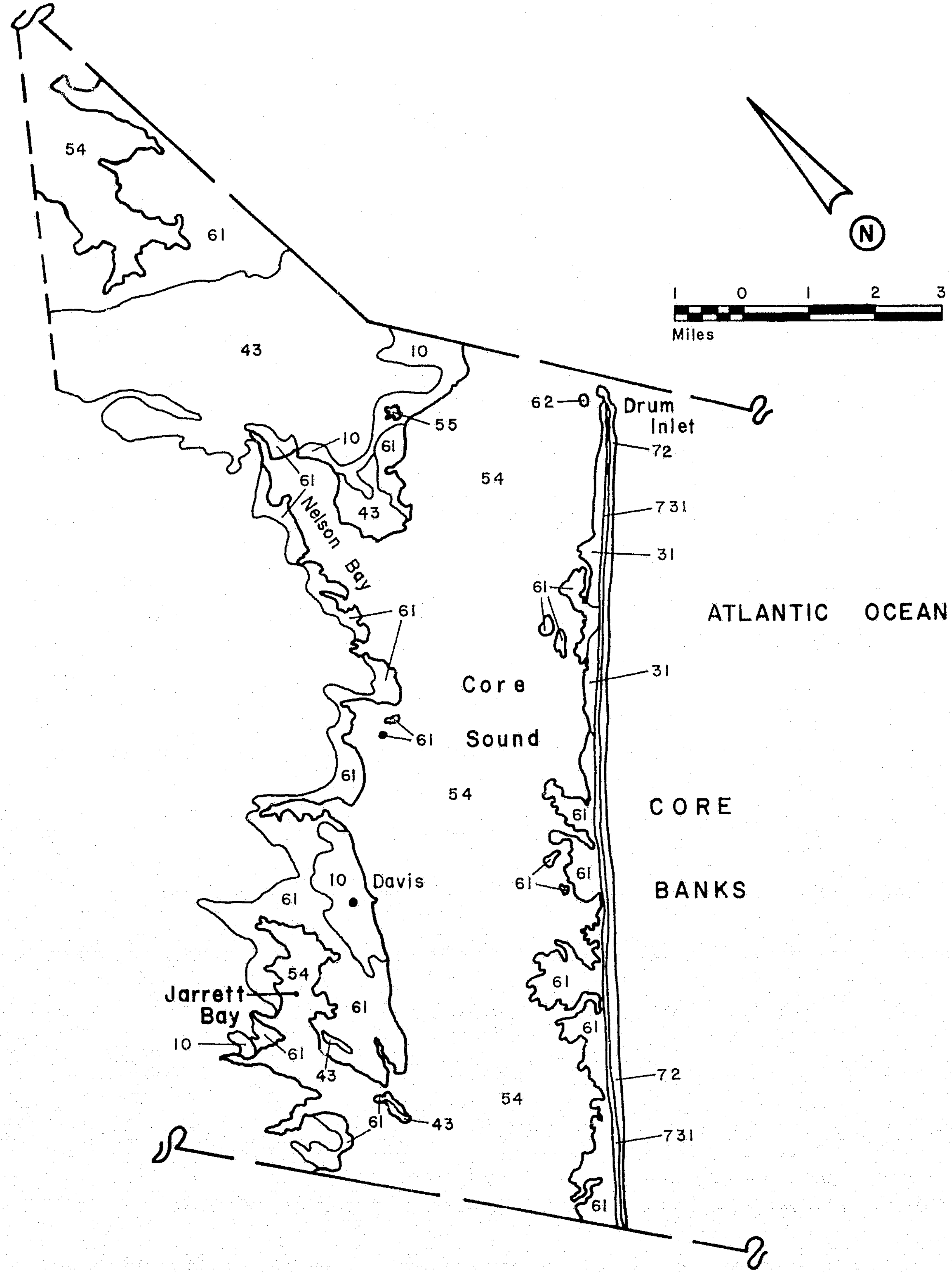


MAP No. 16 — OCRACOKE ISLAND




MAP No. 17 - PORTSMOUTH ISLAND
Ocracoke Inlet
731
35
62
72
61
54
PORTSMOUTH
ISLAND
1 0 1 2 3
Miles
N
Pamlico Sound
ATLANTIC OCEAN
43
Core
Sound
Cedar Island
Bay
10
Cedar
Island
Core
Banks
31
Thorofare
Bay
Drum
Inlet

MAP No. 18 - CORE BANKS



MAP No. 19 — CAPE LOOKOUT