VOLUME II:

HISTORY OF SCIENTIFIC RESEARCH FOR CAPE LOOKOUT NATIONAL SEASHORE

Prepared February, 1987 by

Patricia G. Claxon, Project Director
Hilary Lambert Renwick, Former Project Director

and Supported Through

National Park Service Cooperative Research Unit
Rutgers-The State University of New Jersey
Dr. P.A. Buckley, Director

Dr. Norbert P. Psuty, Director
Center for Coastal and Environmental Studies
Rutgers-The State University of New Jersey
Doolittle Hall - Busch Campus
New Brunswick, NJ 08903

83 4632 DI NPS CRU Resource Documents (Psuty)

TABLE OF CONTENTS

Page

Acknowledgements i

The Barrier Islands Scientific Research Bibliography Project Description iv

Maps of Cape Lookout National Seashore vi

General Keyword Categories xi

Research Reviews 1

- Geology, Hydrology, Soils 2
- Coastal Geomorphology 6
- Vegetation 15
- Invertebrates 20
- Fish 24
- Reptiles, Amphibians 26
- Birds 29
- Mammals 31
- Estuarine Ecology 32
- Cultural, Historical 34
- Management, Legislation 36
- Bibliographies 41

Maps, Charts and Aerial Photographs 42

Computerized Data Bases 55

Ongoing Scientific Research 56

Scientific Research Facilities and In-House Data Collection 63

Preparers of this report 68

ACKNOWLEDGEMENTS

This document is part of a larger project, the production of two volumes of scientific history for each park. The National Park Service has been very helpful in our effort to pull all of this information together.

Regionally, many people at the NPS Boston Office (NARO) have provided invaluable advice and resources. Most notably, we thank Herbert Cables, Regional Director; Dr. Michael Soukup, former Chief Scientist; Dr. James R. Allen, Coastal Geomorphologist; Len Bobinchok, Chief Resource Manager; Francis P. McManamon, Chief, Cultural Resources; Dr. Dwight Pitcaithley, Cultural Resources; and Barbara E. Dorn, Environmental Protection Assistant.

At all stages of our work, we have been provided with guidance and suggestions from Dr. G. Jay Gogue, former Chief Scientist, and Dr. Dominic Dottavio, Chief Scientist, Southeast Region. Also at the Southeast Regional Office (SERO) in Atlanta, we would like to thank Robert M. Baker, Regional Director; Jim Wood, Science Editor; Leonard E. Brown, Regional Historian; William Harris, Cultural Resources Management Division Chief; Chuck Schuler, Rivers and Trails Division; Linda Hall, Librarian; and Trish Patterson, Office of the Chief Scientist.

Other NPS employees have contributed a great deal of time and thought to this project. These include: Dr. John Karish, Chief Scientist, Mid-Atlantic Region; Ed Hay, Resource Manager, Planning Division, Mid-Atlantic Region; Dr. Albert G. Green, Jr. and Dr. William P. Gregg, Jr. of the Washington NPS Office of Science and Technology. Also at the Washington NPS offices, thanks to: Alicia Stamm, Cultural Resources; Audrey Dixon, Science and Technology; and Deborah Lanzone, Program Analyst. Also, thanks to Dr. Harvey Fleet, Chief Scientist; Mr. Gary S. Waggoner, Botanist Branch of Remote Sensing; and Edie Ramey, Technical Information Center, all at the NPS Denver Service Center.

Both the Director of the Center for Coastal and Environmental Studies (CCES), Dr. Norbert P. Psuty, and Dr. P.A. Buckley, Director of the National Park Service/Rutgers University Cooperative Research Unit, have been central to the production of this series of documents.

On a park-by-park basis, we would like to thank the following people:

Cape Lookout National Seashore (CALO)

Superintendent Preston D. Riddell; Bill Springer, former Chief of Operations; Bob Patton and Skip Prange.

Cape Cod National Seashore (CACO)

Superintendent Herbert Olsen; Jim Killian, Research Coordinator; Barbara A. Samora, Resources Management Specialist; John W. Portnoy, Staff Biologist; Michael E. Whatley, Historian and Naturalist; and Dorinda Partsch, Museum Curator.

Fire Island National Seashore (FIIS)

Former Superintendent Jack Hauptmann; Allan O'Connell, Natural Resources Specialist; Don Weir, Chief Ranger; Neal Bullington, Assistant Chief Ranger; Richard Stavdahl, Resource Manager; Mary Laura Lamont, Interpretation; Steven Kesselman, former Curator, William Floyd Estate.

Gateway National Recreation Area (GATE)

Superintendent Robert McIntosh; Bill Shields, Assistant Superintendent; John T. Tanacredi, Natural Resources Management Specialist; John Krisko, Interpretation; Bob Cook and Mary Hake, Natural Resource Management; and Harvey Simon, Laboratory Researcher.

Assateague Island National Seashore (ASIS)

Superintendent Roger K. Rector; Bruce Rodgers; and Dr. Wornie K. Reed, Director, Institute for Urban Research, Morgan State University, Baltimore, MD.

Cape Hatteras National Seashore (CAHA)

Superintendent Thomas Hartman; Kent Turner, Natural Resources Management Specialist; Bebe Midgett, Cultural Resources Specialist; Clay Gifford*, Naturalist.

Cumberland Island National Seashore (CUIS)

Superintendent Kenneth Morgan; Dick Newgren, Chief Ranger; Kevin Kacer, former Chief Ranger; Don Hooker, Ranger, Interpretive; Bert Rhyne, Ranger and Library Curator, and Marcia Stout, Park Curator.

Cape Canaveral National Seashore (CANA)

Superintendent Arthur Graham.

Gulf Island National Seashore (GUIS)

Superintendent Jerry Eubanks; R.W. (Buck) Thackeray, former Assistant Chief Ranger (FL); Thomas Muir, Jr., Supervisory Interpreter (FL); and Theodore R. Simons, Research Biologist (MS).

We would like to thank the following people for their review comments, corrections, and additions to the final draft of Cape Lookout National Seashore Volumes I and II.

Superintendent Preston D. Riddell and his staff at Cape Lookout National Seashore, especially John Cannon.
Ms. Francine G. Buckley
Dr. P.A. Buckley
Dr. Dick Frankenberg
Dr. Duncan Heron
Dr. James Lazell, Jr.
Dr. James Parnell
Dr. W.W. Woodhouse, Jr.

Special thanks go to our correspondents at universities and other research institutions, listed in the "Recent and Ongoing Research" sections of this document. Of particular note is Dr. Susan Bratton, Institute of Ecology, University of Georgia, Athens, who has provided comprehensive updates on southeastern barrier islands research.

At the Center for Coastal and Environmental Studies, our profound gratitude goes to Patricia Eager and Denise Rucci, who have unflinchingly typed and rearranged mass quantities of information in the early stages. Denise Rucci also provided editorial assistance and helped with certain stages of the production of these volumes. Srinarayani Iyer, Jay Murali, Rangarajan (Rajan) Narasimhan, and David Pantos worked extensively on the final stages of entry. Gina Bedoya, Michele Pronio, and Elaine Butterhof (Michael Siegel, Supervisor) of the CCES Cartography Laboratory did the maps. Merry Camhi offered additional suggestions for the Cumberland Island map. Les Smith and Langdon Warner have worked with the early nuts and bolts of computerizing this information; Robert Starcher worked with the intermediate stages; Krishna Murali and Anakkavur Srikanth conducted the complicated transfer of the final versions from our IBM Displaywriter to the IBM PC and MacIntosh versions.

Finally, the "Bib Team," itself is comprised of Rutgers graduate students, past and present, and others who have done the library and field research, and are writing and re-writing the two volumes for each park: Barbara Baker, Sharon Boeglin Worthen, Patricia

Claxon, Helen Dudar, Steven Garber, Caroline Grant, Martha Gulick, Stephanie Hoenig, Kathleen Jagger, Vicky Lentz, Craig Liska, Enid Lotstein, Gudrun (Runa) Marteinsdottir, Anne Marie Newman, Carol Nilson, Richard Paperno, Robert Pavlowsky, Hilary Lambert Renwick, Berta Schreiber, Lisa Trecartin, Usha Vedagiri, Heidi Wearne, Linda Weldon. These researchers and writers have worked diligently and ably.

*We deeply regret that Clay Gifford passed away in the summer of 1985; we wish to acknowledge our appreciation for all the help and friendship he extended to our team members on their visits to Cape Hatteras.

THE BARRIER ISLANDS SCIENTIFIC RESEARCH BIBLIOGRAPHY PROJECT

Background

During the 1960's and 1970's, a series of National Seashores and National Recreation Areas were created by the National Park Service (NPS) along the nation's water boundaries. Unlike many of the more remote, traditional National Parks, many of these newer units are adjacent to or within major urban areas, and hence are subject to very heavy human use. In an effort to balance human and natural interests, the Center for Coastal and Environmental Studies (CCES), as part of its 1983 Cooperative Research Agreement with the NPS, in 1984 began an information-collecting project aimed at better resource management for the East Coast barrier island NPS units.

Purpose

For better resource management, the National Park Service needs a scientific data base. Much research of potential use to resource managers has been carried out in these parks, yet the results of this research have not been centrally located or coherently organized.

This project begins to fill the gap, by collecting published and unpublished research results from many fields of study, and providing a bibliographic guide to research and a narrative history of research for each park. As can be seen in Figure 1, seven NPS units were researched by the CCES group, and two by Morgan State University.

Methods

A team approach was used to review the wide-ranging literature appropriate to the parks. Research citations were obtained from over 100 journals and through library research carried out at each park and at regional and national NPS offices. Helpful park personnel provided responses to several research- related questionnaires. In addition, listings of aerial photographs, maps and charts were assembled for each park, along with information on any available computerized data bases.

Research citations were sorted into the following areas of research: Geology, Hydrology, Soils; Coastal Geomorphology; Vegetation; Invertebrates; Fish; Reptiles, Amphibians; Birds; Mammals; Estuarine Ecology; Cultural, Historical; Management, Legislation, Recreation, Miscellaneous; Bibliographies.

Library research for CACO, FIIS, GATE, CAHA, CALO, and CUIS was completed in December, 1984; library work for GUIS was completed in January of 1987. Incidental citations for the east coast parks are being taken as they are found, but should not be considered exhaustive from 1985 to the present. These citations will be added to the Volume I Bibliography only up until the time of final publication for each park. The computerized versions will allow the updating of any bibliography with new, or newly found, citations.

Products

The history and status of scientific research will be presented in two volumes for each of the parks:

Volume I: Bibliography of Scientific Research

These volumes provide a listing of scientific studies, published and unpublished, in standard bibliographic format. For NPS use they will be available on IBM computer diskettes as well as paper copy. General and specific keywords, title, author, etc. can be used for retrieval purposes. CCES retains an annotated, descriptive and evaluative summary for each listed citation.

Volume II: History of Scientific Research

These volumes provide, first, a narrative history of scientific research in each park, organized by the categories listed above and incorporating the most significant research citations from each Volume I. Secondly, Volume II for each park provides a comprehensive listing of ongoing scientific research, environmental monitoring, and available park research facilities as of 1984.

In addition, Volume II contains a summary of maps, charts and aerial photographs available at the park and from other sources, a summary of computerized databases, and a listing of researchers, individuals, institutions, and agencies contacted in the compilation of this information.

Conclusions

This project's products will provide the basic scientific information base for any researchers working on East Coast and Gulf of Mexico barrier islands. It is hoped that these volumes will be a tool for use by both NPS resource managers and individual scientists.

Figure 1.

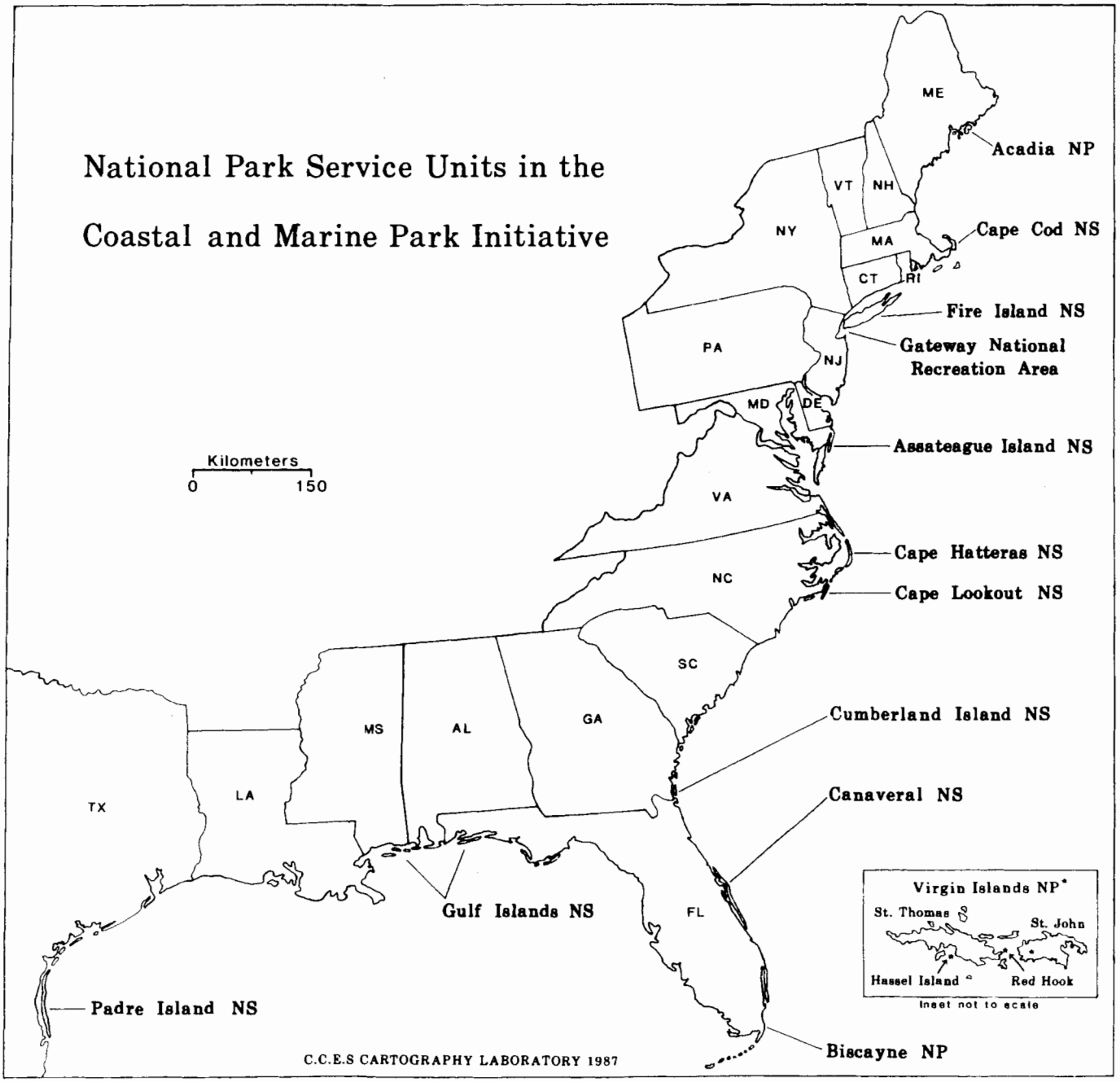

National Park Service Units in the
Coastal and Marine Park Initiative
Kilometers
0
150
ME
VT
NH
NY
MA
CT
RI
PA
NJ
MD
DE
VA
NC
SC
GA
AL
MS
LA
TX
FL
Acadia NP
Cape Cod NS
Fire Island NS
Gateway National Recreation Area
Assateague Island NS
Cape Hatteras NS
Cape Lookout NS
Cumberland Island NS
Canaveral NS
Gulf Islands NS
Padre Island NS
Biscayne NP
Virgin Islands NP*
St. Thomas
St. John
Hassel Island
Red Hook
Inset not to scale
C.C.E.S CARTOGRAPHY LABORATORY 1987

Figure 2.

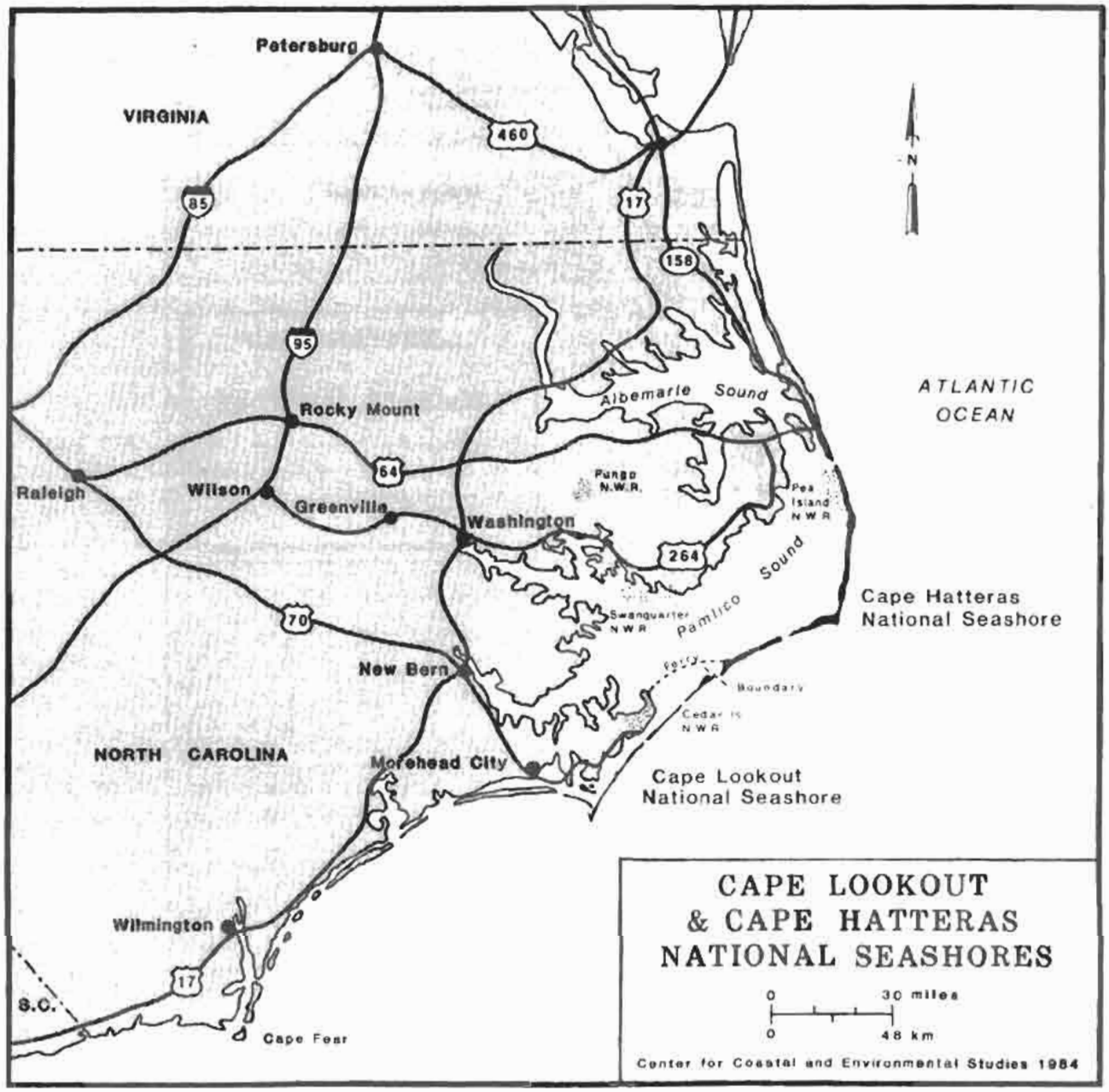
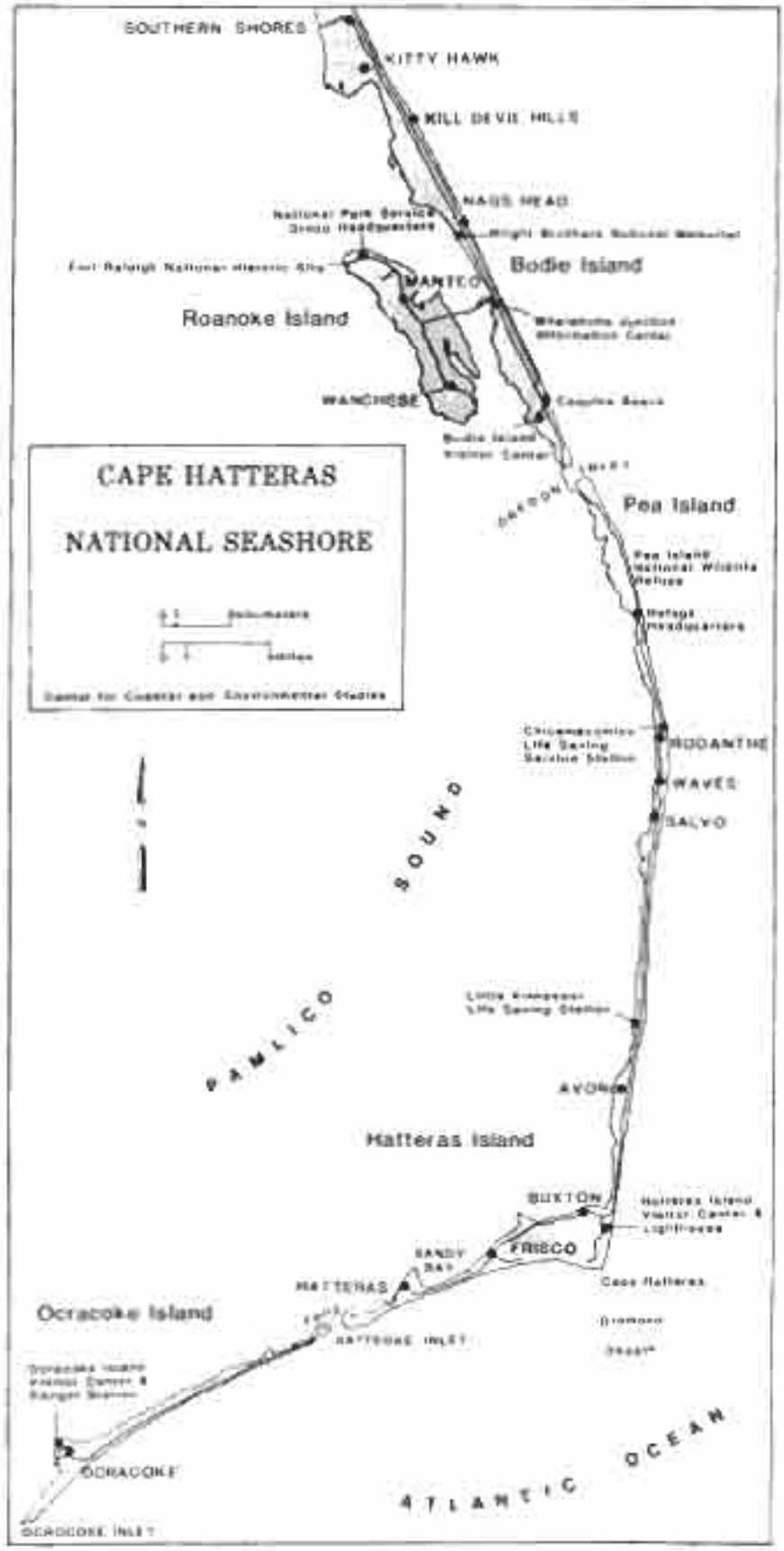

Petersburg
VIRGINIA
460
85
17
158
95
Rocky Mount
Albemarle Sound
ATLANTIC OCEAN
N
64
Raleigh
Wilson
Greenville
Washington
Pungo N.W.R.
Pea Island N.W.R.
264
Pamlico Sound
Cape Hatteras National Seashore
70
Swanquarter N.W.R.
New Bern
Ferry
Boundary
Cedar Is N.W.R.
NORTH CAROLINA
Morehead City
Cape Lookout National Seashore
Wilmington
17
S.C.
Cape Fear
CAPE LOOKOUT & CAPE HATTERAS NATIONAL SEASHORES
0 30 miles
0 48 km
Center for Coastal and Environmental Studies 1984

Figure 3.


SOUTHERN SHORES
KITTY HAWK
KILL DEVIL HILLS
NAGS HEAD
Bodie Island
MANTEO
Roanoke Island
WANCHESE
CAPE HATTERAS
NATIONAL SEASHORE
Pea Island
ROANOKE
WAVES
SALVO
SOUND
PAMLICO
AVON
Hatteras Island
BUXTON
FRISCO
HATTERAS
Ocracoke Island
OCRACOKE
ATLANTIC OCEAN

ACRONYMS USED FOR DOCUMENT LOCATIONS

U.S. Department of Interior, National Park Service Locations:

ASIS:	Assateague Island National Seashore, Berlin, MD.
CACO:	Cape Cod National Seashore, South Wellfleet, MA.
CAHA:	Cape Hatteras National Seashore, Manteo, NC.
CALO:	Cape Lookout National Seashore, Beaufort, NC.
CANA:	Cape Canaveral National Seashore, Titusville, FL.
CUIS:	Cumberland Island National Seashore, St. Mary's, GA.
FIIS:	Fire Island National Seashore, Patchogue, NY.
GATE:	Gateway National Recreation Area, Brooklyn, NY.
GUISFL:	Gulf Islands National Seashore, Florida Unit, Gulf Breeze, FL.
GUISMS:	Gulf Islands National Seashore, Mississippi Unit, Ocean Springs, MS.
MARO:	Mid-Atlantic Regional Office, Philadelphia, PA.
NARO:	North Atlantic Regional Office, Boston, MA.
NPSDC:	National Park Service, Washington, DC.
NPSDSC:	National Park Service, Denver Service Center, Denver, CO.
NPSSAC:	National Park Service, Southeast Archaeological Center,Tallahassee, FL.
SERO:	Southeast Regional Office, Atlanta, GA.

Universities, Institutions, Associations, and Other U.S. Government Agencies:

ABST:	citation taken from abstract.
ADELPH:	Adelphi University, Garden City, NY.
ALEX:	Alexander Library, Rutgers University, New Brunswick, NJ.
AMNH:	American Museum of Natural History, New York, NY.
APCC:	Association for the Preservation of Cape Cod, Orleans, MA.
BIBL:	citation taken from a bibliography.
CAMCO:	Camden County Library, Woodbine, GA.
CCES:	Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, NJ.
COLUM:	Columbia University, New York, NY.
DUKE:	Duke University, Durham, NC.
ECU:	East Carolina University, Greenville, NC.
ENT:	Entomology Library, Cook College, New Brunswick, NJ.
FIRE:	Firestone Library, Princeton University, Princeton, NJ.
FWS:	U.S. Department of Interior, Fish and Wildlife Service, Washington, DC.
GADNR:	Georgia Department of Natural Resources, Atlanta, GA.
GAGS:	Georgia Geologic Survey, Atlanta, GA.
GOOD:	Ralph Good's personal library, Rutgers University, Camden, NJ.
HUSL:	Science Library, Harvard University, Cambridge, MA.
JBWR:	Jamaica Bay Wildlife Refuge, Brooklyn, NY.
LSM:	Library of Science and Medicine, Rutgers University, New Brunswick, NJ.
MABEL:	Mabel Smith Douglass Library, Rutgers University, New Brunswick, NJ.
MANN:	Horace Mann Library, Cornell University, Ithaca, NY.
N.A.:	document location not available.
NCSM:	North Carolina State Museum, Raleigh, NC.
NCSU:	North Carolina State University, Raleigh, NC.
NOAA:	U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, DC.
OICC:	Office in Charge of Construction, Kings Bay Naval Facility, Kings Bay, GA.
PANS:	Philadelphia Academy of Natural Sciences, Philadelphia, PA.
PCCS:	Provincetown Center for Coastal Studies, Provincetown, MA.
PEA:	Pea Island National Wildlife Refuge, Cape Hatteras, NC.
POST:	C.W. Post College, Long Island University, Greenvale, NY.
SFA:	Sports Fishery Abstract.
SKID:	Georgia Marine Science Center, Skidaway Island, GA.

STICK:	David Stick's personal library, Kitty Hawk, NC.
UCT:	University of Connecticut, Storrs, CT.
UFL:	University of Florida, Gainesville, FL.
UGACPSU	University of Georgia, Cooperative Park Studies Unit, Athens, GA.
UGAMN:	University of Georgia, Main Library, Athens, GA.
UGASCI:	University of Georgia, Science Library, Athens, GA.
UMA:	University of Massachusetts, Amherst, MA.
UVA:	University of Virginia, Charlottesville, VA.
UNC:	University of North Carolina, Chapel Hill, NC.
USC:	University of South Carolina, Columbia, SC.
USGS:	U.S. Geological Survey, Washington, DC.
UWF:	University of West Florida, Pensacola, FL.
VIMS:	Virginia Institute of Marine Science, Gloucester Point, VA.
WHOI:	Woods Hole Oceanographic Institution, Woods Hole, MA.
YALE:	Yale Unviersity, New Haven, CT.

GENERAL KEYWORD CATEGORIES

BIBL:	Bibliographies
BIRDS:	Birds
CGEO:	Coastal Geomorphology -- also includes climatology, meteorology, and sea level studies
CUHI:	Cultural, Historical
ESTE:	Estuarine Ecology
FISH:	Fish
GEOS:	Geology, Hydrology, Soils -- also includes limnology, hydrography, and oceanography studies
INVRT:	Invertebrates
MAMM:	Mammals
MANL:	Management Legislation -- also includes recreation and miscellaneous studies
RPTAM:	Reptiles, Amphibians
VEGT:	Vegetation -- including fungi, phytoplankton, macroalgae, submerged aquatic vegetation, saltmarsh and terrestrial vegetation studies

Research Reviews

GEOLOGY, HYDROLOGY, SOILS

Geological Research

General Stratigraphic Research

The majority of the geologic research in the Cape Lookout area has concentrated on Quaternary stratigraphy and the response of the barrier island complex to sea level fluctuations. Richards (1950, 1967) discussed the stratigraphy, structural elements, and depositional basins of the North Carolina coastal plain. He briefly described the Cretaceous through Pleistocene formations lying within the coastal plain, including their lithologic and paleontologic character, and tentative correlations to other Atlantic coastal plain formations. Results of early geophysical investigations of the Pamlico Basin and Cape Fear Arch were also given.

Fisher (1962) distinguished the temporal and spatial distributions of relict inlets on the Outer Banks by their characteristic physiographic features. He combined field studies, and historic maps and records as his data base. He then compared the physical parameters and areal morphology of the facies contained in relict inlet deposits with present day flood tidal delta sediments. Fisher (1965) examined the morphology and internal structure of recent beach ridges on the Outer Banks barrier island system and the adjacent coastal mainland. He determined the origin and evolution of beach ridges and their position as a function of the dynamics of the shoreline, then applied this relationship to reconstruct the positions of former shorelines from the pattern of relict beach ridges.

Stratigraphic Studies - Shackleford Banks

Tippins and Nevins (1972) described the evolution of the barrier island system at Shackleford Banks. Susman (1975), and Susman and Heron (1977, 1979) analyzed Pleistocene and Holocene stratigraphy and the depositional history of Shackleford Banks. They identified four stratigraphic units in the Tertiary and younger section beneath Shackleford Banks on the basis of lithology, color, fossil content, clay mineralogy, and radiocarbon dates. They also discussed the imprint of sea level fluctuations in the Quaternary stratigraphic record and the migration of Beaufort Inlet. They recognized three transgressive-regressive events in the post-Tertiary sedimentary record on Shackleford Banks; however, they observed that extensive erosion by migrating tidal inlets had largely modified these Holocene vertical sequences. Paleoenvironmental analysis of the recent subsurface at Shackleford Banks was conducted by Hamilton (1977). Depositional environments were recognized on the basis of grain size, types of sedimentary structures, and organic content. Hamilton cited marsh accretion on the north shore, spit accretion on the western end of Shackleford Banks, and erosion of the eastern shore as mechanisms for northwestward migration of the island.

Stratigraphic Studies - Core Banks

In the northern Core Banks subsurface, Herbert and Heron (1976) recognized five stratigraphic units on a lithologic basis: 1) Yorktown Formation (Pliocene); 2) Core Creek Sand (late Sangamon); 3) Atlantic Sand (late Wisconsin); and 5) Core Banks Sand (Holocene). Within the Holocene Core Banks Sand, the authors identified five relict tidal inlets on the basis of primary sedimentary structures and geomorphic features. The Quaternary geologic history of the Core Banks, from Cape Lookout to Drum Inlet, was expanded by Moslow (1977a,b, 1978) and Moslow and Heron (1978b, 1979). These studies focused on the Holocene evolution of Core Banks, with particular attention given to its origin and landward migration in response to changes in sea level.

Moslow (1977), and Moslow and Heron (1978a, 1979) described the lithology, geometry, and dimensions of Holocene inlet-fill bodies found in the shallow subsurface of Core Banks, and their facies relationship to adjacent barrier island environments. They estimated the lateral extent and direction of migration for these former inlets. They found that the relict inlet deposits on Core Banks typically consisted of three sub-environments: inlet margin (spit

platform), inlet floor, and channel margin facies. Herbert (1978) analyzed the environments of deposition represented in the Holocene sediments of the Core Banks north of Drum Inlet. He utilized faunal assemblages in addition to standard sedimentological techniques to identify Holocene barrier island facies. He suggested that Portsmouth Island was built on flood tidal delta sediments related either to Ocracoke Inlet or Whalebone Inlet.

Moslow and Heron (1978b) analyzed the Holocene stratigraphy and depositional history of Cape Lookout and Core Banks. They determined that Core Banks was underlain by a transgressive sequence of overwash and backbarrier sediments, whereas the southern portion of Core Banks including the Cape Lookout apex consisted of a regressive sequence of overwash and shoreface sediments deposited during seaward progradation and spit growth. They suggested that the cuspate-foreland morphology of Cape Lookout may have largely formed over the past 4000 years. Moslow and Heron (1981) concluded that the Cape Lookout cuspate foreland evolved through three stages: 1) Core Banks and Shackleford Banks joined to form an erosive headlead 4000-7000 years before present; 2) a drop in the rate of sea level rise allowed spit growth and progradation of Cape Lookout and Lookout Shoals 3000-4000 years before present; and 3) continued sediment accumulation and development of Cape Lookout into a prograding cuspate type of headland 3000 years ago to the present.

Stratigraphic Studies - Shackleford and Core Banks

Heron,, et al. (1984) summarized the results of the stratigraphic studies conducted by Susman, Moslow, Herbert, and their associates at Duke University, and they developed a process-response model for clastic, wave-dominated, barrier island shorelines. They contrasted the vertical sedimentary sequences and preservation potential characteristic of the high energy northeast barrier limb of Cape Lookout (Core Banks and Portsmouth Island) relative to the lower energy northwest (Bogue Banks) and southwest (Shackleford Banks) barrier limbs. They concluded that a decline in the rate of sea level rise approximately 4000 years before present resulted in shoreline stabilization and a divergence of depositional patterns on these limbs. Core Banks and Portsmouth Island are characterized by a transgressive sequence of coarse-grained washover sands overlying back-barrier and lagoonal sediments. These deposits have been reworked locally by ephemeral tidal inlets. The shallow subsurface under Bogue Banks displayed progradational sedimentary sequence, whereas the adjacent Shackleford Banks was found to be dominated by lateral tidal inlet migration. They concluded that tidal inlet fill, back-barrier, and shoreface deposits were the most readily preserved facies in a wave-dominated barrier island setting.

Stratigraphic Studies - Bogue Banks

Steele, et al. (1980) interpreted Holocene relative changes in sea level as evidenced in the shallow subsurface stratigraphy beneath Bogue Banks. The authors concluded that Bogue Banks underwent a period of shoreline retreat between 4000 and 9300 years before present, but their evidence indicated that the shoreline had been prograding since approximately 4000 years before present.

Barrier Island Formation

Welby (1970) conducted reflection seismic traverses across the Pungo River and Pamlico Sound in order to investigate the origin of the Outer Banks. He observed several channels north of Ocracoke Island at a depth of 40 to 50 feet which were trending towards Ocracoke Inlet. He suggested that the marked change in the sedimentation record at a depth of 20 to 30 feet beneath Pamlico Sound indicated that the closing of the Sound could be dated more accurately than it had been at that time, but did not attempt to date this event. Zeigler (1973) discussed the origin of barrier island systems as evidenced by sedimentological characteristics of the sea islands located along the southeastern United States coastal margin.

Berelson (1980) examined the shallow subsurface stratigraphy under Harkers Island and Shackleford Banks in an effort to reconstruct the process of barrier island evolution, and to gain an understanding of its effect on lagoonal sedimentation. He suggested that Harkers Island overrode its own lagoonal sediments when it migrated landward during the mid-

Wisconsin sea level rise. These lagoonal sediments were partially preserved and are represented today as the Diamond City Clay. Berelson suggested that the primary mechanism for landward migration was sedimentation by overwash processes. He also observed that inlet-fill deposits were among the most highly preservable facies during barrier island migration as evidenced by the large percentage of these deposits underneath Shackleford Banks.

Origin of the Carolina Capes

Dolan and Ferm (1968) suggested that crescentic landforms, such as Cape Hatteras and Cape Lookout, observed along the southeastern United States coastal margin represent one order of a continuous hierarchy of coastal landforms. They examined crescentic landforms varying in size (measured from tip to tip) from 1.5 meters (e.g., beach cusplets) to 100,000 meters (e.g., the Carolina Capes). They categorized the landforms according to size, described their spatial distribution, and provided hypotheses on processes controlling the development of each size landform. Dolan and Ferm (1968) suggested that the origin and spatial distribution of the capes observed along the coastal margin was primarily controlled by eddy patterns of ocean currents.

White (1966) related the present-day drainage pattern of the North Carolina coastal plain to these large-scale cape features. He suggested that the asymmetric pattern characteristic of the coastal plain was caused by lines of relict capes which serve as topographic barriers to stream drainage. Blackwelder and Cronin (1981), and Blackwelder,, et al. (1982) discussed the role of pre-Holocene erosion-resistant strata in the development of the Carolina Capes and cuspate forelands. These studies proposed that Pleistocene beach ridges and shoreline orientation indicated that Cape Lookout was the site of one or more pre-Holocene cuspate forelands.

General Geological Research

Brown and Reid (1976) conducted an evaluation of the waste storage potential of Mesozoic sandstone units at Cape Lookout. Mixon and Pilkey (1976) described the general geology and geomorphic features of the coastal plain province in the Cape Lookout region.

Methane Production in Sediments

Crill (1981), and Crill and Martens (1983) analyzed the spatial and temporal distribution of methane production, and sulfate reduction rates during early diagenesis in anoxic marine sediments. These projects focused on the influence of sulfate reducers on the depth distribution of methane production in organic-rich sediments. Results of the studies showed a general increase in methane production during the summer months, and the highest sulfate reduction rates near the sediment-water interface, with a decrease in sulfate reduction rates with depth throughout the year.

Bibliographies

Riggs and O'Connor (1975) published a geological bibliography of North Carolina's coastal plain, coastal zone, and continental shelf.

Hydrological Research

Winner (1977, 1978, 1979) mapped the distribution of potable water sources on Cape Lookout National Seashore to locate areas favorable for the development of recreational facilities. Fresh groundwater was found in three successive stratigraphic layers. Water samples from the lower confined aquifer, occurring at depths between 150 and 550 feet, generally met Environmental Protection Agency standards, though at some sites excessive concentrations of chloride, iron, and manganese were found. The potential yield for the lower aquifer was estimated at approximately 500 gallons per minute. The overlying unconfined aquifer was estimated to have a potential yield of up to 30 gallons per minute to a horizontal well in protected areas but episodic temporary contamination was expected in this aquifer

from overwash during storms. The uppermost confined aquifer at depths between 90 and 150 feet, yielded fresh water only in the vicinity of Drum Inlet and Harkers Island.

Heron (1980) submitted a proposal to study the groundwater potential of the subsurface Tertiary sediments at Cape Lookout. This project was part of an effort to locate water sources to supply areas designated for future development, as well as to sustain already established recreation sites. The proposal called for lithological and faunal analyses of core samples in addition to standard water chemistry evaluations.

The U.S. Environmental Protection Agency (1984) conducted a comprehensive environmental impact study of Cape Lookout to provide Park Service personnel and local government administrators with a foundation on which to plan cost-effective, environmentally-sound wastewater management strategies. This investigation included: 1) water quality analysis of current groundwater supplies; 2) documentation of water quality problems; 3) evaluation of alternative wastewater treatment techniques; 4) estimates of the financial impact of water quality maintenance; 5) studies of non-source pollution and its impact on groundwater supplies; 6) environmental impacts of wastewater facilities on sensitive ecosystems; and 7) a step-by-step guide to wastewater management planning.

Soil Research

Soil surveys in the Cape Lookout region have focused on the influence of soil factors on vegetative productivity. Berenyi (1966) and the U.S. Department of Agriculture Soil, Conservation Service (1977) investigated soil productivity factors which affected the vegetation of the Outer Banks region. Factors considered by Berenyi (1966) included the nature and fertility of the soil material, supply of ground water, and major plant nutrients. The USDASCS report included a generalized soil analysis, soil maps, and a correlation of plant assemblages with soil associations.

Broome, Woodhouse, and Seneca (1973), in an investigation of *Spartina alterniflora* propagation, found fresh sediment to be the dominant factor in determining the height and yield of vegetation. More specifically, they found nitrogen availability to be the major limiting factor in productivity of marsh vegetation, with the lack of phosphorus and high salinity also negatively affecting growth. Troutman (1980a) examined soil-forming factors in Meade River, Alaska, and Portsmouth Island/Core Banks, with particular attention given to the effects of climate and soil on dune vegetation. The study concluded that vastly different climates can support dune soils with similar characteristics (low moisture content, high leaching) and plant communities which show similar adaptive responses. Perkins and Beck (1938) published a soil survey of Carteret County.

COASTAL GEOMORPHOLOGY

Barrier Island Formation

The pioneering work of Abbe (1895) provided the initial impetus for later studies on the evolution of the Outer Banks barrier island chain, by characterizing the morphology of the Carolina coast, and presenting explanations for cuspate cape and spit formation.

Dolan and Smith (1962) reconstructed the former shorelines of the Outer Banks. They distinguished two phases in barrier island development: an older, inner phase marked by very prominent, closely spaced, parallel to subparallel beach-dune ridges, and a younger phase characterized by seaward-facing, low, inconspicuous, more widely spaced beach ridges. Extensive remnants of the older phase were found to be linked by spit-like units to the younger phase shorelines.

Welby (1970) conducted reflection seismic traverses in the Pungo River and in Pamlico Sound in order to investigate the origin of the Outer Banks. He observed several channels north of Ocracoke Island at a depth of 40 to 50 feet which were trending towards Ocracoke Inlet. He suggested that a marked change in the sedimentation record at a depth of 20 to 30 feet beneath Pamlico Sound indicated that the closing of the Sound could be dated more accurately than it had been at that time; however, Welby did not attempt to date this event.

Pierce and Colquhoun (1970, 1971) evaluated the evolutionary development of the North Carolina barrier island chain during Holocene times. They distinguished between primary and secondary barriers; primary previous barriers were characterized as an initial form; their development was attributed to drowning of low-lying land behind a mainland beach during a slight rise in sea level. Secondary barriers were distinguished from primary barriers by the substrate upon which they were built: primary barriers were built on material of terrestrial origin; secondary barriers, on marine sediment. Most of the North Carolina coast was considered to be secondary barriers.

Hoyt and Henry (1971) rejected previous hypotheses of how barrier islands were formed. They proposed that: 1) continued sea level decline at the beginning of a glacial period resulted in the extensive formation of low ridges; 2) when the ridges became resubmerged, they became loci for barrier island development; 3) accumulation of cape complex sediments occurred during the late Pleistocene; and 4) the barrier island chain from Cape Hatteras, North Carolina to Little Saint Simons Island, Georgia has developed atop these sediments.

Fisher (1973) reviewed Johnson's theory of emergent shorelines in the light of new data obtained along the Outer Banks from the analysis of mean gradient of the offshore slope of projected bathymetric profiles. He concluded that Johnson's assumptions on the relationship of the mean gradient of the offshore slope to barrier island development were not valid along the North Carolina-Virginia coast (one of Johnson's "type locality" coastal areas), and that at least portions of the Cape Hatteras barrier island chain developed in response to longshore drift.

Zeigler (1973) discussed the origin of barrier island systems as evidenced by the sedimentological characteristics of the sea islands located along the southeastern United States coastal margin.

Berelson (1980) examined the shallow subsurface stratigraphy under Harkers Island and Shackleford Banks in an effort to reconstruct the process of barrier island evolution and gain an understanding of its effect on lagoonal sedimentation. He suggested that Harkers Island overrode its own lagoonal sediments when it migrated landward during the mid-Wisconsin sea level rise. He proposed that the primary mechanism for landward migration was sedimentation by overwash processes. He also observed that inlet-fill deposits were among the most highly preservable barrier island facies as evidenced by the large percentage of these deposits underneath Shackleford Banks.

General Scientific Background Information

Dolan (1972c) reported on the progress of a National Park information system prototype encompassing the physical and biological aspects of barrier islands along the mid-Atlantic margin. The information base was to consist of field data, a literature review, charts and maps, aerial photographs, and an analysis of historical trends. The information was intended to facilitate management decisions in coastal regions. A symposium on the barrier island ecosystems of North Carolina was sponsored by the American Association for the Advancement of Science to discuss the status of ongoing research in the Atlantic Coast National Seashores, and the adequacy of the scientific research base (Godfrey 1972a).

Geomorphic Impacts of Coastal Development

A symposium on the impact of coastal development on the North Carolina barrier island ecosystems was held at East Carolina University (1975). Particular attention was directed to the delineation of areas of environmental concern and possible courses of action to alleviate environmental problems. Klump and Smith (1976) discussed the geomorphological features and aesthetic values of the North Carolina barrier island system. Special attention was devoted to the potential impact of human development and activities on the barrier island environment, and the role of environmental planners in the protection of these natural resources.

Regional Geomorphic Studies

Tatham (1807) provided a general geomorphic and historical survey of the North Carolina coast. He included descriptions of shoals and inlets along the coast, as well as accounts of shipwrecks in the region.

Dolan and Ferm (1968) suggested that crescentic landforms, such as Cape Hatteras and Cape Lookout, observed along the southeastern United States coastal margin represent one order of a continuous hierarchy of coastal landforms. They examined crescentic landforms that varied in size (measured from tip to tip) from 1.5 meters (e.g., beach cusplets) to 100,000 meters (e.g., the Carolina Capes). They categorized the landforms according to size, described their spatial distribution, and provided hypotheses as to processes controlling the development of each size landform.

Rochna (1961) described the physiography and the sedimentary deposits of the Outer Banks between Cape Lookout and Ocracoke Inlet. Smith (1961) examined the geomorphic and sedimentary characteristics of the Outer Banks. Discussion centered on barriers as beach ridge systems, dune building, geomorphic evidence for the former position of inlets, sedimentary evidence for beach development, and seasonal variations in beach configurations.

The U.S. Army Corps of Engineers (1964) conducted an inventory of the coastal resources of the Outer Banks between Ocracoke Inlet and Beaufort Inlet. The Coastal Plains Center for Marine Development Services (1971) and the University of North Carolina Sea Grant Program (Baker, 1975) compiled a series of papers on the physical features and management aspects of the North Carolina coastal margin. The Coastal Plains Center seminar included discussions on: 1) the physical processes operating in the coastal zone; 2) primary environmental objectives; and 3) management alternatives. The University of North Carolina symposium identified the extent and distribution of areas of environmental concern, as well as possible courses of action to alleviate environmental problems. Particular attention was directed to sensitive historic and archeological sites, and to the environmental impacts of coastal development.

Public Information Documents

Baker (1977) provided a discussion of geomorphological aspects of the Outer Banks designed to increase public awareness of the dynamic nature of the coastal zone. Particular attention was devoted to the effects of inlet stabilization techniques on shoreline change. This study utilized aerial photographs to illustrate geomorphic changes which have occurred in recent times at Cape Lookout.

Pilkey,, et al. (1978) produced a handbook for development and living on the dynamic barrier islands of the North Carolina coast. Background information included discussions on shoreline dynamics, hurricane-resistant building construction, flood legislation, structural shore protection techniques, and a history of hurricanes and human occupation.

Overwash

Godfrey (1970) examined the ecological implications of overwash deposition on the Outer Banks. Boc and Langfelder (1977) utilized aerial photographic analysis to determine the distribution and extent of overwash sites along the North Carolina coast between the years 1938 and 1944. They described the types of overwash that occurred in each county during the study period, and assessed the susceptibility of selected areas within each county to overwash. They concluded that overwash frequency had declined over the course of the study period, and attributed this phenomenon to a decrease in the number of landfall hurricanes that have hit North Carolina in recent years and an increase in dune heights along the North Carolina coastline.

Hosier and Cleary (1978) analyzed storm washover impact and recovery patterns resulting from Hurricane Hazel (1954) and the March 1962 northeaster. The authors detected two basic geomorphic patterns of island recovery which they correlated with grain-size distributions of the washover sediments.

Overwash Fans and Tidal Inlet Formation

Pierce (1970a) provided a theoretical discussion of the conditions under which washover fans or tidal inlets develop. He supplemented his discussion with evidence from a series of aerial photographs dating from 1945 to 1962 showing the effects of tropical and extratropical storms along the North Carolina coast. He concluded that storm surge and wave energy penetration of a barrier island from the seaward side would result in washover fans on wide barrier islands where extensive adjoining tidal flats existed; whereas storm surge overtopping narrow barrier stretches where no tidal flats were present would result in inlet formation. He demonstrated that bayside storm surge would cut new inlets when channeled along tidal creeks.

Storm Induced Erosion

In addition to the following investigations, a discussion of the effects of selected landfall storms on the Outer Banks can be obtained from the U.S. Army Corps of Engineers (1962a). Dolan (1972) examined the erosion that resulted from the Ash Wednesday storm of 1962, as well as beach erosion related to sea level rise. Dolan considered engineering methods of shore protection to be stop-gap solutions which delayed, rather than arrested, shoreline erosion and the loss of property. Knowles (1973) evaluated shoreline change along the Outer Banks with a special emphasis on storm induced erosion. Hayden,, et al. (1979a,b,c) studied shoreline erosion and the landward penetration of storm surges. Variations and periodicities of shoreline change rates along the Outer Banks were determined. The authors considered that site-specific measures of storm surge penetration were representative of approximately ±500m along the coast.

Climate and Storms

Bosserman and Dolan (1968) investigated the frequency, magnitude and occurrence patterns of extratropical storms affecting the Outer Banks between 1942 and 1967. They classified the storms according to type, origin, development, and movement. Pietrafesa,, et al. (1978, 1981) collected data on sea level and its variability along the North Carolina coast, including Beaufort Inlet and Cape Hatteras. Dolan (1969b) considered erosion and shoreline change to be inherent processes in the formation of barrier island systems; shoreline change has been attributed to sea level rise and a diminishing sediment supply.

Remote Sensing

Welby (1973), and Dolan, Hayden, and Alfonsi (1977a) used remote sensing techniques to analyze coastal processes in Cape Lookout and Cape Hatteras National Seashores. Welby (1973) discussed use of remote sensing as a means of formulating models of coastal processes and water mass behavior. Dolan,, et al. (1977a) identified remote sensing as a solid data base of coastal processes for barrier island monitoring; they emphasized the regional nature of the barrier island processes that can be identified using remote sensing.

Nearshore Processes and Sediment Transport

Dolan and Ferm (1966) estimated swash velocities along the Outer Banks in an attempt to establish a more direct link between breaking waves and beach change. Sonu,, et al. (1967) emphasized the role of topography as a responding variable, as well as a process variable, in the physical scheme of longshore currents. Their fieldwork indicated that a longshore current was a velocity field whose basic pattern varied depending upon the interactions of waves, currents, and topography.

Pierce (1969) evaluated sediment budgets for the barrier island systems from Hatteras Inlet to Cape Lookout, including sediment lost or gained by the barrier island chain, shoals, and inlets. In addition, sediment amounts transported by overwash or eolian processes were determined. Heron (1975) described the three sediment supply systems on Shackleford Banks: 1) the longshore current system; 2) offshore bars; and 3) sediment stored in tidal deltas. He found that offshore bars served as sediment sources under normal wave conditions, whereas tidal delta sediments were activated during major storms in order to restore post-storm dynamic equilibrium. The data collected in this study were intended to aid in the development of environmentally compatible approaches to coastal planning.

Dolan, Hayden, and Felder (1979a,b) analyzed the relationship between shoreline periodicities, linear offshore shoals, and edge waves. Cape Hatteras and Cape Lookout revealed a hierarchy of longshore periodicities that closely matched wavelengths of hypothetical standing waves trapped between the offshore shoals of the two capes. Levine (1982) analyzed nearshore processes and sediment transport along the Outer Banks. Fisher (1982) examined shoreline topography along the Outer Banks.

Beach Dynamics

Dolan, Ferm, and McCloy (1967) assessed the variability of beach morphology within the zone of breaking waves and across the subaerial beach. The results of beach profiles suggested that most variation occurred seaward of the innermost bar, and that the subaerial beach and inner trough are the most stable portions of the system. Murali (1975) evaluated sediment characteristics as beach-dune discriminators along the Outer Banks. Klump and Smith (1976a) investigated beach and shoreface dynamics, as well as barrier island migration mechanisms, along the Outer Banks. This study included an analysis of beach profile variations, sediment movement, current patterns, and overwash processes.

Shoreline Change

Smith, Dolan and their associates have been investigating shoreline processes, responses, and adjustments along the Outer Banks since the 1960s. Smith and Dolan (1960) discussed the erosional development of beach cusps along the Outer Banks of North Carolina. Dolan (1965b, 1966) measured seasonal variations in beach profiles. Price (1964) analyzed conditions effecting cyclic cuspate spits. Some of the critical factors studied included wave fetch and shoreline curvature, and their relationship to the efficiency and competency of longshore drift.

El-Ashry (1967), and El-Ashry and Wanless (1968) used sequential aerial photographs from 1945 to 1962 to assess long-term trends in shoreline features, as well as alterations by storms. They reconstructed the morphological changes that occurred during this period in the beaches, lagoons, bays, estuaries, and sounds along the Outer Banks. Particular attention was given to: 1) inlet modification and migration, especially as effected by hurricanes; 2) the

occurrence of tidal deltas in former bays and marshes; and 3) the role offshore shoals play as traps for sediment lost by beaches.

Langfelder,, et al. (1968, 1970) assessed coastal erosion along the entire North Carolina coast. They emphasized two methods that would best provide this information, aerial photography and wave refraction techniques. Erosion was considered the dominant process on the North Carolina coast. Littoral drift was taking place in the vicinity of Cape Hatteras, Cape Lookout, and Cape Fear. Stafford (1971) explained a procedure developed to make use of existing aerial photographs to survey beach erosion. Differences between stable and transient reference points on the beach represented change in location of the beach between the dates of the aerial photographs; this difference was converted to an annual rate of change. Changes in the beach, in the dune line, and at the high water line were determined. Stafford (1971), Knowles,, et al. (1973) and the U.S. Department of Agriculture, Soil Conservation Service (1975) examined beach erosion for the entire North Carolina coast.

Pierce,, et al. (1970) analyzed the relationship between wave refraction and coastal erosion between Virginia and North Carolina. They found that only waves from the northeast, east, southeast, and south have significant effects on shoreline change in this region, with northeast waves contributing 37% of the total energy input, and waves from the east contributing 30%. Waves from the southeast contributed 21% of the energy, while waves from the south accounted for only 12%. They observed that most of Cape Lookout was not affected by northeastern storms because of refraction around (and the wave shadow created by) Cape Hatteras. Cape Lookout received the greatest concentration of energy from the south, while erosion north of Cape Hatteras was considered to be caused by wave attack from all directions except the south.

Dolan and Linwood (1970) analyzed rates of shoreline change from Ocracoke Inlet to Cape Lookout. Although erosion was found to be extensive in the region, it was not considered an immediate problem except in the vicinity of Cape Lookout Lighthouse. Vincent and Dolan (1970) analyzed aerial photographs of the Outer Banks dating from 1958 to 1969, in order to pinpoint areas of rapid change, and to identify regions with the potential for serious erosion problems. Dolan (1971b) established a data base which was intended to aid in making engineering and planning decisions for Cape Lookout and Cape Hatteras National Seashores. This report summarized research completed between 1966 and 1971 on beach and dune dynamics, inshore bathymetry, sediment transport, and storm- induced erosion and included recommendations for future research at Cape Lookout.

Beach Stabilization and Shore Protection Alternatives

Stratton and Hollowell (1967) studied techniques of sand fixation that utilized fencing and plantings as a means of beach and dune erosion control. Dolan (1967*) discussed beach dynamics and shore protection alternatives, devoting particular attention to the interactions of private development and beach erosion. Langfelder, Stafford, and Amein (1970) looked at beach erosion as it related to coastal development and the economy of the Outer Banks. Dolan (1971c) discussed the efficiency of structural versus dynamic shore protection methods. Structural alternatives were considered to have a detrimental effect on the barrier island system in general, and the soundside ecology in particular. Dolan recommended the continuation of beach nourishment and marsh grass planting practices at Cape Lookout National Seashore, as well as the continued acquisition of additional park lands.

Dolan (1971d) analyzed the magnitude and frequency relations of selected processes influencing shoreline change along the North Carolina coast. This report summarized the results of 23 technical reports written between 1965 and 1971. The major conclusions of these reports included: 1) winter storms played a larger role in affecting shoreline change than hurricanes along the North Carolina coast; 2) North Carolina beaches were predominantly coarse-grained, therefore fine-grained sands were ineffective for beach nourishment; and 3) sediment loss due to erosion was the primary problem facing park planners. The results of this report were intended to aid park personnel in formulating management and coastal engineering policies. Dolan (1972c) provided a status report of research conducted along the Outer Banks from 1971 to 1972. Emphasis was placed on the effect of engineering structures on

beach erosion. Dolan (1972a) also analyzed the ecological implications of beach stabilization methods at Cape Lookout.

Godfrey (1972b) discussed the impact of the early settlers dating back to the sixteenth century, as well as modern development and stabilization efforts, on shoreline stabilization. He suggested that the ecosystems of the Outer Banks were once able to adapt to the energy of the coastal environment; however, the development and artificial stabilization of the barrier islands have made the barrier island system vulnerable to storm damage and, therefore, ecologically unstable. Dolan, Godfrey, and Odum (1973) considered large scale manipulations of the coastal environment which were undertaken to prevent natural processes from being a detriment to shoreline stability. They recommended that future development at Cape Lookout be undertaken in harmony with, and in consideration of, the dynamic nature of coastal processes.

Godfrey (1974) outlined the ecological consequences of barrier island migration as it related to coastal management policies. Godfrey and Godfrey (1975) discussed the impact of barrier island stabilization on estuarine ecosystems. Soucie (1974) reviewed factors influencing beach erosion at the Atlantic Coast National Seashores, including Cape Lookout, to increase public awareness of the dynamic nature of the coastal zone. He reviewed National Park Service efforts to control beach erosion, and suggested that these efforts were unsuccessful in the long-run, as evidenced by average recession rates of 6 to 22 feet per year on the Outer Banks.

Brauer (1974) segregated the surficial sediments of Shackleford Banks into genetic units based on topographic expression, sediment characteristics, and vegetative cover, in order to study the evolution and alteration of morphogenetic units. The results of this study indicated that: 1) plant succession was responsible for the stabilization of sediments; 2) the surface of the island was effectively elevated when vegetative cover preserved overwash deposition; and 3) the island was migrating landward in a northwest direction as a result of spit and marsh accretion. Dolan, Hayden, and Heywood (1977) investigated the relationship between the orientation of shoreline segments and shoreline change; they found that a strong correlation existed between these factors.

The U.S. Army Corps of Engineers (1978) investigated erosion rates due to inlet migration in the area of the Cape Lookout Lighthouse. They proposed construction of a stone riprap revetment along the lighthouse facilities to protect the lighthouse. Dolan, Hayden, Rea, and Heywood (1980) also analyzed coastal erosion and inlet migration at Cape Lookout; in addition, they examined the effects of these processes on the Cape Lookout Lighthouse. Also included were recommendations for arresting erosion in the vicinity of the lighthouse. Shabica (1980) discussed natural and engineering approaches to shoreline management at Cape Lookout. The report also provided an historical perspective on shoreline change, public policy, and stabilization efforts in the region. Jarrett (1983) examined factors affecting barrier island change, with special emphasis on the importance of sea level rise.

Estuarine Research

Dolan and Bosserman (1967) studied wind patterns on the sound side of the Outer Banks. They also developed graphs to aid in the prediction of height and type of storm surge for selected areas along the Outer Banks. Stirewalt and Ingram (1974) documented changes in the shoreline morphology of Pamlico Sound, utilizing aerial photographs dating from 1938 to 1971 as an information base. They found that shoreline retreat exceeded shoreline advance at all observed sites with the exception of the site at Solne where shoreline advance dominated. Katuan and Ingram (1974) examined sedimentary processes and the resultant sedimentary structures characterizing Pamlico Sound. Godfrey and Godfrey (1975) analyzed the effects of barrier island stabilization techniques on the estuarine environment. Amein and Airan (1976) designed a mathematical model to predict hurricane surge in Pamlico Sound.

Inlet Research

Batten (1962) examined bottom samples from Beaufort Inlet to determine the

distribution of sediments in the inlet, and more specifically, in the inlet subenvironments. The bottom sediments fell into size categories, each of which was correlated with distinct physical environments. Fisher (1962), in a study of the Outer Banks region, determined that relict inlets in barrier island chains can be distinguished, both spatially and temporally, by characteristic physiographic features. He then compared the physical parameters and distribution of lagoonal sediments contained in relict inlet deposits with present day flood tidal delta sediments in the Outer Banks region. He utilized historic maps, records, and geomorphic field studies as his data base. Ingram (1968) studied recent sedimentary processes in Beaufort Inlet, and the resultant lithofacies in the barrier island, estuary, and marsh environments. Based on these observations, Ingram constructed a vertical profile depicting the sedimentary sequence associated with the migration of Beaufort Inlet.

In a geomorphic study of the Outer Banks, Byrnes,, et al. (1970) concluded that tidal inlets and their associated deposits never account for more than 10-11% of the barrier island complex. They concluded that washover fan, tidal delta, lagoonal, dune, and beach sediments are of greater importance in the depositional framework of barrier island systems. Custer and Ingram (1974) studied sedimentary processes and grain size distribution patterns in Beaufort Inlet, Ocracoke Inlet, and Core Sound. Godfrey and Godfrey (1974b) concluded that the present pattern of salt marshes behind the Outer Banks is the result of overwash deposition, which provided sand to the marshes and inlet closures, thereby resulting in the formation of new salt marshes. The authors examined sedimentary processes at Cobb's Creek, Cedar Inlet, and Drum Inlet.

Langfelder,, et al. (1974) analyzed historic migration trends of selected inlets along the North Carolina coast to provide an information base from which to predict future inlet migrations. They included descriptions of the geographic setting of each inlet, freshwater sources, general geomorphology, and inlet stability. They observed that Barden Inlet had widened between 1945 and 1972, with a net migration to the east. They suggested that this migration may eventually cause a breakthrough of Core Banks on the ocean side, resulting in a new easterly oriented inlet. Beaufort Inlet has been narrowing since 1953, largely through accretion of Shackleford Banks on the east side of the inlet. The west side was stabilized with a series of groins and one major jetty; however, they identified a potential breach site on the east side of the inlet. Klump and Smith (1976b) discussed the dynamic nature of North Carolina's barrier island inlets. They placed particular emphasis on the processes controlling inlet configuration and inlet migration mechanisms.

Blankinship (1976) studied the influence of the flow dynamics in Drum Inlet on the salinity, tidal dynamics, and circulation of Core Sound. The author then used these data as a basis to recommend dredging of the main channel. Cleary (1977) examined coastal islands between Cape Fear and Cape Lookout with respect to inlet migration and distribution of overwash deposits. During the past 300 years, active inlet migration has occurred to the majority of locations along this coastal section. The frequency of washover in any one section appeared to be dependent on a complex function of variables, the most important of which was sediment supply. The grain size distribution controlled dune redevelopment, which in turn determined the susceptibility of the island to future washovers.

Inlet Classification

Nummedal (1977), Nummedal,, et al. (1977), and Hubbard,, et al. (1979) compared tidal inlet variability along the United States coast between Cape Hatteras and Cape Canaveral (the Georgia Bight), and along the North Sea coast between the Netherlands and Denmark (the German Bight). Nummedal (1977) analyzed the hydrology, sediment movement, and history of morphological change for selected inlets within the two bights in an effort to identify sedimentation patterns and morphological features distinctive of microtidal, intermediate, and macrotidal inlets. Hubbard,, et al. discussed the role of waves and tidal currents in the development of inlet types (e.g., microtidal, macrotidal) as evidenced by examples from North Carolina, South Carolina, and Georgia. They described the depositional environments and sediment body geometries found in each type of inlet. They concluded that the wave-dominated inlets of North Carolina were largely areas of landward sediment transport. Vincent and Corson (1980) measured parameters indicative of tidal inlet geometry in a series of inlets from

New York to North Carolina. Application of statistical analyses to the data led the authors to classify the inlets into six distinct morphological groups.

Inlet Stabilization

The U.S. Army Corps of Engineers (1964) published a report discussing the stability of Ocracoke and Beaufort Inlets, and the effects of selected hurricanes on these inlets. Jarrett (1976) reanalyzed data published by previous investigations (especially O'Brien 1931, 1969) on the tidal prism-inlet area relationships for Drum Inlet and Beaufort Inlet. Statistical analyses of these data led Jarrett to conclude that the tidal prism-inlet area relationship is not a unique function for all inlets, but varies with inlet location and the jetty stabilization system. Sarle (1977) observed that the narrowing of Beaufort Inlet by the stabilization of Fort Macon Point had caused tidal current velocities to increase, shoaling of the flood-tidal delta, and the westward migration of Shackleford spit. The ebb-tidal delta was found to play an important role in barrier island equilibrium, serving as a sediment sink in fair weather, and a sediment source during storms.

Machemehl (1977) examined the effects of the 1971 dredging of New Drum Inlet. The inlet had widened significantly by 1973, and was still in a stage of transition in 1977. Formation of interior shoals, tidal flow, and wave transmission were found to be greater than was typical for the inlet prior to dredging. Forman and Machemehl (1978) developed a hypothetical model for sediment movement in Drum Inlet. They also examined the stability of the inlet, the sediment budget, and the shoaling rates for the inlet and the flood tidal delta. In itself, the inlet was found to be fairly stable, although its presence was found to cause severe erosion of the shoreline adjacent to the inlet mouth. Priddy and Carraway (1978) studied selected inlets along the North Carolina coast to identify hazardous areas. They considered Ocracoke Inlet to be naturally stable and navigable. Beaufort Inlet is regularly maintained and it serves as a seaport channel. Drum Inlet, however, was found to have a history of dramatic widening and shoaling.

Dunes

Fisher (1965) studied the morphology and internal structure of present day beach ridges on the Outer Banks barrier island system and the adjacent coastal mainland. He provided information on the origin and development of beach ridges, and their relationship to the position of the shoreline. By analyzing the pattern of relict beach ridges, Fisher reconstructed the positions of former shorelines. Klump and Smith (1976c) discussed the relationshp between dune dynamics and morphology as evidenced by the barrier dune system along the North Carolina coast.

Dune Stabilization

The majority of the dune research in the Cape Lookout region has been concerned with dune construction. More specifically, research has focused on the progress of revegetation efforts, and the effects of dune construction on the natural environment. Woodhouse and Hanes (1966, 1967) tested the effectiveness of selected planting and fertilization techniques, both at the shore and in the nursery, in order to devise an accelerated and more effective revegetation program on the beach and dune areas of North Carolina. At this stage, American beachgrass, sea oats, saltmeadow cordgrass, and bitter panicum showed the most promise for dune stabilization. Ten years later, Woodhouse,, et al. (1976), and Seneca,, et al. (1977) reported on the progress of the dunes initiated by the selective planting techniques. Mixed plantings of the grasses were found to offer greater protection from disease than monospecific plantings. American beachgrass was found to initially accumulate the most sand, but it was short-lived in the region. Eventually it was replaced by sea oats and bitter panicum which effectively stabilized and accumulated sand. Woodhouse,, et al. (1976) also discussed modes and rates of dune growth, and the major factors affecting dune vegetation.

Dolan (1972a,b,d; 1975) discussed the geologic and economic implications of human manipulation (e.g., dune construction) on the natural barrier island environment. Dolan (1972c) combined his own investigations on the dune construction project with existing

literature to compile a park-wide information system. This information retrieval system was designed to aid park personnel in formulating management policies. Schroeder,, et al. (1976) examined changes in vegetational succession associated with barrier-dune construction on the Outer Banks. They concluded that dune construction helped to reduce sand movement and overwash and it accelerated vegetative succession to woody communities. Stembridge (1978) investigated the use of aerial infrared photography in the study of dune dynamics. The aspects of dune structure that can be monitored by infrared photography include: 1) potential blowout sites; 2) oversteepened dunes; and 3) disturbances caused by humans.

Holocene Stratigraphy

For a review of research into the stratigraphy of Cape Lookout, refer to the Geology Section.

VEGETATION

Introduction, General Studies

Studies of the vegetation of the Outer Banks date back to the turn of the century, providing a long-range data base on floristic changes. In 1928, Wells conducted a study of the plant communities of the coastal plain of North Carolina and their successional relationships. Brown (1959) conducted a botanical/ ecological reconnaissance of the vegetation of the Outer Banks, catalogued plants, and reviewed the success of sand stabilization and dune building projects from the 1930's on Cape Hatteras versus the natural dunes on Cape Lookout. In 1961, Burk surveyed the plant communities of the Outer Banks which were found to contain more than 520 plant species. In 1966, Burk compared the similarities and dissimilarities of the flora between Cape Cod, Massachusetts, and the Outer Banks of North Carolina. He studied floristic relationships in terms of community structure, major phyletic groups, and patterns of plant distribution. Radford,, et al. (1965) published an atlas of the vascular flora of the Carolinas, and, in 1968, published a manual on the same subject. The National Park Service (USDOINPSCALO, 1977) conducted an inventory of the vertebrates and vascular plants of Cape Lookout National Seashore. Snow and Godfrey (1978) published an excellent species list for Cape Lookout in which they described the vegetation by ecological habitats. Bellis (1980) also published the results of his survey on the vegetative cover on the barrier islands of North Carolina. Troutman (1980b), in a memorandum to the Chief Ranger, reported on the species composition of vegetational transects at Cape Lookout, and supplied a vertical profile indicating vegetational community changes.

Shackleford Banks

A number of general vegetation studies have been completed for Shackleford Banks, the southernmost barrier island of Cape Lookout. In 1900, Johnson described the flora, including the presence of lichens. Lewis (1917) published an extensive study of the plant associations by habitat. Kerley (1962) wrote an honors essay on the vegetation of Shackleford Banks. Au (1969) completed an extensive study of the vegetation of Shackleford Banks, and the ecological processes that have affected the area. Godfrey (1967) supplied photographic transects across the western end of Shackleford Banks from the Atlantic Ocean to Back Sound showing the major vegetation types. He described and mapped 23 plant communities for the island and concluded that wind, soil, and topography had the greatest effect on distribution and composition of plant communities. He also concluded that both "human disturbance and severe hurricanes [had] destroyed a large portion of the primeval maritime forest in the past." In 1973, Papperman and Benedict set up three transects on Shackleford Banks through a blowout, a marsh, and a maritime forest. These transects were to be used for continuing interpretive programs by visitors, in order that they might learn about different plant communities. In 1974, Au published further vegetation studies that were a continuation of his earlier work.

Portsmouth Island

Several vegetation studies were done on Portsmouth Island, the northernmost island at Cape Lookout National Seashore. Burk (1961b) studied the flora, listing 73 vascular species. He discussed ecological associations and escaped, non-native species (probably from the town of Portsmouth established in 1753). In 1974 Burk published an updated study of the vegetational changes from 1959 to 1973 which he concluded were due to reduced human activity and the near absence of hurricanes. A 1976 unpublished report by Burk and Lauermann extended the study, noting that the absence of grazing animals also helped to increase the plant diversity of the island.

Dune Vegetation

Dune vegetation studies have taken place for many years on Cape Lookout. In 1908, Bond reported on sand stabilization of the Outer Banks to prevent the total loss of the maritime forest due to dune movement. Among his suggestions were the planting of grasses on

both sides of the dune, and the planting of trees in the lee of the littoral dune. Woodhouse (1964) reported on the use of American beachgrass (*Ammophila breviligulata*) for dune stabilization. Seneca (1967, 1969) presented data on seed germination and seedling development of four dune grasses (*Ammophila breviligulata*, *Panicum amarulum*, *Spartina patens*, and *Uniola paniculata*) from the Outer Banks. He found *S. patens* to be the least salt tolerant, and that all four species could substitute sodium for potassium when potassium levels were low. In 1967, Woodhouse and Hanes published the results of field and nursery experiments on the use of the four grasses, *Ammophila*, *Uniola*, *Panicum*, and *S. patens*, for revegetation of the beaches and dunes. Savage and Woodhouse (1968) studied the use of both planted dune grasses (*Ammophila* and *Uniola*) and sand fences for the creation and stabilization of dunes. They found fencing to assist only in the earliest stages. Also, although *Ammophila* established itself rapidly, *Uniola* -- the naturally occurring species on southern Atlantic coastal dunes -- eventually replaced it. Therefore, they recommended interplanting of the two species for maximum effect.

Fletcher (1971) studied the ecology of the winter annual beach plant, *Cakile harperi* (searocket). He found that the dimorphic fruit allowed for germination of plants disturbed by overwash and burial. Harper (1973) studied the floral processes of *Uniola* and found that vegetative reproduction was replaced by sexual reproduction (floral initiation) when sufficient energy reserves were present in the vegetatively reproduced rhizomes. In 1974, Harper and Seneca continued studies of the flowering of *Uniola*. They found that day length had no effect, but that temperature was the key to the initiation of flowering, and that carbohydrate accumulation was reduced at the northern end of the gradient. The possibility existed that reserves of these carbohydrates may promote flowering at the southern end. Fletcher (1975) studied the adaptations of *Cakile harperi* and *Euphorbia polygonifolia*, which have similar spatial distributions. He found that both species retained temperature tolerances that were consistent with their presumed evolutionary history. Also, Fletcher found that each species existed on the Outer Banks through synchronization of its growing season to appropriate existing temperature conditions.

Seneca,, et al. (1976, 1977) reported on the use of *Panicum amarum* in dune stabilization for the U.S. Army Corps of Engineers. Results indicated that *Panicum* was better at stabilization than dune building (sand entrapment), and should be used only in mixed plantings with *Ammophila* and *Uniola*. Schroeder,, et al. (1976) investigated changes in vegetational succession associated with artificially-created dunes, through the use of remote sensing, aerial photography, and vegetational transects. They found that construction of high dunes reduced salt spray exposure, sand movement, and overwash. In addition, they discovered vegetational succession accelerated toward woody communities, which were vulnerable to extreme salt spray and overwash during storms. Also addressed was the lack of awareness of the dynamic nature of barrier islands, which in the past may have placed the entire system in jeopardy. Stembridge (1978) made use of aerial infrared photography in establishing a model for the prediction of dune growth and deflation patterns. His study was based on the high infrared reflectance produced by the mutual interdependence of pioneer dune vegetation and windblown sand.

Maritime Forests

Several studies have been conducted on the maritime forests at Cape Lookout. Ashe (1906) described historic conditions on Shackleford Banks that resulted from the cutting of timber for lumber and firewood. Around 1840 sand began drifting into the forest; by 1903 Diamond City residents were forced to relocate to Harkers Island due to loss of the forest (among other reasons), and by 1905 the eastern end of the island was completely sanded over. Ashe recommended an immediate attempt to reforest the barrier areas in order to protect remaining forest areas. In 1908, Pratt noted that heavy grazing and deforestation were contributing to dune movement. He made recommendations for dealing with the livestock problems, and for a program of reforestation. In an effort to avoid destruction by land developers, Bourdeau and Oosting (1959) recorded live oak communities on the Outer Banks and adjacent mainland. Floristic composition and community associations were described in detail. Burk (1962a) evaluated three oak populations on the Outer Banks that contained hybrids, and in 1963 published a report on the hybrid nature of three species of oak: *Quercus laurifolia* (laurel oak), *Q. nigra* (water oak), and *Q. phellos* (willow oak). He found that *Q.*

laurifolia did not occur outside the natural ranges of the other two species, but that both parents occurred outside the range of the hybrid. In addition, he was able to recover the parental types in the F_2 generation from hybrids, and found that neither *Q. nigra* nor *Q. phellos* appeared to be hybrids. A final study by Rebertus (1979) examined the factors affecting woody vegetation on barrier islands, and the possibility of using black pine (*Pinus thunbergii* Parl.) for planting. The study included a history of deforestation and reforestation on the Outer Banks.

Salt Marshes

The salt marshes of the Outer Banks have undergone extensive study in recent years, mainly because human-induced alterations in dune height and stabilization have affected the frequency of overwash which supplies the marshes with sediments, and because dredging of channels on the bays for navigation has also disturbed them. In 1962 Wilson prepared a technical report on wetlands distribution and management in North Carolina. Williams and Murdoch (1966) studied the annual production of *Spartina alterniflora* and *Juncus roemerianus*, in which estimates of the daily loss of dead plants approximately equalled 1% of the total weight (biomass) for both species. Waits and Cooper (1966) studied net primary productivity in order to produce crop estimates for the major species of the four community types in the marsh. Godfrey (1970a) examined the concept of overwash as an ecological factor in the formation of marshes; he recommended maintaining a wide berm, having scattered dunes of varying heights, and maintaining extensive grasslands and salt marshes. In 1971 Donnelly conducted a marsh resource investigation for the North Carolina Wildlife Resources Commission.

Williams and Murdoch (1972) did a compartmental analysis of the production of *Juncus roemerianus* to test a model they had worked on that would predict production. The data supported the original assumptions that total biomass is relatively constant throughout the year and that transfer rates undergo seasonal cycles. Woodhouse, Seneca, and Broome completed a study in 1972 for the U.S. Army Corps of Engineers' Coastal Engineering Research Center concerning the use of dredge spoil for creating new marsh habitat. Various techniques for planning and maintaining the marshes were discussed. Hosier (1973) conducted a major study on the effects of overwash on the vegetation of barrier islands. He found that overwash had three main effects -- erosion, burial, and short-term saltwater flooding -- all of which affected vegetational distribution. The data showed that areas of frequent washover were dominated by annuals, plants that withstand frequent burial such as dune grasses, or salt-tolerant species from marsh areas.

Broome,, et al. (1973) researched the propagation of *Spartina alterniflora* from seed, and investigated the relationship of mineral nutrients to the growth of *Spartina*. They found that the protective cover established by seedling growth exceeded protective cover produced by transplants during the first growing season, and that nitrogen fertilizer increased yields, indicating that a lack of nitrogen availability was limiting productivity in the marshes. They also investigated the effects of phosphorus and iron addition on the growth of the marsh. Phosphorus increased standing crop approximately three-fold; however, no growth response was noted with the application of iron to the marsh. The authors concluded that fresh sediment input to the marsh was the dominant factor in determining the height and yield of *S. alterniflora*, and that the marsh acted as a buffer for the entire estuarine system, providing a sink for excess nutrients which resulted from municipal wastes and land runoff. Also in 1973, Cooper and Waits investigated the types of vegetation found in an irregularly flooded salt marsh on the Outer Banks. Godfrey and Godfrey (1974b) elaborated on the role of inlet dynamics and overwash in the formation of salt marshes, emphasizing the dune/marsh dynamic interrelationships. Woodhouse, Seneca, and Broome (1974) published further studies on reclaimed marsh land through deposition of dredge spoil along baysides and as islands. The main thrust of this study was the use of *S. alterniflora* to stabilize the newly deposited substrate. They found that transplants were more vigorous than seedlings and were better able to survive both on exposed sites and at lower elevations; furthermore, primary productivity was equal to that of long-established marshes after two growing seasons. Broome,, et al. (1975) proceeded with further investigations into the relationship between mineral nutrients and

growth of *S. alterniflora*. The authors specifically looked at the nutrient status of plants and soils in natural marsh stands. Tall and short *S. alterniflora* height zones of seven natural stands were sampled three times during the growing season. Regression analysis was used to detect relationships between nutrient levels in soil, plant tissue, and production. The results showed that plant tissue concentrations of several nutrients and soil properties were significantly associated with variations in yield and height of *S. alterniflora*. Silander's Ph.D. dissertation (1976) examined the distribution and abundance of *Spartina patens* as related to ecological and evolutionary processes.

Stiven and Plotecia (1976) used a regression model to estimate salt marsh primary productivity. Beal (1977) did extensive field collections of aquatic and marsh vascular plants in which he showed a continuum of species rather than well-defined groupings. Longstreth and Strain (1977) examined the dynamics of the physiological ecology of *Spartina alterniflora* by varying light intensity, salinity, and tidal cycle simulation. They found that salinity alone rarely inhibited photosynthesis, but low illumination and high salinity (30 $^{00}/_{0}$) can cause a 50% reduction. In 1979, Silander and Antonovics did further work on the genetic basis of the ecological amplitude of *S. patens*, based on morphometric and physiological traits. They found that the occurrence of *S. patens* across a range of conditions was associated with divergent evolution among adjacent subpopulations, or manifested itself by significant differences in vegetative and reproductive culms, and morphometric responses to salinity, nutrient levels, and drought. Wilson (1981) published a field guide to the salt marsh plants of North Carolina which incorporated information on the salt marsh habitat, the value of salt marshes, and zonation in the marsh; diagrams and a key were included.

Algae

Williams (1948a) conducted a study on the ecology of the marine algae growing on a rock jetty at Cape Lookout, and a general study (1948c) of the marine algae of an artificial rock jetty. In a more specific work, Williams (1948b) investigated the abundance, distribution, reproduction, and ecology of *Codium* spp. in North Carolina. In addition, Williams (1948d) investigated the seasonal alternation of marine flora on the jetties at Cape Lookout National Seashore. Williams (1949) gave a detailed account of the ecology of marine algae around Cape Lookout. Sixty new species were described, and it was found that the species composition differed between Cape Lookout and the Beaufort Estuary. Williams (1950) worked on the role of algae in stabilizing beach sand, and found that algae tended to "tie down" sand to a firmness which, during World War II, allowed the military to use the beaches as landing strips. Schneider (1975) documented previously unrecorded species of rhodophytes for the Cape Lookout area. Six new species of Ceramiales were added including a new species of *Dipterosiphonia*. Polimeni (1976) studied the seasonality and life history of a blue-green algal mat on Shackleford Banks. Kapraun (1977) conducted taxonomic and ecological investigations of nine species of *Polysiphonia* occurring along the North Carolina coast. The study included keys, descriptions, and illustrations, as well as ecological information for these species, and comparisons with other areas. Searles and Schneider (1978) compiled a checklist of North Carolina seaweeds, and a bibliography of studies on seaweeds. Richardson (1979) investigated the possible overwintering of *Dictoyata dichotoma* by an early developmental stage in its life history. It was demonstrated that *D. dichotoma* was maintained throughout the year and did not require yearly immigration; a young gemling stage was shown to function as an overwintering structure.

Amsler and Searles (1980) studied the distribution of seaweed spores in a water column off the coast of North Carolina. The authors were interested in the resulting differences in dispersal between species whose spores drifted at different levels in the water column. Four different taxa were observed. They found that the occurrence of certain kinds of spores in the upper level of the water column supported the hypothesis that these species had large dispersal shadows due to their location in the water column, and that those species located in the upper levels of the water column were typically opportunistic. Also in 1980, Searles and Schneider investigated the biogeography of the seaweeds of North Carolina. They assessed the importance of North Carolina waters as a transition region or boundary in seaweed biogeography, and investigated the significance in differences between deep and shallow water

floras of the North Carolina area. Through data compiled from previous research (Searles and Searles, 1978) it was concluded that there were basic differences between deep and shallow water assemblages of seaweeds. The shallow water flora included a larger number of species (78) which were known to both northern and southern regions, than did the deep water species (45). This study demonstrated that the North Carolina segment of the coastline was an especially significant transition zone with respect to total number of species and to the northern limit of tropical elements. Peckol and Searles (1984) documented temporal and spatial population variability in a seaweed-dominated, continental shelf community. It was found that seaweed and invertebrates exhibited destructive spatial distribution patterns which appeared to be associated with seasonal variation in storm surges and strong currents. The results suggested that the observed seasonal variations in abundance were a reflection of the fluctuating environmental conditions.

Fungi

Both a new genus and species of fungi from Mullet Pond was described by Johnson and Gold (1957); it was separable at the generic and specific levels on the basis of ascospore septation. In 1975, Warren and Lucas investigated how various dune plants were affected by the blight-causing fungus *Marasmiellus mesosporus*. The results confirmed that *M. mesosporus* was the cause of Marasmius blight and that the fungus was pathogenic to American beachgrass as well as to several other dune species. The authors hypothesized that any species that were found to be resistant to this pathogen would be useful in stabilizing the areas where American beachgrass was dying.

Field Guides

Several field guides to the vegetation of Cape Lookout National Seashore are available. First, Harrar and Harrar (1962) published a guide to southern trees. Small (1972) wrote a manual of southeastern trees; Duncan (1975) wrote a guide to the woody vines of the southern United States; Duncan and Foote (1975) published a guide to the wildflowers of the southeastern United States; and Silberhorn (1982) published a guide to the common plants of the mid-Atlantic coast. Finally, Graetz published a book (1973) on seacoast plants of the Carolinas planted for conservation and beauty. It was hoped to encourage people to plant native vegetation on their homesites rather than introducing exotic species.

INVERTEBRATES

Introduction

This portion has been divided into two sections: 1) studies dealing mainly with terrestrial invertebrates such as insects and 2) studies that focus mainly on aquatic invertebrates such as benthic fauna and zooplankton.

Terrestrial Invertebrates

Insects

Research on the insect fauna of the Outer Banks is fragmentary. The existing articles concentrate on the ecology and behavior of small groups. No broad censuses exist to document the insect populations, and interestingly, no publications were found citing the important issue of major pest species, such as mosquitoes, and their control.

Lepidopteran population distributions were surveyed by Sherman (1904) and Maturo (1953). Sherman determined that the Orange Dog Swallowtail (*Papilio= Heraclides cresphontes*) populations of Shackleford Banks were located on the fringes of the range extensions. Maturo surveyed butterfly distributions on the Shackleford Banks and Mullet Pond in the Beaufort area of Carteret County. For this study, species and their relative abundances were tabulated from June 1952 to June 1953. Fifty-nine species were recorded; twenty-nine were new sightings in Carteret County. At least 13 of these new species were found outside of their previously known ranges. Davis and Gray (1966) determined zonal and seasonal distributions of the insects found in North Carolina salt marshes. They divided the insect species into orders, and listed them by habitat and season. A plant/pest control relationship was studied by Campbell and Fuzy (1968). American beachgrass, planted extensively along North Carolina's Outer Banks for coastal dune stabilization, was by 1968, threatened by an insect pest. Campbell and Fuzy (1971) investigated the biology of the pest, a naked scale, *Eriococcus carolinae*, with respect to its damage and seasonal coincidence. They found that the scale population peaked in mid-July, coinciding with high vegetative growth of the beachgrass. A few minute alate male scales fertilized many females, and ovisacs were deposited in late summer. The ovisacs were then wind dispersed, resulting in a widespread distribution. The authors observed 15.8% of the ovisacs being preyed upon by ants. They suggested use of this predator as a method of biological control for the pest species. Gifford and Opler (1983) observed several species of hairstreaks in their natural habitats and discussed the life history of each species.

Arachnids

Barnes (1953) investigated the distribution of spiders in non-forest maritime communities. He found that each different vegetation community supported a different spider community. In addition, he found that as vegetative succession proceeded toward a climax community, there was an increase in both the number of species and in the population density of spiders associated with the increasing niche diversity of the forest.

Aquatic Invertebrates

Sponges, Cnidarians, Ctenophores

The marine sponges of North Carolina were documented in two papers by Wells,, et al. (1960, 1961). In these studies, the species of the area were listed and described, representing a significant taxonomic contribution. Schwartz and Chestnut (1973, 1974) surveyed and described the jellyfish (cnidarians) and comb jellies (ctenophores) in the coastal waters off North Carolina.

Annelids

Hartman (1945) compiled a list of the marine annelids of North Carolina. The influence of grain size and organic content of sediment on polychaete distribution was studied by Potts (1967). He found that the species distribution patterns appeared to be affected more by changes in factors associated with increasing depth. Nelson (1979) studied the settlement patterns of *Janua brasiliensis* on *Zostera marina*. The study revealed a strong seasonal pattern of larval recruitment. Also demonstrated was the importance of a diatom mat, and the gregarious settlement of *J. brasiliensis*. Cammen (1980) used a new method for measuring ingestion rates of deposit feeders. Using the polychaete, *Nereis succinea*, he found that the ingestion rates varied with both temperature and size. Total ingestion, as determined with this technique, was much greater than previously reported, and the contribution of small infauna such as *N. succinea* to the functioning of the marsh ecosystem requires more intense study.

Mollusks

Porter (1962) undertook a study to determine to what extent the hard shell clam was parasitized by the nemertean *Malacobdella*. It was found that the parasite occurred in 83.3% of the 2,000 hard clams collected and infestation increased in beds further offshore. Although no damage to tissues was reported, the presence of a parasite in a commercial resource was extremely significant. Porter (1964) also worked on hard clam reproduction cycles. Changes in the gonadal cycle of the hard clam, *Mercenaria mercenaria*, were documented, and it was found that both males and females had their first major spawn in June and gradually dropped off through early fall. Peterson,, et al. (1983) used a mark-recapture technique to test the annual periodicity of internal growth band deposition in the shells of the hard clam, *M. mercenaria*, from a small southern population. Peterson,, et al. (1984) measured the influence of seagrass cover on population structure and individual growth rates of *M. mercenaria*. It was found that the average density of the hard clams taken from an eelgrass bed ($9.0/m^2$) was more than five times greater than the density from a nearby sand flat ($1.6/m^2$). Size frequency distributions differed in that the sand flat environment contained less of its members in the larger size classes (7/cm). The differences may be attributed to the baffle effect on currents by the eelgrass, creating higher particulate food concentration in the area.

Macrocrustaceans

Pearse (1945) conducted a study on the ecology and distribution of the mud shrimp, *Upogebia affinis* (Say), around the Cape Lookout area. The results of the study showed that above 37°C and at low salinities, high mortality rates occurred. A summary of the penaeid shrimp nursery grounds was compiled by Williams (1955). On the basis of juvenile population densities and species composition, the nursery grounds were divided into four areas: 1) Brunswick- Onslow; 2) Carteret-Onslow; 3) West Pamlico Sound; and 4) North Pamlico Sound. Highest populations of juveniles were found to occur in the shallow parts of the estuary. In general, sparse populations occurred in areas with weak currents and no perceptible tide. McCoy (1972) studied the dynamics of North Carolina's pink and brown shrimp populations. He attempted to develop potential yield estimates for these commercially important species which would maintain a maximum sustainable yield (MSY) as a management objective. Purvis and McCoy (1972) investigated the overwintering of the pink shrimp, *Penaeus duorarum*, in Core and Pamlico Sounds. Results showed that the migration of pink shrimp from the sounds to the ocean did not occur in the fall. Mass migration, as well as significant growth, was brought to a halt by cooler water temperatures in the fall. Fox and Bynum (1975) compiled a listing of the amphipod crustaceans found in the estuarine waters of North Carolina. Colby and Fonesca (1984) worked on the population dynamics and ecology of the fiddler crab, *Uca pugilator*. They found that the number of crabs fluctuated greatly during their study. Although the fluctuation affected both sexes equally, females always outnumbered males.

Zooplankton

Hadley (1936) described the species of Foraminifera obtained from shallow water

dredgings at three stations around Cape Lookout. Twenty-three species were described, including one new species, *Bolivina beaufortana*. Grossman (1962) studied the ecology of the rhizopods and ostracods of the southern Pamlico Sound region. Coull and Vernberg (1970) studied the metabolic rates of two harpacticoid copepods (*Enhydrosoma propinquum* and *Longipedia helgolandica*) from two different habitats. It was found that respiratory rates differed significantly and could be correlated with activity patterns and habitat preferences of these two species. The results of a ten-year study of the meroplankton in North Carolina estuaries by Williams (1971), Williams and Porter (1971), and Williams and Bynum (1972) have supplied much of the information on the zooplankton species of the area. Williams (1971) investigated the annual occurrence of some brachyuran crab developmental stages in the meroplankton. The largest and most abundant megalopae at all stations were the portunids. It was also demonstrated that these developmental stages occurred predictably in space and time, but varied in number from year to year. Williams and Porter (1971) studied the occurrence of postmetamorphal bivalves in the meroplankton. Only a few species of clams occurred with any regularity. Williams and Bynum (1972) studied the distribution and seasonality of amphipods in North Carolina estuaries. A total of 48 species were identified. In addition, it was discovered that the benthic amphipods migrated vertically to the surface at night, and that all amphipods appeared to have a seasonal cycle of abundance. Paffenhoffer and Knowles (1979) studied the ecological significance of copepod fecal pellets. Production of pellets was found to be a function of food concentration. The authors investigated how zooplankton size distribution could determine the residence time of pellets in the water column, and the probability of pellets being ingested or reaching the benthos. In 1982, Paffenhofer compared the abundance and composition of zooplankton in water intrusions with that of surface waters, and attempted to relate these to hydrographic and biologic variables. Thiriot-Quievreux (1983) compiled a list of planktonic prosobranch larvae observed off Beaufort during the summers of 1977, 1979, and 1981. A total of 42 species of prosobranch larvae were described, and a key for the identification of prosobranch veligers was also included.

Surveys, General Community Studies

Pearse,, et al. (1942) studied the flora and fauna associated with the sand beaches at Beaufort. A quantitative study was made of the animals that thrived on the algae growing on the jetty at Cape Lookout (Sutcliffe, 1947). The results identified 40 different species; seasonal variation was exhibited by several of these species. Most algae-inhabiting animals were found to be highly specialized for this lifestyle by way of special coloration and organs of attachment. Cammen (1976a,b) investigated colonization of *Spartina* marshes (artificially established on dredge spoil) by macroinvertebrates. Insect larvae were dominant at spoil sites, while polychaetes were dominant on natural marshes (unaltered). The estimated annual macrofaunal production was much higher for the natural marsh than for the planted marsh. A list of the common invertebrates of the Beaufort area was compiled by Smith and Gray (1977). Wilson (1979) studied the macrofaunal communities associated with the tube-building polychaete, *Petaloproctus socialis*. The presence of this polychaete as a substrate modifier acted to increase species diversity of the associated macrofauna. The author concluded that in areas where disturbance was frequent, these densely packed, tube-building worms provided a refuge to other macrofauna.

Miscellaneous Studies

In an early study, Gutsell (1928) accidentally discovered an association between jellyfish and spider crabs. He observed that spider crabs were frequently found within the jellyfish that were brought up in trawls. This was just an observation; no further investigation was carried out. Maturo (1957) did an extensive study of the bryozoans of Beaufort and vicinity. Specimens were collected from shells, rocks, pilings, submerged debris, and algae. Fifty-nine species were reported, and twenty new species were described. It was found that 26.3% of the species occurred only in the sounds and estuaries, 42.1% occurred only offshore, and 31.6% were distributed over both locations. In 1969, Gray,, et al. put together a key for the identification of the sea stars of North Carolina. A total of 33 species belonging to 22 genera were identified. Lindgren (1971) investigated the distributional pattern of psammolittoral tardigrades from North Carolina, and their conformity to worldwide zonation patterns. Blue crab ova were examined for the fungal parasite, *Lagendinium callinectes* by Bland and

Amerson (1974). *Callinectes sapidus* showed a 95% infection rate, with the mature crabs showing a 10-20% higher infection rate than the younger ones. Robertson and Mau-Lastovicka (1979) presented a history of the available information on the North Atlantic odostomioids Boonea and *Forgea*. Included were comparisons of present occurrences and frequencies, with host and host preferences of *B. seminuda* and *B. bisuturales*. Wolcott and Wolcott (1983, 1984.) conducted several studies on the impact of off-road vehicles (ORVs) on beach invertebrates at Cape Lookout National Seashore. Three groups of invertebrates were studied: ghost crabs, mole crabs, and coquinas. Results showed that the macrofauna of high energy beaches tolerated moderate levels of diurnal ORV traffic on the foreshore of the beach.

FISH

Introduction

Fish research at Cape Lookout National Seashore has predominately consisted of listing and quantifying the species present. In addition, several studies have made efforts to correlate species habitat preference to the influences of temperature, salinity, and seasonal parameters.

Surveys, Checklists

One of the earliest comprehensive studies of North Carolina fish was Hildebrand's (1941) list, which included a reclassification of Atlantic menhaden. Tagatz and Dudley (1961) examined seasonal variation for all species present in the Beaufort shore area. Over a three-year period of seining, a total of 65 species from 34 families were collected from study areas including Bogue Banks and the Neuse River. Mullet Pond on Shackleford Banks was one of the few permanent bodies of fresh water on the barrier island system where a number of studies were conducted. Schwartz (1970) reviewed studies from 1914-15, 1926, and 1930. Previously, the pond contained 26 species; however, the closing of the pond's connection to the sea in 1933 resulted in a gradual decrease in salinity and the survival of only four fish species: Cyprinodon variegatus, *Fundulus confluentus*, *Lucania parva*, and the dominant species, *Gambusia affinis*. Adams (1976) studied the ecology of eelgrass fish communities in Bogue Sound and Phillips Island. Both communities were dominated by pinfish (*Lagodon rhomboides*). A larger survey area covering the Outer Banks region was conducted by the National Marine Fisheries Service (USDCNOAANMFS, 1976); a total of 101 species were captured using trawls and seines. Ross (1977) compiled a checklist of marine fish in the shore areas of North Carolina, which separated species according to the following habitats: salt marshes, eelgrass beds, Onslow Bay, hard substrate areas, Newport River, and Newport Estuary. Schwartz (1982) surveyed the fish and ecology of the freshwater ponds of Cape Lookout National Seashore. A total of 13 species were collected. Each species and its habitat characteristics were discussed separately.

Management

Wolff (1978) prepared a preliminary stock assessment of the paralichthid flounder in North Carolina waters. Southern flounder made up 95.8% of the pound net catch; other flounder caught included summer and Gulf flounder. As part of the North Carolina estuarine finfish management project, DeVries and Harvell (1982) attempted a tagging project of the southern flounder (*Paralichthys lethostigma*) to determine movement, numbers, and distribution in the estuarine waters of North Carolina, particularly in Pamlico and Core Sounds. Only 29.9% of the southern flounder that were marked were recaptured. The authors recommended further tagging studies. Hawkins (1982) sampled finfish in the nursery areas of North Carolina. Eighty-eight species of fish and twenty-three species of invertebrates were captured. Sciaenids made up 72% of the total fish catch, while blue crabs were the most abundant invertebrate captured. Most species preferred the shallow tributaries as initial recruitment habitat. Ross (1982) sampled Pamlico and Core Sounds to evaluate species composition, seasonality, and age and size structure of each species present. Forty-six species were captured, with spot, Atlantic croaker, Atlantic menhaden, pinfish, and weakfish comprising 95% of the catch.

Reef Fish

Ross and Fast (1977) updated records of the tropical fish found on reefs in Onslow Bay. Harris and Lindquist (1979) looked at trophic partitioning in four species of reef fish in Onslow Bay: *Haemulon aurolineatum*, Pareques ombrosus, *Centropristis striata*, *Stenotomus aculeatus*. Lindquist and Harris (1979) investigated population trends of reef fish on a rock scarp in the bay. An assessment was made of relative abundance of non-cryptic, diurnal reef fish.

Miscellaneous Studies

Lewis and Mann (1971) looked at the distribution and abundance of larval menhaden in Onslow Bay. Larvae were found to enter the bay from November through April, with the highest frequency occurring in March. Migration of juvenile menhaden was studied by Kroger and Guthrie (1973). Juveniles tagged in the mid- and north Atlantic regions moved southward in the fall, whereas one-year-old juveniles migrated northward in the spring, with large fish segregating from the smaller during northward movement. A study of paralichthid flounder distribution by Powell and Schwartz (1977) correlated salinity and sediment types with species preference.

REPTILES, AMPHIBIANS

Introduction

Almost all of the research done on reptiles and amphibians at Cape Lookout National Seashore has centered on sea turtles. The remainder of the studies are mostly general surveys with a small amount of research specifically on snake and/or lizard species.

Sea Turtles

Much of the current knowledge on sea turtle distribution along the Outer Banks is the result of the many surveys conducted over the years. A survey of marine turtles nesting in the United States was taken by Lund (1974). He conducted a literature review to gather data that related to the nesting locations of U.S. marine turtles. The National Park and Conservation Association conducted a survey in 1977 to find which sea turtle species nested at which National Seashores. Also in 1977, Voges conducted a survey for the National Park Service. He supplied information on the significance of Cape Lookout as a turtle habitat, and started a base for continued monitoring and future management. As a result of this project, future surveys were easier to analyze. In 1979, two surveys were carried out (Davis and Hoggard, 1979; Hoggard, 1979). Through use of aerial surveys and intense night patrolling, David and Hoggard monitored and described populations of sea turtles, and identified and documented nesting sites and nesting periods. A total of 162 observations were recorded over a 6.5 mile stretch of beach on Core Banks. The nesting success rate was 44%, with an average of 1.24 nests per mile. Emergence of hatchlings occurred between May 28 and July 14. The most concentrated nesting activity occurred on the Cape Point region. Hoggard (1979) provided the National Park Service with a procedure for data collection. All nests were marked with tags. Tagging and data collection included meteorological data, maps of crawls, times of nearest high and low tides, beach characteristics, distance from dunes, presence of fixed light sources, and the time and date. Data were also collected on the number of hatchlings, success rate of reaching the ocean, presence of obstacles, and the effects of predation. In 1981, Hoggard again conducted the turtle survey for the National Park Service. His results showed a decrease in the number of nesting turtles as compared to the 1971 survey. He concluded that it may have been due to unusually cool air and water temperatures during the early part of the season. The average hatch rate was 86% and incubation time was 61 days. Also, the highest concentration of nesting in the research area happened to be in the area that was most used by visitors to the park. Mengel and Rea (1982) reported on the turtle tagging survey for the following year. They found a decrease in the number of nests, and a decrease in turtle preference for the study site. The hatchlings were found to be disoriented by light. On Cape Lookout the hatchlings frequently travel toward the light, thereby increasing the risk of predation or elimination by ORVs. Predation by ghost crabs was the primary problem; birds and raccoons accounted for a small portion of hatchling removal. Parrish (1982) surveyed nesting loggerhead sea turtles, and, in addition, presented a compilation of data from past years. Information on strandings, tagging, hatchling success, predation, and erosion as a mortality factor were analyzed. This survey revealed a notable decrease in nesting activity at the Seashore. The author recommended flexibility in closure, dates, lengths and locations, an increased study area, protection of nesting females (if nesting continued to decline), and an ongoing interpretive program for visitors, school children, and fishermen.

Incidences of loggerhead sea turtles encountering shrimp trawls was recorded by Ogren,, et al. (1977). In a North Carolina Workshop on Endangered and Threatened Sea Turtles, Barick (1978a,b) presented a series of papers on biology and distributional patterns, sea turtle nesting at Cape Hatteras and Cape Lookout National Seashores, and descriptions of individual agencys' authority, responsibility, and participation in sea turtle conservation along the North Carolina coast. The purpose was to help define the Wildlife Commission's role in the protection and management of sea turtles. The author concluded that there was a need for further research, in addition to the need for protection, preservation, and designation of critical habitats; the need for interagency cooperation was also noted. Lutterbie (1978) reported the discovery of a dead Atlantic ridley sea turtle, which is not commonly found in the Cape Lookout area. The author described the turtle, its normal habitat, and its behavior. Schwartz (1978) investigated the behavioral and tolerance responses of three species of sea turtles to cold

water temperatures. His results showed that when all three species -- loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), and green sea turtle (*Chelonia mydas*) -- were subjected to water temperatures lower than what they usually encounter, they died. Shabica (1979b) discussed the results of a monitoring program begun in 1977 that was designed to systematically survey coastal National Parks of the southeast region in an effort to determine where sea turtles nest, when nesting activity takes place, and to estimate relative nesting turtle population sizes over time. Four species were known to nest on National Seashores in the southeast: loggerhead (*Caretta caretta*), green sea turtle (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*), and leatherback (*Dermochelys coriacea*). A brief status report for each park was provided. Long-term systematic surveys are important because they make it easier to document the reduction of nesting beaches for sea turtles due to human encroachment. In a publication specific to the Cape Hatteras and Cape Lookout area, Shabica (1979a) supplied much of the same information as in the previous publication. He found a strong correlation between false crawls and permitted ORV activity, and on the presence of nests in areas where ORV use is prohibited. In two publications Stoneburner (1979, 1980) investigated heavy metal concentrations in loggerhead eggs as evidence that demes exist in the western Atlantic population. He found that there were no uniform patterns in the distribution of the 13 heavy metals discovered in the eggs, either within or among nesting beaches. Stoneburner postulated that heavy metal data could be used to identify clutches of eggs from different nesting beaches. His data, however, did not show that distinct demes existed within that population of turtles. Woodward (1930a,b) reported on the status of leatherback and Kemp's ridley turtles in the United States. Included were descriptions of habitat, diet, and range for each species. Lee and Palmer (1981) reported on the occurrence of five species of marine turtles in North Carolina waters. In the warmer months of the year, loggerheads were found to stay within one to two miles offshore. Maps of the worldwide distribution of sea turtle nesting sites were provided by Sternberg (1981). Following that, Sternberg (1982) compiled a directory of sea turtle conservation programs found in the southeastern United States. The National Park Service (USDOINPSSERO, 1983) published a sea turtle monitoring handbook for Cape Lookout, Cumberland Island, and Cape Canaveral National Seashores. The handbook described nesting site locations, when nesting occurred, and the establishment of an estimate of the nesting turtle population. This information was to be used by park personnel to identify potential conflicts between turtle nesting and human activities, and to determine the necessity for beach restrictions. An update on the nesting distribution of loggerheads in coastal North Carolina was provided by Crouse (1984). A total of 430 km of barrier island beaches were surveyed by fixed-wing aircraft at regular intervals during the 1980/1981 nesting seasons in an attempt to determine the feasibility of using aerial surveys as a tool for making population estimates. It was concluded that aerial surveys were useful for determining relative density and distribution of nesting attempts. However, the differential retention of crawl tracks on individual beaches precluded using aerial crawl surveys for total population estimates.

Snakes

A handbook of the snakes of the United States and Canada was compiled by Wright and Wright (1957), which included descriptions of species found at Cape Lookout. Conant and Lazell (1973) reported on a distinct form of *Natrix sipedon*, the Carolina salt marsh snake, through review of available literature and preserved specimens. They concluded that this was a subspecies and described it. Lazell and Musick (1973) reaffirmed *Lampropeltis getulus sticticeps* as a solid subspecific form. Blaney (1979) analyzed this species for color patterns, proportions, and scutellation characteristics. Because he found no unique characteristics, it was concluded that this species did not warrant status as a subspecies. He suggested instead that it be recognized as a relict intergrade population. Lazell and Musick (1981), however, rebutted Blaney's views. The authors pointed out that "*sticticeps* is in no way intermediate between nominate *getulus* and *floridanus*, and that Blaney based his opinions on specimens that were not *sticticeps* and not from within the geographic range of that subspecies." (Lazell, personal communication).

Lizards

Engels (1949b) investigated the presence of blue-tailed skinks on two North Carolina coastal islands and described their distribution. *Eumeces inexpectatus* was found to occur on

two of the barrier islands, Shackleford Banks and Harkers Island.

General Surveys

Since the 1940's the reptiles and amphibians of North Carolina have been surveyed several times. Brimley (1944) described the range and habits of the common non-mammal vertebrates of North Carolina. Robertson and Tyson (1950) compiled notes on 42 species and subspecies of reptiles and amphibians collected in eastern North Carolina. Habitat descriptions for each species were included. A general all-purpose field guide to the reptiles and amphibians of eastern North America was written by Conant (1958). A preliminary checklist and bibliography of the reptiles and amphibians of North Carolina was compiled by DePoe,, et al. (1961). Lazell (1972) assembled a list of reptiles and amphibians from the intra-capes ecological zone. An illustrated guide to the amphibians and reptiles of the Carolinas and Virginia was compiled by Martot and Palmer (1980). Palmer (N.A.) compiled a species list of reptiles and amphibians collected at Cape Lookout National Seashore.

BIRDS

Introduction

Studies dealing with the avifauna of the Cape Lookout area are surprisingly sparse. Those reports that are available concentrate mainly on shorebird communities. Many early studies provided a general overview of the birds of the North Carolina area. As early as 1919 Pearson,, et al. compiled a book on the birds of North Carolina. Later, in 1940, Pearson censused waterbird colonies along the coast of North Carolina. His observations indicated that the most abundant species was Least Terns. In another early ecological study, Engels (1949a) found that the Great Crested Flycatcher nested in areas that required adult birds to travel to nearby woods in order to feed.

Nesting Site Preference

The role of dredge spoil islands as nesting habitat for colonial waterbirds has been investigated by several researchers. Buckley and Buckley (1974) confirmed the importance of these artificial dredge spoil islands to the ecology of the estuary as a whole. The authors recommended that steps be taken to protect these valuable habitats. The utilization of both natural and human-made habitat has been extensively studied by Jernigan (1977). In a study of Least Tern nesting preference, he found that 72% of all nests were located on dredge spoil islands, "as opposed to mainland, barrier island, and natural estuarine island locations." The majority of colonies (93%) were located approximately 100 meters from foraging areas, and 95% of the colonies were adjacent to resting sites (beaches or dikes). Exposure to adverse conditions was a factor in site selection; 59% of the colonies were found on sites with depressed wind, flooding, and wind-blown sand conditions. Vegetation height was not "measurably different" on dredge islands compared to barrier islands. The effects of vegetation were not important; 92% of the colonies were found on bare or slightly vegetated sites. In a continuation of the previous study, Jernigan,, et al. (1978) produced different values for the same preference parameters. Nesting percentages were 72% for dredge spoil islands, 28% for barrier islands, and less than one percent on natural estuarine islands and the mainland. Forage areas were located less than 100 meters distant for 95% of the colonies. Protected sites (reduced exposure to flooding, wind, and/or wind- blown sand) were observed for 81% of the colonies.

Everhart (1978) studied nesting preferences in Common Terns, Black Skimmers, and Gull-billed Terns. He found a shift in preference to dredge spoil sites, and stated that the reason for this behavior was undetermined, but may have resulted from the incursion by humans into natural sites, population pressure, or an increase in breeding success. Everhart,, et al. (1980) found that the shift to dredge spoil sites corresponded with a movement to areas which infrequently experienced overwash and consequently little vegetative succession. In areas outside of those studied, 90% of the Gull-billed Terns, Common Terns, and Black Skimmers preferred barrier to dredge spoil islands, the difference possibly resulting from the degree of human interference in the study and non-study locations. This study also included data from substrate analysis, microtopography, and presence of vegetative cover.

Migration Studies

North Carolina coastal areas serve as an important stopover for migrating birds. Hailman (1961) reported an unusual northward migratory flight of flocks consisting mainly of warblers in the early fall of that year. Possible reasons for these unusual sightings were not offered. The migration of shorebirds on the Outer Banks was studied by Buckley and Buckley (1973). This study stressed the idea that the Outer Banks be considered as one ecological unit in the development of future management policies. Seasonal migration of hawks was studied by Lee and Lee (1978). They found that hawks remained directly over islands during their southern migration. The species observed included accipiters (87%), falcons (10%), along with harriers, ospreys, and others. Sharp-shinned Hawks were the most abundant species, with a total of 85 sightings. Walters (1983) stressed the importance of coastal North Carolina as a migration stopover for shorebirds.

Colonial Waterbirds

Parnell and Soots (1980) summarized the proceedings of a planning workshop on the management of colonial waterbirds in North Carolina. An important document for the characterization of gull and tern colonies was compiled by Portnoy,, et al. (1981). Included in the volume were colony locations, site descriptions, estimates of numbers of breeding adults, nesting substrates, and frequency data for all species. In 1983, Kushlan published an article on colonial waterbirds in U.S. National Seashores which included a section on the Cape Lookout area. McCrimmon and Parnell (1983) evaluated the aspects of colony distribution, site tenacity, and habitat among five colonial waterbird species.

Surveys, Field Guides, and Checklists

The remaining publications consist of surveys or checklists of bird species of the North Carolina coastal area. They are comprised mainly of field observations and censuses. Included are Brimley (1941), Parnell and Soots (1976), Godfrey (1977), Lee and Booth (1979), Potter,, et al. (1980), Fussell (1983a,b), and U.S. Department of Interior, National Park Service, Cape Lookout National Seashore (N.A.).

MAMMALS

Introduction

The available documents on mammal research of the Cape Lookout area are sparse. However, the studies that are included consist mainly of distributional information on several species, or focus on the damaging effects of feral ungulates.

Surveys and Miscellaneous Studies

An early study by Brimley (1946) listed the mammal species of North Carolina. Gray (1962) compiled a species list of the fauna of transitional marine habitats, including information on distribution and abundance. The stranding of marine mammals was documented by Caldwell and Golley (1965). They provided useful information on the distribution and biology of animals that are usually difficult to study. The animals sighted included common finback whales, pilot whales, humpback whales, dolphins, and seals. In all, 18 species of mammals were reported as stranded over a 56-year period. Undoubtedly, many more were not reported or found, due to the inaccessibility of the coastline. The only single species ecology and behavior research was conducted by Spitzer (1972). This report consisted of preliminary work on a small population of rice rats on Cape Lookout. A general work compiled by Lazell (1979) investigated the dispersal of land vertebrates on barrier islands. Through observations and reading of previous research reports, Lazell concluded that barrier island faunas generally originate from the direction of prevailing longshore currents. In addition, he found barrier island fauna to be tenacious, resilient, and highly evolved. The U.S. Department of Interior, Fish and Wildlife Service (1981) conducted a survey of the major natural areas of North Carolina and listed the wildlife found in them. Finally, in 1982, an anonymous author conducted a distributional survey of the mammals of North Carolina.

Feral Ungulates

Several studies on the environmental impacts and ecology of feral ungulates on Shackleford Banks have been undertaken (Wood and Murphy, 1979; Rubenstein, 1981; and Wood, 1981).

ESTUARINE ECOLOGY

Introduction

The Outer Banks of North Carolina represent a significant faunal break for many species of coastal and estuarine organisms. Much of the early research in the area was conducted by Pearse (1936, 1943, 1945). Sutcliffe (1947), and Williams (1955) have also added to the knowledge of the Outer Banks faunal component. Hobbie (1971), Thayer (1971, 1974), and Sanders (1978) have contributed much to the knowledge of phytoplankton ecology. In addition, Thayer, Kenworthy, and others (1978, 1981, 1982, 1984), and Summerson and Peterson (1984) have supplied valuable ecological information on submerged aquatic vegetation (SAV).

Phytoplankton

Hobbie (1971) compiled a species and population listing of the phytoplankton in the Pamlico River estuary. Thayer (1971) undertook a study to determine to what extent the seasonal distribution of phytoplankton production in shallow, unstratified systems was associated with seasonal changes in nutrient concentrations. In 1974, Thayer attempted to determine what limiting factor was controlling phytoplankton production, and to ascertain the role of microbial organisms in limiting available nutrients. Sanders (1978) described the response of natural phytoplankton to manganese (Mn) in an effluent-receiving estuary.

Zooplankton

Hadley (1936) described the species of Foraminifera obtained from shallow water dredgings at three stations around Cape Lookout. A total of 23 species were described. Williams,, et al. (1968) assessed the standing crop and importance of zooplankton in shallow estuaries. The meroplankton of North Carolina estuaries were studied over a period of ten years by several researchers (Williams, 1971; Williams and Porter, 1971; Williams and Bynum, 1972). Williams (1971) documented the presence and distribution of developmental stages of brachyurans present in the meroplankton. Williams and Porter (1971) studied the swimming ability and seasonality of post- metamorphal bivalves found in the meroplankton, and Williams and Bynum (1972) provided a comprehensive checklist including distribution and seasonality of amphipods found in North Carolina estuaries.

Macroinvertebrates

Pearse (1936) conducted an in-depth study of the estuarine animals in the Cape Lookout area. Twenty-two stations were censused over a two-year period near Shackleford Banks and in Mullet Pond. Besides supplying a list of the organisms found, data were presented on the average time that 28 test species survived dessication and variations in salinity. In 1962, Gray compiled a species list of the fauna of transitional marine habitats, including distribution and abundance. Canoy (1970) employed a unique approach to measure similarity of the fauna located around Cape Lookout. DNA was extracted from each sessile organism from a one meter square quadrant located at mean high water, mean low water, and one meter below mean low water. The DNA values at Cape Lookout were found to be similar to those at Morehead City, North Carolina, as was species diversity. Peterson and Peterson (1979) provided an introduction to the ecology of intertidal sand and mudflats. The authors drew examples from the intertidal flats of coastal North Carolina, and described the ecological processes characterizing a habitat, that at first glance, appeared barren.

Submerged Aquatic Vegetation (SAV)

Thayer,, et al. (1978) attempted to determine whether the faunal community associated with eelgrass derived its carbon from plankton or the seagrass itself. They found that the deposit feeders (sea urchins and brittle stars) derived the major portion of their carbon from eelgrass, whereas the majority of other fauna derived their carbon from the plankton associated with the eelgrass. Kenworthy (1981), and Kenworthy,, et al. (1982) worked on the interrelationship between the seagrasses, *Zostera marina* and *Halodule wrightii*, and the

physical and chemical properties of sediments in the coastal plain estuary near Beaufort, North Carolina. They found that the magnitude of the physical and chemical properties of the sediments varied with location in relation to the amount and type of vegetation present. In general, once established, seagrasses appeared to modify the sediment texture and the amount of organic matter and nitrogen present. In addition, the seagrass beds developed nitrogen sinks. Kenworthy and Thayer (1984) looked at the functional role of organic matter derived from the production of the roots and rhizomes of seagrasses. The authors compared two species of seagrass, *Zostera marina* (temperate) and *Thalassia testudinum* (tropical). Summerson and Peterson (1984) studied the role of predation in organizing the benthic communities of seagrass beds. The study was undertaken to test whether the density and species diversity of sedentary macrobenthos varied with the presence of seagrass. The results suggested that epibenthic predators remained inside seagrass beds during the day, and restricted their predation on sand infauna to the evenings.

CULTURAL, HISTORICAL

Introduction

Publications on the cultural and historical aspects of the Cape Lookout area span nearly 200 years -- 1795 to the present. The topics are varied, but, in general, themes concentrate on 1) legends and folklore of the Outer Banks; 2) the Life-Saving Service; 3) history of Portsmouth Island; 4) history of Carteret County; 5) geographical history of barrier islands; and 6) natural history, architecture, and archeology.

The earliest publication was a coastline survey done by Price (1795). The embellished title, typical of that time, conjured up the spirit of early explorers: "A description of Occacock Inlet: and of its coasts, islands, shoals, and anchorages, with the courses and distances to and from the most remarkable places and directions to sail over the bar and thro' the channels, adorned with a map taken by actual survey."

Legends and Folklore

Whedbee (1966) compiled a collection of the legends of North Carolina. Also included was a portrait of the people of the Outer Banks and their culture. Walser (1980) provided an historical review of the North Carolina coast in his book, North Carolina Legends. The pirates of North Carolina were described in a book by Rankin (1983).

Life-Saving Service

Weber (1881) highlighted five handwritten volumes containing records of the U.S. Signal Service Station at Cape Lookout. This information was compiled through the daily journals kept by the men, weather data, and telegrams. Stick (1976) compiled an historical account of the storms, hurricanes, and shipwrecks of the Outer Banks. In 1977, Ebersole recounted the first rescue by the Coast Guard at Cape Lookout. The U.S. Coast Guard (1979) compiled an historical account made up of excerpts from the Life-Saving Service logbook, 1874-1942. In an unpublished technical report, O'Brien and Noble (N.A.) gave a history of the Cape Lookout Lighthouse, and workers that have been associated with it over the years.

Portsmouth Island

Burke (1958) outlined the primary chapter of Portsmouth's history, from its founding in 1753, to its evacuation in the face of advancing Federal forces in 1861. Portsmouth, at that time, was the major seaport where cargo from larger, ocean-going ships was reloaded to smaller vessels for inland transport via inlets, rivers, and canals. Recommendations were made to the National Park Service by Olszowski (1970) concerning the growth and history of Portsmouth, and the preservation and management of this historical resource. Salter (1972) published a book of short stories, recounting many of the personal stories surrounding Portsmouth's rise and decline. In 1978, the National Park Service (USDOINPSCALO) inventoried Portsmouth Village for the National Register of Historic Places.

Carteret County

Grayden and Grayden (1975) provided an informal account of the folk history of Carteret County. Gilliken (1975) gave an historical interpretation of Carteret County during the American Revolution. A number of historical articles were compiled by East Carteret High School (1977) including "How they built the lighthouse", "When the U-boats hit Cape Lookout", and "History of the Reeves Family at Cape Lookout", among others. The historical development of individual communities was prepared by the County Extension Office of Carteret County (1979). The history of Carteret County from 1700 to the present was compiled by Hill (N.A.), and contained timetables of events, as well as a listing of places of historical interest. The genealogy of the prominent Moore family and related clans was presented by a namesake, Arthur Moore (N.A.).

Geographical History

The early history of the North Carolina shore was chronicled by Brown (1937). Dunbar (1956, 1958) described the nature of the occupation of the Outer Banks area in an historical perspective. The author's primary interest was to show the cultural evolution of a homogeneous, somewhat isolated coastal community of English descent. Stick (1958) provided another comprehensive history of the Outer Banks from 1584-1958.

Natural History, Archeology, and Architecture

Holland (1968) compiled a general historical data base for the creation of a master plan for park management and development. These data supplied the Park Service with a listing of the historical sites and structures within the park. Godfrey (1969) compiled a natural history of the Outer Banks from Ocracoke Inlet to Beaufort Inlet. Included was a description of what the Outer Banks were like prior to European settlement. Loftfield (1970) investigated archeological sites on Harkers Island. His objectives were to understand aboriginal occupation of the area, and to demonstrate some specific ecological changes from an historical point of view. Ehrenhard (1976) documented archeological and historic resources at Cape Lookout National Seashore. Loftfield (1976) compiled archeological and ethnohistorical data pertaining to prehistoric and early historic period American Indians who lived in coastal North Carolina. Loftfield concluded that the coastal area of North Carolina had been occupied continuously from paleo-Indian times to the present, with a decreasing aboriginal population coinciding with settlement by Europeans in the 17th and 18th centuries. The Indian sites may have actually been located in an area that was inland at that time and not littoral, as it is presently. An historical-pictorial profile of Beaufort was prepared by Safort and Kell (1977). Littleton (1979) wrote an historical account on the raising of livestock along the Outer Banks. Information on North Carolina lighthouses was compiled by Stick (1982). An anonymous author (Anonymous, 1983) compiled a visitors guide to the Outer Banks with historical information and many photographs. An architectural study of the Outer Banks was conducted by Steinholtz and Howell (N.A.).

Bibliographies

Two bibliographies have summarized the historical literature of the North Carolina coast. A Bibliography of the Historical Literature of North Carolina (Weeks, 1895) included many early non-scientific anecdotes. Christopher and Junkin (1971) compiled A Preliminary Bibliographical Inventory of Park Historical and Architectural Studies, which included most of the publications mentioned in this section.

MANAGEMENT, LEGISLATION

Introduction

Management/Legislation, as a category encompasses a large range of topics. Major legislation covering the National Seashore's inception and future directions are herewith included. Broad management topics are discussed here, as well as in the sections of any other category to which they may apply, such as the land-use, development, recreation (including off-road vehicles (ORVs), and pest management. Finally, citations which are broad and include several other categories, such as general ecological investigations, are included in this section.

Park Management

The earliest documents concerned the acquisition and development of land for what was to become Cape Lookout National Seashore. The Southeast Regional Office of the National Park Service in Atlanta, Georgia (USDOINPSSERO, 1963) published a report identifying the major remaining opportunities for conservation of natural seashores (or coastal areas) for recreational purposes. This document was considered a pre-Cape Lookout planning/acquisition recommendation. Huyck (1964) also reported on the planning of the proposed Cape Lookout National Seashore. Godfrey and Melbye (1967) reported on the National Park Service's plan for the development of Shackleford Banks for intense recreational use. These authors recommended keeping Shackleford Banks preserved in its natural state. Since the area was found to be unstable, it was recommended that it be kept "as is."

The remaining documents are concerned with specific management problems after the park was established. Hosier (1972) emphasized working with the natural changes that occur on the Outer Banks rather than against them. He stated that the research management concept should be developed based on present knowledge concerning the dynamics of these systems. Once these natural responses are recognized, resource managers should consider preservation techniques that in no way interfere with the natural responses of the barrier island system to environmental changes. The National Park Service, Denver Service Center (USDOINPSDSC, 1973) published a Cape Lookout master plan for management that included physical descriptions of the islands, a description of the plan itself, and a legislative history. They concluded that in order to properly manage this area, the managers must realize that physical change is inevitable; humans must adapt to these changes and not try to adapt the changes to suit their needs. The authors suggested that before such management techniques could be implemented, some restoration and/or modification should be carried out in areas of the seashore that have accelerated erosion due to past abuses by humans. Along the same vein, Dolan and Hayden (1974b) commented on the Park Service's new management policy concerning adjustment to nature rather than trying to control it. They concluded with a statement on the responsibilities of the Park Service in maintaining our National Seashores.

The House Committee on Interior and Insular Affairs (1974) published an amendment to the act providing for the establishment of Cape Lookout National Seashore. A memorandum by Woodhouse (1974) discussed the management of both Cape Lookout and Cape Hatteras. After conducting field studies of the area, Woodhouse concluded that Cape Lookout was not suitable for highways and heavy human use. Riddell (1976) published a statement for the management of Cape Lookout with a concern for the influence of legislative, administrative, and environmental constraints on management practices. Also, in 1976, the National Park Service (USDOINPSCALO) published a natural resource management plan. It contained information on geology, climate, endangered and threatened wildlife, human use and influence, and beach and inlet management. Hensley-Schmidt, Inc. (1978) compiled a mainland feasibility study for the Seashore for development within the park, based on the management plan and environmental impact statements, limited development of the area was preferred. Leatherman,, et al. (1978) conducted a discussion concerning the various factors that played a role in Seashore management. Included was a discussion of a management strategy that stressed the dynamic character of barrier islands. However, the authors noted that this strategy could only be effectively applied to areas where natural processes have not been severely interrupted. Also stressed was the importance of a flexible strategy for each park,

taking into account the inherent geographic variability of the natural environment, subsequent human modifications, and the legislative mandates and constraints for each park.

The National Park Service, Denver Service Center (USDOINPSDSC, 1978) issued an environmental assessment of Cape Lookout National Seashore, and in 1980 the Harpers Ferry Center (USDOINPSHFC) published an interpretive prospectus stating ideas on development of interpretive facilities and management of the park. Also in 1980, the Park Service (USDOINPSCALO) presented a review of alternatives for the general management plan and wilderness study for Cape Lookout. The goal was to maximize the wilderness areas and minimize development, especially on-island transportation. The National Park Service issued several documents that contained wilderness recommendations for Cape Lookout National Seashore (USDOINPSDSC, 1981; USDOINPSCALO, 1980b, 1981a,b). These documents presented the wilderness recommendations to the public in order to generate responses, then attempted to present an interpretation of these responses. Four basic issues were significant enough to warrant a possible change: 1) vehicle use; 2) wilderness; 3) proposed management plan versus alternatives; and 4) on-island transportation. A total of 48% of all respondents opposed ORV use and favored the management plan. An unpublished undergraduate paper by Troutman (1981) discussed the history and management of Cape Lookout, in addition to providing a description of the area. Finally, in 1984, the Park Service (USDOINPSHFC) made available an annual statement for interpretation and visitor services at Cape Lookout. The document included an analysis of park users and use patterns, an analysis of the current management influences and concerns, and an inventory of facilities.

Land-use Management

This section addresses management of available land, for either public or private use. In the specific area report by the National Park Service (USDOINPSSERO, 1963), the objective was to acquire more land for public use. The conclusions indicated that the agencies of Carteret County and the state officials of North Carolina supported the National Park Service's suggestions for obtaining more land. Clay (1974) compiled a land-use bibliography of North Carolina. Dolan, Hayden, and Vincent (1974) investigated CARETS (Central Atlantic Region Ecological Test Site) to determine the environmental types that were present, and to ascertain any differences in composition of land-use and cover. Area percentages for each class in the modified Anderson classification were presented. Recommendations were made for a remote sensing system to monitor the CARETS shore zone. A state survey conducted by Christenson (1976) expressed the position of some North Carolina residents on concepts related to land-use planning. Warner and Strauss (1976) compiled an inventory of the barrier islands of the southeast coast. The authors summarized island size, development status, ownership, property assessment, and local land-use regulation; Warner (1976) summarized this inventory. Baker (1978) provided a history and background of storms and related damage for the Cape Lookout area. His objective was to increase public awareness of dynamic island processes. The MTMA Design Group (1980) provided the National Park Service with various options for transportation management on Cape Lookout. Three alternative options were identified: 1) private sector approach; 2) NPS purchase and ownership of equipment and facilities, but operation and maintenance by a concessionnaire; and 3) NPS ownership and operation of all facilities and equipment. In a technical report, Nierstedt (1980) examined wastewater management in coastal North Carolina. Finally, Denison (1981) discussed the available resources of the barrier island system of North Carolina, concluding that management of the barrier island system must be pragmatic to satisfy the public interest and demand for use of the resources, in addition to protecting the barrier islands as a valuable natural resource.

Coastal Zone Management

The documents on this topic concern the various aspects of the management of North Carolina's coastal area. Dolan (1967*) supplied a general discussion on beach dynamics, beach sediments, waves and currents, sea level changes, methods for beach protection, and the role of local, state, and federal governments, with the purpose of aiding developers in planning and development, and to increase public awareness of the risks of development. The author concluded that the best solution to beach erosion was careful planning in the development process, and stated that a beach should be treated as a separate problem, taking into

consideration its own set of unique characteristics. In addition, an understanding of the relationship between beach width, beach slope, and storm run-up is needed so that construction can be planned within a probability framework of wave damage within a given number of years. Tilley (1974) reported on citizen involvement in the coastal management of North Carolina. Parker,, et al. (1976) compiled an overview and appendices on the ecological determinants of coastal zone management; incorporated were sections on environmental processes of the North Carolina coastal area, and processes and policies on barrier island systems and lagoon-estuary systems. In 1982, the North Carolina Department of Natural Resources And Community Development formed a task force to study conflicts between agriculture/forestry and fish/wildlife in relation to management of the Albemarle-Pamlico peninsula. Dubach (1977) compiled information on the coastal plain, estuaries, and offshore waters, addressing such categories as engineering, geology and geophysics, hydrology and groundwater, and oceanography, among others. The North Carolina Department of Natural Resources and Community Development, Office of Coastal Management (1977) compiled two volumes on the North Carolina coastal plain, covering genesis of coastal area management, coastal zone boundaries, and procedures for ongoing management, among others.

The National Oceanic and Atmospheric Administration, Office of Coastal Zone Management (USDCNOAACZM, 1978) published documents on the coastal management program of North Carolina. Also, they produced an environmental impact statement containing chapters on the genesis of coastal area management, coastal zone boundaries, and procedures for ongoing management. In addition, the statement contained a description of the study area, environmental impacts that could not be avoided, the relationship between local short- and long-term enhancement of the area, and the irreversible commitment of resources, among others. Companion appendices provided the amended Coastal Area Management Act, state and county guidelines, maps, information on other legal authorities, federal lands, and criteria implementation and enforcement of the management program. Berquist (1979) developed a geographic perspective of coastal zone management for the Outer Banks. Her objective was to provide a framework for the planning of seashores with specific attention given to their ecological and geomorphological sensitivity, as well as their use and development for the public. This document provided data for planning and management of the seashores along the Outer Banks.

Off-road Vehicles (ORVs)

Meekins,, et al. (1980) investigated the effects of ORVs on the physical environment and on the organisms that live near the shore. Conclusions based on this study implied that the tracks of vehicles in well-developed sandy trails had localized effects, while renegade tracks created impacts over significant areas of the berm and dunes. ORVs that traveled on the berm undermined the sand on which sea oats were rooted, and a possible impact was the complete removal of annual vegetation which acted to stabilize the dune area. Results indicated that ghost crabs, coquinas, clams, and mole crabs were able to survive the impacts of ORVs. Several studies investigated the overall impact of ORVs on our National Seashores. Primack (1980) compiled information from other studies concerning the effects of ORVs on wildlife and found that most scientists agreed that even low level impacts may result in severe environmental degradation. Palmer (N.A.) supplied a status report on ORV use in National Seashores. The National Park and Conservation Association (1982) produced a citizens action guide to over-sand vehicles in National Seashores. It included an assessment of ORV impact, what the Park Service was doing about the problem, and what the public could do. Meekins and Hosier (1983) compiled a report on the effects of ORVs on the environment and communities of Core Banks. As a result of their findings, the authors recommended that the park have only one major road rather than several intermediate ones, and recommended the elimination of travel through primary and secondary dunes.

Dune Stablilization

Several studies have addressed dune stabilization as a management technique. Woodhouse, Seneca, and Cooper (1968) investigated the use of sea oats for dune stabilization. Distribution, habitat, seed germination, seedling development, and propagation of sea oats were examined. Dolan (1971c, 1972a,c,d,e) conducted several investigations into dune

stablization and erosion processes. In 1971, he reported on development and erosion trends along the Outer Banks and offered engineering solutions. He concluded that engineering responses, especially nourishment, were too costly in terms of protection measures. He recommended that the practice of attempting to "hold off" the sea be stopped, except at Cape Hatteras Lighthouse. He recommended that barrier dunes should be allowed to resume natural processes, and that narrow sections of barrier islands should be enlarged on the sound side by nourishment and marsh grass cultivation. Again in 1972, Dolan issued a series of reports concerning the stabilization of dunes along the Outer Banks, and as in his previous studies, concluded that the best erosion strategy was to let nature take its course.

Ecology

The documents in this section concern management problems of an ecological nature. The two earliest publications concerned a review of the research done at the U.S. Marine Biological Station at Beaufort (Radcliffe, 1914; Hildebrand, 1916). Engels (1952) supplied an assessment of the vertebrate fauna of Shackleford Banks, including amphibians, reptiles, birds and mammals, as well as the geography, vegetation, climate, and recent history of the area. Approximately 34 species of land vertebrates were surveyed. Gifford (1966) summarized the National Park Service's interest in estuarine ecology research in North Carolina. Godfrey and Melbye (1967) compiled a document on the scientific and aesthetic value of Shackleford Banks. They recommended that this area be preserved as an example of "a wild and unaltered maritime formation." In 1971, Godfrey and Godfrey prepared a technical report on the barrier island ecology of Cape Lookout and vicinity. The use of high altitude and satellite photography as a possible tool for monitoring ecological and physical changes in the marine environment was investigated by Stetka (1971). In a semi-annual research report Dolan (1972c) examined shoreline erosion problems along the Outer Banks caused by storms. Dolan stated that engineering methods would only delay the unavoidable -- the loss of structures in the area. Godfrey (1972a) reported on barrier island ecosystems of North Carolina, and on the National Park Service ecology research program. A review of the physical, chemical, and biological oceanography of Onslow Bay, and a summary of fisheries statistics of the area was done by Kruczynski (1974). The purpose of this report was to provide practical data for the fishermen of the area.

A few articles investigated the ecological aspects of artificially constructed dredge spoil islands along the North Carolina coast. Parnell and Soots (1974) studied the value of these dredge islands to nesting coastal birds. A list of major marine organizations, along with summaries of their current activities and projects, was provided by Hill (1975); in 1978, Snow updated this information. Cammen., et al. (1976) looked at the possible benefits of stabilizing dredge spoil with *Spartina*. The research was aimed at determining differences in animal life on spoil areas versus natural marsh areas. The authors concluded that the planting of *Spartina* on dredge spoil would lead to the creation of a salt marsh that would closely resemble that of a naturally developed marsh. How quickly this proceeded would depend on: 1) how closely the spoil resembled the natural marsh sediment; 2) the natural sedimentation rate of the area; and 3) the elevation and maturity of the natural marsh compared to the area of spoil deposition.

In 1976, Godfrey and Godfrey re-evaluated the ecology of the barrier islands that compose Cape Lookout National Seashore in a book that discussed the origin and maintenance of barrier islands, and the effects of humans on the Outer Banks. They attempted to integrate some of the factors that tied the island system together from beach to estuary. In 1977, Cooper, Robinson, and Funderburg compiled a species list of the endangered and threatened plants and animals of North Carolina; that same year the National Park Service (USDOINPSCALO, 1977) conducted a resource inventory of the vertebrates and vascular plants of the Cape Lookout area. Later, a dredge spoil study by Soots (1978) concluded that dredge islands were often crucial habitat for colonial waterbirds, and should be maintained and managed as such. The report provided recommendations and guidelines for management of existing islands and creation of new islands. Voges (1978) provided a status report on certain plants and animals at Cape Lookout that had been classified as endangered or threatened.

Wolff (1978) assessed the stock of paralichthid flounder in North Carolina and found

that southern flounder made up 95.8% of the pound net catch. Other types of flounder caught were summer and Gulf flounder. Parker and Dixon (1980) surveyed the endangered and threatened wildlife of Kentucky, North Carolina, South Carolina, and Tennessee. Terry, Claude, and Associates (1981) provided a generic environmental impact statement and plan of study for North Carolina's barrier islands. As part of the North Carolina Estuarine Finfish Program, DeVries and Harvell (1982) tagged inshore paralichthid flounder to determine movements, numbers, and distribution of the stocks of southern and summer flounder in North Carolina. However, only 29.9% of the southern flounder that were marked were recaptured, therefore the authors suggested further tagging studies. The final draft of the management plan for the North Carolina National Estuarine Sanctuary Program was published by the North Carolina Department of Natural Resources and Community Development, Office of Coastal Management (1982). The plan defined how the goals of the organization would be met, and provided procedures for research and educational activities. Another project of the North Carolina Estuarine Finfish Management Program conducted by Ross (1982) assessed the long haul seine and pound net fisheries. The objective was to evaluate species composition, seasonality, age, and size structure of the involved species, in addition to locating major finfishery areas. A total of 29 long haul seine samples yielding 46 species were taken. Spot, Atlantic croaker, menhaden, pinfish, and weakfish composed 95% of the catch. Samples from the pound net fishery were dominated by flounder. Finally, the National Park Service (USDOINPSSERO, 1982) supplied a science directory including the names, addresses, telephone numbers, and fields of expertise of scientists from the Southeast Region.

BIBLIOGRAPHIES

Included in this section are several bibliographic documents that contain listings of publications pertinent to subject areas such as history, geology, the coastal zone, and miscellaneous groupings. The earliest publication by Weeks (1895) was a bibliography of the historical literature of North Carolina. Laney and Wood (1909) compiled a bibliography of the geology, mineralogy, and geography of North Carolina, which included maps of the area. The Coastal Plains Center for Marine Developmental Services (1977) put together a directory of bibliographies relevant to the environment and activities of the coastal plains region, arranged by subject. A bibliographic inventory of park historical and architectural studies was assembled by Christopher and Junkin (1971). Buck (1975) listed publications concerning the coastal area of North Carolina in addition to selected publications from other states. East Carolina University (1975) published a similar listing. A geological bibliography of North Carolina's coastal plain, coastal zone, and continental shelf was compiled by Riggs and O'Connor (1975). Dolan (1976) produced a bibliography of papers and reports on the Outer Banks from 1958-1976. A bibliography on the maritime history of North Carolina was compiled by Still (1976).

MAPS, CHARTS, AND AERIAL PHOTOGRAPHS

Order of Contents

Abbreviations List
Aerial Photographs
Books and Articles Concerning Maps
Maps, Various Topics:
- Ecology/Vegetation
- Floods/Storms
- Geology/Hydrology
- Miscellaneous Topics
- Zoning/Land-use

National Ocean Survey (U.S. Coast and Geodetic Survey)
Topographic Maps
Government Agencies from which Maps and Photos can be Obtained
Source Address List

Abbreviations

ASCS -	Aerial Photography Field Office, Agricultural Stabilization and Conservation Service
CAHA -	Cape Hatteras National Seashore
CALO -	Cape Lookout National Seashore
DSC	National Park Service Denver Service Center, Technical Information Center
DUKE -	Duke University Library
EROS -	Earth Resources Observation Systems Data Center
MIAASC -	Abrams Aerial Survey Corp.
NARC -	National Archives and Record Service
NASA -	National Aeronautical and Space Administration
NPSDSCDMA -	National Park Service, Denver Service Center, Defense Mapping Agency
NC -	North Carolina
NOS -	National Ocean Service
SCS -	U.S. Department of Agriculture, Soil Conservation Service
USACE -	U.S. Army Corps of Engineers
USAF -	U.S. Air Force
USDOI -	U.S. Department of Interior
USDOIFWS -	U.S. Department of Interior, Fish and Wildlife Service
USDOINPS -	U.S. Department of Interior, National Park Service
USGS -	U.S. Geological Survey
USN -	U.S. Navy
WALL -	NASA/WALLOPS Flight Center
WEYER -	Weyerhauser Company

AERIAL PHOTOGRAPHS

Introduction

Most of the aerial photographs are cited from the Handbook for Remote Sensing - Mid-Atlantic Coast National Seashores: Assateague Island, Cape Hatteras, Cape Lookout (Dolan, Hayden and Heywood, 1977). This listing has been supplemented and updated by inventories done at the National Park Service Technical Information Center of the Denver Service Center; the National Cartographic Information Center, and Cape Lookout National Seashore Natural Resources Office, and through questionnaires sent to several aerial photograph companies.

Aerial photographs are listed in chronological order in the following format: Producer, Date, Location, Scale, Type, Source.

Producer: listed as found in citations, indexes, and on photographs. If producer is not given, it is listed as Anon. Addresses of producers are included in the Source Address List.

Date: xxxx (xx/xx), month, and day if known.

Location: given by present-day towns or feature names.

Scale: given as the representative fraction (i.e., 1:24,000) or as unknown.

Type: indicates whether photo is black and white (BW), black and white infrared (BWIR), color (COL), or color infrared (CIR). If photos of the same date are available in two different types this is indicated.

Sources: indicates the agency from which aerial photographs can be purchased, copied, or viewed. Addresses of sources are included in the Source Address List. Unless otherwise noted the sources are the same as the producers.

Cape Lookout Aerial Photographs

NARC. (1938). (6/5) Barden Inlet 1:20,000 BW
NARC. (1939). (1/2) Beaufort Inlet to Core Banks (partial) 1:20,000 BW
USGS. (1940). (10/15) Whalebone Inlet 1:24,000 BW
USGS. (1940). (10/15) Sand Island Inlet 1:24,000 BW
USACE. (1940). (10/21) Corolla, NC to Lookout Point 1:24,000 BW
USACE. (1940). (10/21) Ocracoke Inlet to Whalebone Inlet 1:24,000 BW
USACE. (1940). (10/21) Ocracoke Village to Lookout Point 1:24,000 BW
USAF. (1942). (1/12) Horsepen Point to Atlantic 1:40,632 BW
USGS. (1943). (2/15) Sand Island Inlet 1:40,000 BW
USACE. (1943). (2/23) Swash Inlet to Lookout Point 1:40,000 BW
USACE. (1943). (3/30) Bogue Banks to Drum Inlet 1:40,000 BW
USGS. (1943). (6/15) Whalebone Inlet 1:60,000 BW
NOS. (1945). (1/5) Atlantic 1:20,000 BW
NOS. (1945). (1/24) Lookout Point 1:20,000 BW
NOS. (1945). (1/24) Drum Point to Ocracoke Inlet 1:20,000 BW
NOS. (1945). (6/15) Sand Island Inlet 1:20,000 COL
NOS. (1945). (6/15) Whalebone Inlet 1:20,000 BW
USACE. (1950). (11/21) Styron Bay - Atlantic 1:58,000 BW
NOS. (1951). (3/15) Beaufort Inlet 1:24,000 BW
NOS. (1953). (6/10) Beaufort Inlet to Lookout Point 1:20,000 BW
NOS. (1953). (6/15) Beaufort Inlet 1:20,000 BW
ASCS. (1953). (6/15) Beaufort Inlet 1:20,000 BW
SCS. (1953). (11) Horsepen Point to Styron Bay 1:20,000 BW
NOS. (1954). (11/30) Morehead City to Harkers Island 1:24,000 BW
NOS. (1954). (11/30) Drum Inlet to Lookout Point 1:24,000 BW
NOS. (1954). (11/30) Barden Inlet to Beaufort Inlet 1:24,000 BW
NOS. (1955). (3/29) Lookout Point to Ocracoke Inlet 1:18,000 BW
NOS. (1955). (3/29) Lookout Point 1:24,000 BW
USN. (1958). (1/1) Cape Lookout to Atlantic 1:40,000 BW
NOS. (1958). (5/4) Beaufort Inlet 1:24,000 BW
NOS. (1958). (5/4) Drum Inlet 1:25,000 BW
NOS. (1958). (5/4) Barden Inlet to Lookout Point 1:25,000 BW
NOS. (1958). (5/4) Barden Inlet 1:25,000 BW
ASCS. (1958). (6/15) Carteret County, NC 1:20,000 BW
ASCS. (1958). (6/15) Beaufort Inlet 1:20,000 BW
NOS. (1958). (10/10) Ocracoke Inlet to Bogue Banks 1:18,000 BW
NOS. (1958). (10/10) Swash Inlet to Lookout Point 1:80,000 BW
NOS. (1958). (10/10) E of Lookout Point to E of Beaufort Inlet 1:18,000 BW
NOS. (1958). (10/10) Barden Inlet 1:18,000 BW
NOS. (1958). (10/15) Beaufort Inlet 1:18,000 BW
ASCS. (1958). (11/11) Horsepen Point to Wainwright Island 1:20,000 BW

NOS. (1959). (6/15) Barden Inlet
NOS. (1959). (8/16) Beaufort Inlet to N of Lookout Point 1:25,000 BW
NOS. (1959). (8/16) S of Lookout Point to Swash Point 1:25,000 BW
NOS. (1959). (9/16) Whalebone Inlet 1:25,000 BW
NOS. (1959). (10/13) E of Swash Inlet to E of North Core Banks 1:4,000 BW
US Marines. (1960). (9) Drum Inlet BW
ASCS. (1960). (11/15) Barden Inlet 1:20,000
NOS. (1961). (11/25) Beaufort to E of Lookout Point 1:36,000 BW
NOS. (1962). (3/13) Barden Inlet 1:20,000 BW
NOS. (1962). (3/13) Beaufort Inlet to E of Beaufort Inlet 1:24,000 BW
NOS. (1962). (3/13) Lookout Point to Ocracoke Inlet 1:24,000 BW
NOS. (1962). (4/4) Back Sound to Beaufort Inlet 1:10,000 COL
NOS. (1962). (4/4) Fort Macon to Beaufort 1:10,000 COL
NOS. (1962). (4/4) Lookout Point to N of Barden Inlet 1:10,000 COL
NOS. (1962). (4/4) Barden Inlet to W of Lookout Point 1:10,000 COL
NOS. (1962). (5/3) Ocracoke Inlet to N of Lookout Point 1:20,000 BWIR
NOS. (1962). (5/3) N of Lookout Point to Beaufort Inlet 1:20,000 BWIR
NOS. (1962). (5/3) Lookout Point to S of Drum Inlet 1:20,000 BWIR
NOS. (1962). (5/15) Beaufort Inlet 1:20,000 BW
NOS. (1962). (6/15) Barden Inlet 1:20,000 BW
NOS. (1962). (6/15) Whalebone Inlet 1:20,000 BW
NOS. (1962). (6/15) Swash Inlet 1:20,000 BW
NOS. (1962). (6/15) Sand Island Inlet 1:20,000 BW
NOS. (1962). (6/15) Drum Inlet 1:20,000 BW
NOS. (1962). (6/15) Sand Island Inlet 1:30,000 BW
NOS. (1962). (6/15) Swash Inlet 1:30,000 BW
NOS. (1962). (6/15) Whalebone Inlet 1:60,000 BW
USAF. (1964). (4/16) Styron Bay to Roanoke Island 1:50,000 BW
NOS. (1964). (5/8) Horsepen Point 1:30,000 BW
ASCS. (1964). (6/15) Carteret County, NC 1:20,000 BW
ASCS. (1964). (6/15) Beaufort Inlet 1:20,000 BW
ASCS. (1964). (6/15) Barden Inlet 1:20,000 BW
NOS. (1964). (6/15) Beaufort Inlet 1:30,000 BW
MIAASC. (1965). (7/23) Portsmouth Island 1:6,000 BWIR
NOS. (1965). (10/27) Beaufort Inlet to Barden Inlet 1:20,000 BW
NOS. (1965). (10/27) Lookout Point to N of Lookout Point 1:20,000 BW
NOS. (1965). (11/25) Beaufort to Harkers Island 1:20,000 BW
NOS. (1967). (5/8) Jarrett Bay to Hog Island 1:30,000 COL
NOS. (1967). (5/8) Whalebone Inlet 1:30,000 COL
NOS. (1967). (5/8) E of Hog Island to E of Davis 1:30,000 COL
NOS. (1967). (5/8) Hog Island to Swash Inlet 1:30,000 COL
DSC. (1967). (7) Cape Lookout National Seashore General 1:12,000 BW
NOS. (1968). (4/7) Beaufort Inlet to Barden Inlet 1:20,000 BW
NOS. (1968). (4/7) N of Lookout Point to Swash Inlet 1:20,000 BW
NOS. (1968). (4/12) N of Lookout Point to Lookout Point 1:20,000 BW
NOS. (1968). (4/12) Lookout to Drum Inlet 1:20,000 BW
NOS. (1968). (4/25) Swash Inlet to N of Lookout Point 1:20,000 COL
NOS. (1968). (4/25) Lookout Point to S of Swash Inlet 1:20,000 COL
USN. (1969). (2/12) Ocracoke Inlet to Bogue Banks 1:22,000 BW
USN. (1969). (4/1) Ocracoke Inlet to Bogue Banks 1:20,000 BW
USN. (1969). (6/4) Ocracoke Inlet to Bogue Banks 1:20,000 BW
USN. (1969). (8/7) Ocracoke Inlet to Bogue Banks 1:20,000 BW
NASA. (1970). (9/15) Beaufort Inlet 1:60,000 CIR
NASA. (1970). (9/29) Lookout Point to Core Banks 1:60,000 CIR
ASCS. (1970). (10/15) Barden Inlet 1:20,000 BW
NASA. (1970). (10/15) Drum Inlet 1:32,000 CIR
NASA. (1970). (10/15) Swash Inlet 1:60,000 COL
NASA. (1970). (10/18) Core Banks 1:60,000 COL
EROS. (1970). (10/18) Cape Fear to Ocracoke Inlet 1:60,000 CIR
NASA. (1970). (11/15) Beaufort Inlet 1:32,000 CIR

NOS. (1970). (12/6) Harkers Island 1:20,000 COL
ASCS. (1971). (6/15) Carteret County, NC 1:20,000 BW
ASCS. (1971). (6/15) Beaufort Inlet 1:20,000 BW
ASCS. (1971). (6/15) Beaufort Inlet 1:20,000 BW
WALL. (1971). (8/25) NC Coast 1:10,000 CIR
WALL. (1971). (8/25) NC Coast 1:20,000 CIR
WALL. (1971). (10/7) NC Coast 1:12,000 CIR
WALL. (1972). (2/4) NC Coast 1:5,000 CIR
WALL. (1972). (2/4) NC Coast 1:10,000 CIR
WALL. (1972). (2/4) NC Coast 1:20,000 CIR
WALL. (1972). (4/19) NC Outer Banks to VA Outer Banks 1:12,000 CIR
WALL. (1972). (4/19) NC Outer Banks to VA Outer Banks 1:20,000 CIR
WALL. (1972). (8/9) NC Coast to Virginia Coast 1:10,000 CIR
WALL. (1972). (8/9) NC Coast to Virginia Coast 1:20,000 CIR
NOS. (1972). (10/21) E of Harkers Island to Barden Inlet 1:10,000 COL
WALL. (1972). (11/7) NC Coast 1:12,000
NOS. (1973). (1/15) Beaufort Inlet 1:10,000 CIR
NOS. (1973). (1/30) Beaufort Inlet to E of Beaufort Inlet 1:20,000 COL
NOS. (1973). (1/30) E of Beaufort Inlet to Beaufort Inlet 1:20,000 COL
WALL. (1973). (2/13) NC Coast 1:3,000
WALL. (1973). (2/13) NC Coast 1:13,000
WALL. (1973). (5/11) NC Coast 1:11,000 CIR
WALL. (1973). (5/11) NC Coast 1:19,000 CIR
WALL. (1973). (6/15) NC Coast 1:10,000
WALL. (1973). (6/15) NC Coast 1:11,000 CIR
WALL. (1973). (6/15) NC Coast 1:19,000
WALL. (1973). (6/15) NC Coast 1:19,000 CIR
WALL. (1973). (8/14) NC Coast 1:11,000 CIR
WALL. (1973). (8/14) NC Coast 1:19,000 CIR
NOS. (1973). (10/12) Lookout Point to N of Lookout Point 1:40,000 COL
NOS. (1973). (10/12) Swash Inlet to N of Lookout Point 1:40,000 COL
NOS. (1973). (10/13) Barden Inlet to Beaufort Inlet 1:60,000 CIR
NOS. (1973). (10/13) Barden Inlet to Beaufort Inlet 1:60,000 CIR
NOS. (1973). (10/15) Barden Inlet to Beaufort Inlet 1:60,000 CIR
WALL. (1973). (11/18) NC Coast 1:11,000 CIR
WALL. (1973). (11/18) NC Coast 1:19,000 CIR
NOS. (1974). (4/1) Styron Bay to Buxton 1:60,000 CIR
NOS. (1974). (4/1) Horsepen Point 1:15,000 CIR
NOS. (1974). (4/3) Styron Bay to Buxton 1:60,000 CIR
NOS. (1974). (4/7) Styron Bay to Buxton 1:60,000 CIR
WALL. (1974). (6/4) Cape Henlopen to Core Banks 1:20,000 CIR
WALL. (1974). (12/3) NC Coast 1:20,000
USGS. (1975). (4/6) Harkers Island to Roanoke Island 1:78,000 BW
WALL. (1975). (6/20) NC Coast 1:23,000 CIR
WALL. (1975). (7/2) NC Coast to Fisherman Island 1:24,000 CIR
WALL. (1975). (9/5) Delaware Coast to NC Coast 1:20,000
WALL. (1975). (12/2) NC Coast to VA Coast 1:20,000 CIR
WALL. (1976). (7/20) Cape Henry to Beaufort Inlet 1:20,000 CIR
WALL. (1976). (8/12) Back Bay to Beaufort Inlet 1:20,000 CIR
WEYER. (1978). (3) Davis 1:15,840 BW
WEYER. (1978). (3) Davis 1:63,360 BW
NOS. (1979). (10/9) Styron Bay 1:15,000 BW
NOS. (1979). (10/9) Styron Bay to Wainwright Island 1:15,000 COL
ASCS. (1980). (11/2) Horsepen Point to Atlantic 1:40,000 BW
MIAASC. (1980). (11/8) Horsepen Point to Roanoke Island 1:24,000 BW
NOS. (1980). (11/22) Cape Lookout to Buxton 1:40,000 BW
USGS. (1981). -, Cape Lookout to Green Island 1:80,000 BW
NOS. (1981). (4/21) Cape Lookout to Green Island 1:40,000 COL
NOS. (1981). (4/21) Cape Lookout to Ocracoke 1:40,000 COL
USGS. (1982). (3) Portsmouth 1:58,000 CIR

USGS. (1982). (3) Styron Bay 1:58,000 CIR
USGS. (1982). (4) Styron Bay - Wainright Island 1:58,000 CIR
ASCS. (1982). (4) Cape Lookout to Roanoke Island 1:58,000 CIR
USDOINPS. (1982). (12/22) Cape Lookout National Seashore 1:24,000 IR
USGS. (1983). (4) Cape Lookout to Wainwright Island 1:80,000 BW
USGS. (1983). (4) Horsepen Point to Wainwright Island 1:58,000 CIR
USGS. (1983). (4) Portsmouth 1:80,000 BW

Books and Articles Concerning Maps

Au, S. 1975. Vegetation and Ecological Processes on Shackleford Banks, North Carolina. NPS Monograph Series No. 6, U.S. Department of the Interior, National Park Service, Washington, DC. 86 pp.

Baker, S., 1976. Aerial Photography for Planning and Development in Eastern North Carolina: A Handbook and Directory. University of North Carolina Sea Grant Program Publication, Raleigh, NC. 107 pp.

Civco, D.I. 1982. An Annotated Bibliography of Remote Sensing Applications on Coastal Salt Marshes. Department of Renewable Natural Resources, University of Connecticut, Storrs, CT. April 16.

Clark, D.S. 1976. Index to Maps of North Carolina in Books and Periodicals (Illustrating the History of the State from the Voyage of Verrazzano in 1524 to 1975). Published Fayetteville, NC. 229 pp.

Cumming, W.P. 1958. The Southeast in Early Maps. Princeton University Press, Princeton, NJ. 284 pp.

Cumming, W.P. 1966. North Carolina in Maps. North Carolina State Department of Archives and History, Raleigh, NC. 40 pp.

Dolan, R. 1970. Aerial Photography of Coastal North Carolina 1930-1970.

Dolan, R., Hayden, B. and Heywood, J. 1977. Handbook for Remote Sensing, Mid- Atlantic Coast National Seashores: Assateague Island, CapeHatteras, Cape Lookout. Natural Resources Report No. 10, NASA/WALLOPS Flight Center,Wallops Island, VA.

Karpinski, L.C. 1938. Early Maps of Carolina and Adjoining Regions from the Collection of Henry P. Kendall, Boston, MA, Second Editionprepared by Louis C. Karpinski of the University of Michigan on thebasis of the 1930 catalogue compiled by Priscilla Smith. 67 pp. D.Stick.

Ray, G.C. and McCormick-Ray, M.G. 1980. Eastern United States Coastal and Ocean Zone Data Analysis, National Aeronautical and Space Administration, Washington, DC.

Stafford, D.B. 1971. An Aerial Photographic Technique for Beach Erosion Surveys in North Carolina. CERC Technical Monograph No. 36, U.S. Army Corps of Engineers, Wilmington District, Wilmington, NC.

USACE. 1967. Project Maps, Fiscal Year 1967. U.S. Army Corps of Engineers Wilmington District, Wilmington, NC. 200 pp.

Vincent, C.L. 1970. Aerial Photography of Coastal North Carolina. NPS Technical Report No. 70-2, U.S. Department of the Interior, National Park Service, Washington, DC. 40 pp.

Wahl, H.E., 1973. A Survey of North Carolina Beach Erosion by Air Photo Methods - 1973. Report No. 73-1, Center for Marine and Coastal Studies, North Carolina State University, Raleigh, NC. 31 pp. CAHA

MAPS, VARIOUS TOPICS

Introduction

Included under this general heading are maps on Ecology/Vegetation, Floods/Storms, Geology/Hydrology, Miscellaneous Topics, and Zoning/Land-Use.

Format: Author, date, title, scale, contour, field survey, revision dates etc., publisher source.

Author: Person or group that did cartography.

Date: Year of publication.

Title: Taken from citations and maps.

Scale: Given as the representative fraction (i.e., 1:24,000) or as unknown.

Contour: Information given where appropriate.

Field Survey: Field survey date, given where appropriate.

Revision date, etc.: Date revisions were made of previous copy.

Publisher: First name given after scale or after contour, field survey, and revision date where appropriate if two are presented. Addresses will be given in Source List.

Source: Indicates agency/individual where map can be obtained, copied or viewed. Addresses given in Source List.

Ecology/Vegetation Maps

USDOIFWS. (1980). Manteo Ecological Inventory, 1:250,000, field survey 1980, USGS.

Flood/Storms Maps

USGS Water Resources Division (1974). Atlantic Flood Prone Areas Overlay, 1:24,000, contour 5', field survey 1951, USGS.

USGS Water Resources Division (1974). Harkers Island Flood Prone Areas Overlay, 1:24,000, contour 5', field survey 1971, USGS.

USGS Water Resources Division (1975). Davis Flood Prone Areas Overlay, 1:24,000, contour 5', field survey 1971, USGS.

USDOI Bureau of Land Management, Selected Hurricanes Affecting the Southern United States, 1954-1970, no scale.

USDOI - Bureau of Land Management, 1978, Selected Hurricanes Affecting the Southern United States, 1954-1977, visual no. 10, scale not given, CCES.

Geology/Hydrology Maps

Behrendt, J.C., and Kligord, K.D. (1979). High resolution aeromagnetic anomaly map of the U.S. Atlantic continental margin, geophysical investigation map GP-931, 1:1,000,000, USGS, Reston, VA.

Blake Plateau Planning Unit. (-).Blake Plateau - upland sediments and bottom sediments, 1:1,000,000, U.S. Department of the Interior - Bureau of Land Management - Blake Plateau Planning Unit.

North Carolina Department of Conservation and Development. (1958). Geologic Map of North Carolina, North Carolina Department of Conservation and Development, Raleigh, NC.

Pierce, J.W. (1969). Wave refraction plots for the coastline between Chesapeake Bay and approximately Beaufort, NC, 1:539,978, Division of Sedimentary Petrology, National Museum of Natural History, Smithsonian Institution, Washington, DC, 29 sheets, CAHA.

Stuckey, J.L., and Stephenson, G.C. (1958). Explanatory text for geologic map of North Carolina, North Carolina Department of Conservation and Development, Bulletin 71, Raleigh, NC. 51 pp. NCSU.

Miscellaneous Topics

Hassan, A.F. (1909). State of North Carolina, 1:500,000 revised 1921, USGS.

Lobb, J. (1764). A Plan of the Harbour of Cape Lookout surveyed and sounded by his majesty's Sloop Viper, 1:14,200, Library of Congress.

MacKay, A. (1756). A survey of the coast about Cape Lookout in North Carolina, taken the 29 of June 1756, Library of Congress.

Mann, V.I. (1962). Bougure Gravity Map of North Carolina, no scale given in citing, Southeastern Geology 3(4). DUKE.

North Carolina Department of Transportation, Division of Highways, Roadsystem Carteret County, North Carolina, 1:31,680, revised 1980, North Carolina Department of Transportation.

Sheridan, K. (1976). Maritime disasters of the Cape Hatteras Area, 1:1,000,000, Library of Congress.

USGS. (1975). Beaufort Planimetric Map, 1:250,000, field survey 1953, revised 1971, USGS.

Zoning/Land-Use Maps

USGS. (1979). Beaufort Land Use and Land Cover, 1:250,000 field survey 1974, 4 sheets 1. Political Unit Overlays 2. Hydrologic Units Overlay 3. Census County subdivision overlay 4. Federal ownership overlay, USGS.

USGS. (1979). Beaufort Land Use and Land Cover, 1:250,000, field survey 1974, USGS.

USGS. (1979). Land Use and Land Cover, 1972-1973, Eastville, Virginia, North Carolina, Maryland, map L-58, 1:250,000, USDOIGS, CAHA.

NATIONAL OCEAN SURVEY (U.S. COAST AND GEODETIC SURVEY) MAPS

The National Ocean Survey was formerly known as the U.S. Coast and Geodetic Survey. Copies of original plane table surveys of the National Ocean Survey can be obtained from the National Archives by specifying place name, county, and state location. Charts are listed in chronological order.

NOS Hudrographic Surveys

Format: year, number of map, title, scale.

Year: Year of survey.

Number of Map: Number used for identification.

Title: Indicates area covered by chart.

Scale: Given as the representative fraction (i.e., 1:24,000).

Source: Charts can be obtained from the U.S. Coast and Geodetic Survey, and older surveys from the National Archives.

Addresses: Included in the Source Address List.

1852, H-321, Ocracoke Inlet 1:10,000
1857, H-613, Ocracoke Inlet 1:20,000
1857, H-577, Beaufort Inlet 1:40,000
1857-8, H-661, Pamlico Sound 1:20,000
1864, H-854, Cape Lookout 1:20,000
1864, H-855, Core Sound 1:4,000
1864-66, H-884, Beaufort Inlet 1:24,000
1865-66, H-885, Core Banks 1:40,000
1866-70, H-1083, Core Sound (Portsmouth) 1:40,000
1876, H-1316a, Core Sound 1:20,000
1876, H-1316b, Core Sound 1:20,000
1877, H-1347, Core Sound 1:20,000
1877, H-1364, Ocracoke Inlet 1:20,000
1880-81, H-1561, Cape Hatteras to Cape Lookout 1:1,200,000
1886, Core Sound, H-1850, H-1851, H-1852, H-1853, H-1854, H-1855, H-1856 1:10,000
1887-88, H-1871, Ocracoke Inlet 1:20,000
1905, H-2798, Ocracoke Inlet 1:20,000
1913, H-3529, Core Banks 1:20,000
1916, H-3902, Ocracoke Inlet 1:20,000
1927, H-4734, Ocracoke Inlet 1:10,000
1927, H-4778, Ocracoke Inlet 1:10,000
1928, H-4802, Cape Lookout Point 1:10,000
1942, FE No. 6 1942, Cape Lookout 1:80,000
1942-43, H-6835, Ocracoke Inlet 1:20,000
1943, Beaufort Inlet to Cape Lookout Point 1:10,000
1943, H-6834, Ocracoke Inlet 1:10,000
1943, H-6836, Ocracoke Inlet 1:10,000
1952-53, H-7963, Beaufort Inlet 1:12,500
1955, FE No. 12 1957, Ocracoke Inlet 1:40,000
1956, H-8291, Ocracoke Inlet 1:10,000
1960, H-8564, Beaufort Inlet 1:5,000
1960, H-8565, Beaufort Inlet 1:5,000
1962, H-8766, Ocracoke Inlet 1:10,000

NOS Nautical Charts

A description of the National Ocean Survey (NOS) is given in the previous section. Charts are listed in chronological order.

Format: Date, title, number, scale, number of historical editions.

Date: Date of latest edition.

Title: Area covered by chart.

Number: Present number, date of number change, previous number.

Scale: Given as representative fraction (i.e., 1:24,000).

Source: Charts can be obtained from the National Ocean Survey or National Cartographic Information Center, and older chartsfrom the National Archives. Addresses included in the Source Address List.

1981, Cape Lookout to New River, North Carolina, as of 8/76 #11543 previously #1234, 1:80,000, 16 historical editions 1971 to 1981.

1982, Beaufort Inlet and part of Core Sound, as of 3/75 #11545 previously #420, 1:40,000, 37 historical editions 1910 to 1982.

1982, Ocracoke Inlet and part of Core Sound as of 7/74 #11550 previously #419, 1:40,000, 19 historical editions 1946 to 1982.

1982, Portsmouth Island - Beaufort, including Lookout Shoals, as of 3/75 #11544 previously #12331, 1:80,000, 25 historical editions 1915 to 1982.

TOPOGRAPHIC MAPS

Topographic maps are divided by quadrangle, and then listed in reverse chronological order.

Format: producer, year, title, scale, contour, field survey, photo survey, revised, source.

Producer: agency that produced the map.

Date: year map was published.

Title: taken directly from topographic map.

Scale: given as the representative fraction (i.e. 1:24,000).

Contour: contour interval given in feet.

Field Survey: year that area was field checked.

Photo Survey: year that area was photo revised.

Revised: year that information was revised from previous editions .

Source: indicates the agency where the map can be purchased. Addresses of sources are in the Source Address List.

Topographic Maps

Atlantic Quadrangle - Point of Grass Creek to North of Long Point

NOS. (1972). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS
USGS. (1951). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS
NOS. (1950). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS

Beaufort Quadrangle - Atlantic Beach to Shackleford Banks

USGS. (1984). 1:24,000, contour 5', field survey 1949, photo revised 1983, USGS
USGS. (1975). 1:250,000, contour 25' and 50', field survey 1953, revised 1971, USGS
USGS. (1965). 1:250,000, contour 25' and 50', field survey 1953, revised 1964, USGS
DMA. (1954). 1:250,000, contour 25' and 50', field survey 1953, USGS

Cape Lookout - Quadrangle Cape Point to Cape Lookout Lighthouse

USGS. (1963). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS
NOS. (1951). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS

Davis Quadrangle - Johnson Creek to Old Channel Point

USGS. (1984). 1:24,000, contour 5', field survey 1949, photo survey 1983, revised 1983, USGS
USGS. (1963). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS
NOS. (1951). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS

Harkers Island Quadrangle - Shackleford Slue to Gunning Hammock Island

USGS. (1973). 1:24,000, contour 5', field survey 1949, photo survey 1971, revised 1971, USGS
USGS. (1963). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS
NOS. (1951). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS

Horsepen Point Quadrangle - Gunning Hammock Island to Guthrie Hammock

USGS. (1950). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS
NOS. (1950). 1:24,000, contour 5', field survey 1949, photo survey 1946, USGS

Portsmouth Quadrangle - Whalebone Island to Ocracoke Island

USGS. (1976). 1:24,000, contour 5', field survey 1948, photo survey 1970, revised 1970, USGS
NOS. (1972). 1:24,000, contour 5', field survey 1948, photo survey 1970, revised 1970, USGS
NOS. (1950). 1:24,000, contour 5', field survey 1948, photo survey 1946, USGS

Styron Bay Quadrangle - Yaupon Hammock Gut to North of Cross Shoal Channel

USGS. (1974). 1:24,000, contour 5', field survey 1949, photo survey 1971, USGS
NOS. (1951). 1:24,000, contour 5', field survey 1947, photo survey 1946, revised 1949, USGS

Wainwright Island Quadrangle - The Sands to Kathryne Jane Islands

USGS. (1976). 1:24,000, contour 5', field survey 1949, photo survey 1971, USGS
NOS. (1950). 1:24,000, contour 5', field survey 1949, photo survey 1947, USGS

GOVERNMENT AGENCIES FROM WHICH MAPS AND AERIAL PHOTOGRAPHS CAN BE OBTAINED

The Agricultural Stabilization and Conservation Service (ASCS) of the Department of Agriculture has probably the largest collection of aerial photography. Both contact prints and a variety of enlargements are available on either paper or on a polyester base. Local ASCS offices (state and county) hold the most recent coverage for their area. A personal visit is recommended to review photography before placing an order:

ASCS - USDA
2505 Parley's Way
Salt Lake City, UT 84109

Defense Meteorological Satellites provide data in the visible/near infrared (0.4 to 1.1 μm) and the infrared (8 to 13 μm). Positive transparencies of both high and low resolution are

available for both the visible and infrared, and can be obtained from:

DMSP Satellite Data Library
Space Science and Engineering Center
1225 W. Dayton Street
Madison, WI 53706

The Earth Resources Observation System (EROS) Program is administered by the Geological Survey and operates a Data Center to provide access to aerial photography resources. This is imagery acquired by the U.S. Department of the Interior, NASA, LANDSAT imagery and photography, Skylab, Apollo, and Gemini spacecraft, and from research aircraft. A free computer search can be requested by giving the geographic coordinates or path/row designated by EROS:

User Services Unit
EROS Data Center
Sioux Falls, SD 57198

Mosaics of LANDSAT imagery of the U.S. have been prepared by the Soil Conservation Service. They are not available from the Data Center, and should be ordered from:

Cartographic Division
Soil Conservation Service
Federal Center, Building No. 1
Hyattsville, MD 20782

The National Archives and Record Services has available aerial photography dating from the middle 1930's. They also have the old U.S. Coast and Geodetic Survey charts of the Atlantic Coast. These are the original plane table surveys, many of which date back to the 1840's. Information on what they have available can be requested by giving county and state name in which the area of interest is located. They have no listing of records by area (i.e., specific name):

John A. Dwyer
Assistant Chief, Cartographic & Architectural Branch
General Services Administration
National Archives and Records Service
Washington, DC 20408

The National Cartographic and Information Center (NCIC) collects and sells information relative to the cartographic holdings (including imagery) of many federal agencies, as well as state, county, and private organization. A computer search can be requested by supplying the geographic coordinates of an area:

National Cartographic and Information Center (NCIC)
U.S. Geological Survey
536 National Center
Reston, VA 22092

SOURCE ADDRESS LIST

Aerial Photography Field Office
USDA - ASCS
2222 West 2300 South
P.O. Box 30010
Salt Lake City, UT 84125

Cape Hatteras National Seashore
Route 1, Box 675

Manteo, NC 27954

Cape Lookout National Seashore
P.O. Box 690
Beaufort, NC 28516

Denver Service Center - NPS
Technical Information Center
P.O. Box 25287
Denver, CO 80225

EROS - User Services Unit
Data Center
Sioux Falls, SD 57198

Library of Congress
10 First Street SE
Washington, DC 20540

Abrams Aerial Survey Corp.
124 North Larch St.
Lansing, MI 48901

National Archives & Record Service
Cartographic Branch (NNTS)
8th and Pennsylvania Ave., N.W.
Room 2W
Washington, DC 20408

National Aeronautical & Space Administration
400 Maryland Ave. SW
Washington, DC 20546

North Carolina State Department of Archives and History
Raleigh, NC

National Cartographic and Information Center (NCIC)
U.S. Geological Survey
536 National Center
Reston, VA 22092

National Ocean Survey, NOAA
Nautical Data, CG222
WSCI, Room 818
Rockville, Maryland 20852

U.S. Army Corps of Engineers
Wilmington District
Wilmington, NC 28402

US Air Force
Maps and charts available through National Cartographic and Information Center.

USDOI National Park Service
Science & Technology DPS
Division of Park Science
1100 L St. N.W. Room 3319
Washington, DC 20240

US Geological Survey

Reston, VA 220909

US Marines Corps
Maps and charts available through National Cartographic and Information Center.

US Navy
Maps and charts available through National Cartographic and Information Center.

NASA/WALLOPS Flight Center
Wallops Island, VA 23337

Weyerhauser Company
CHB-38, Timberland Drive
Tacoma, Washington 98477

COMPUTERIZED DATA BASES

With the advent of computerized systems for data management, a powerful tool has become available for integrating many types of diffuse information into a coherent and useful base of knowledge. The National Park Service has undertaken several projects of this nature.

In 1982, Gary S. Waggoner of the NPS Geographic Information Systems (GIS) Field Unit at Denver, CO, became project manager for a new computerized data base called NPFLORA. The base makes use of the latest checklists of vascular plants available from each park to form a dynamic resource base containing information on presence and distribution of both exotic and native species, and rare, threatened, or endangered species. Information may be accessed in taxonomic groups, within or between park units, and in a variety of other ways. The analysis package, SYSTEM 2000, was chosen for its flexibility of design and for its capacity for update and revision.

As of early 1986, 108 park units including Cape Lookout have been added to NPFLORA. For inquiries or updates, please contact:

Mr. Gary S. Waggoner
Manager, NPFLORA Data Base
U.S. Department of the Interior
National Park Service
Geographic Information Systems Field Unit
P.O. Box 25287
Denver, CO 80225-0287

The Rutgers NPS Bibliographic Research Team has produced a computer diskette of Volume I, Bibliography of Scientific Research, for each park. The software allows for rapid search by general keyword, specific keywords, authors, and date, or a combination of these. As with the NPFLORA, this data base will be most useful if it periodically updated with new citations for each park. Diskettes are available for both IBM® and MacIntosh®, using the Procite® bibliographic progam.

ONGOING SCIENTIFIC RESEARCH

What follows is a listing of ongoing research at Cape Lookout National Seashore (CALO), as indicated by park personnel in Spring of 1984, (and partially updated in February 1987) on an Ongoing Research Questionnaire. A description of in-house facilities at the Seashore is also furnished. Also included are summary comments on other ongoing research, as received from correspondents and other sources.

ONGOING RESEARCH AT CALO

This form is designed to record yet-to-be-completed ongoing research at the Seashore, and not-yet-published results.

Please use a separate form for each relevant project.

1. Principal Investigator

Name: Ian J.W. Firth

Institution: School of Environmental Design

The University of Georgia, Athens, GA 30602

Address: The University of Georgia

Athens, GA 30602

2. Funding Agency: NPS

3. Subject:

Project Title: Historic Vegetation Patterns of Portsmouth Village.

Unpublished, available at U.S. Department of Interior, National Park Service,

Cape Lookout National Seashore, Beaufort, NC.

Attach copy of abstract of summary if available. (*)
Contains maps, short summary of project.

4. Location

List stations or research sites within the Park:

Portsmouth Village

5. Status

Date project started: 4/9/84

Date project is to be finished: To be decided (project finished, not yet reviewed).

Have progress reports been submitted to NPS? If so, list date of submission:

(*) Study involves mapping of the enclosures around structures at Portsmouth Village which would delimit the private yards from the free range grazing areas on the island. This research may be categorized as vegetation/history (pers. comm. from Ian Firth, Sept. 28, 1984).

ONGOING RESEARCH AT CALO

This form is designed to record yet-to-be-completed ongoing research at the Seashore, and not-yet-published results.

Please use a separate form for each relevant project.

1. Principal Investigator

Name: Beau McCaffrey

Institution: North Carolina State University

Raleigh, NC

Address: _____

_____

2. Funding Agency: NPS

3. Subject:

Project Title: Fuels modeling/vegetation map of CALO. Maps only available at U.S. Department of Interior, National Park Service, Cape Lookout National Seashore, Beaufort, NC.

Attach copy of abstract of summary if available.

4. Location

List stations or research sites within the Park:

CALO

5. Status

Date project started: 3/1984

Date project is to be finished: No completion date (project finished).

Have progress reports been submitted to NPS? If so, list date of submission:

ONGOING RESEARCH AT CALO

This form is designed to record yet-to-be-completed ongoing research at the Seashore, and not-yet-published results.

Please use a separate form for each relevant project.

1. Principal Investigator

Name: Joe Ferris

Institution: Independent

Address: _____

2. Funding Agency: NPS

3. Subject:

Project Title: Turtle biology

Publication:

Ferris, J. 1986. Nest success and the survival and movement of hatchlings of the loggerhead sea turtle, Caretta caretta, on Cape Lookout National Seashore. Technical Report No. 19, University of Georgia - National Park Service Cooperative Research Unit, Athens, GA.

Attach copy of abstract of summary if available.

4. Location

List stations or research sites within the Park:

Core Banks South

5. Status

Date project started: 6/1983

Date project is to be finished: 6/1984 (finished).

Have progress reports been submitted to NPS? If so, list date of submission:

Report in progress

ONGOING RESEARCH AT CALO

This form is designed to record yet-to-be-completed ongoing research at the Seashore, and not-yet-published results.

Please use a separate form for each relevant project.

1. Principal Investigator

Name: Susan Bratton

Institution: Institute of Ecology

University of Georgia

Address: Athens, GA

---

2. Funding Agency: NPS

3. Subject:

Project Title: Systems Analysis, CALO

Attach copy of abstract of summary if available.

4. Location

List stations or research sites within the Park:

CALO

5. Status

Date project started: Summer 1984

Date project is to be finished: Summer 1985 ongoing

Have progress reports been submitted to NPS? If so, list date of submission:

Other Ongoing Research

Detailed accounts of past and ongoing research were received from several scholars in response to a detailed research questionnaire.

Colonial Waterbirds

Dr. James F. Parnell (Department of Biological Sciences, University of North Carolina at Wilmington) provided numerous citations on colonial waterbird research, which will be available in Volume I, Bibliography of Scientific Research at CALO. He states that he is continuing work on colonial waterbirds in North Carolina, and expects to publish a supplement to his Atlas of Colonial Waterbirds of North Carolina Estuaries this year (1984), through the North Carolina Sea Grant Office.

Estuarine Research

Michael W. Street (Chief of the Fisheries Management Section, North Carolina Department of Natural Resources, Division of Marine Fisheries, Morehead City, NC) writes that "current work includes estuarine sampling with small mesh trawls in Core Sound and in various areas in eastern Pamlico Sound. We also sample adult fishes from the commercial catches from the winter trawl fishery off the Outer Banks, the long haul seine fishery in Pamlico and Core Sounds, and the summer pound net fishery in Pamlico Sound behind the Outer Banks. We are also tagging croaker in the Pamlico Sound area and red drum within Cape Hatteras National Seashore. We sample shrimp and bay scallops in various areas of Core Sound, including the sea grass beds immediately adjacent to Core Banks and Shackleford Banks. This summer (1984), we have an intern student investigating the socioeconomic effects on the fishing industry of shoaling at Oregon Inlet.

T.R. Rice (Laboratory Director, Southeast Fisheries Center, Beaufort Laboratory, Beaufort, NC) states that over the years, the Beaufort Laboratory has conducted some research in estuarine waters near Cape Lookout, and publications are listed in Volume I, Bibliography of Scientific Research at CALO, as is a study on population dynamics of fiddler crabs on Shackleford Banks.

John Costlow (Director, Duke University Marine Laboratory, Beaufort, NC) states that their library holdings and ongoing research are significant to the CALO/CAHA research base.

Vegetation Research

W.W. Woodhouse, Jr., S.W. Broome, E.D. Seneca, and A.W. Cooper, with graduate students and colleagues, have, over the past 20 years, conducted research on the vegetation of frontal dunes and salt marshes in Cape Hatteras and Cape Lookout National Seashores. E.D. Seneca (Professor, Department of Botany, North Carolina State University, Raleigh, NC) states, "we have studied the building and stabilization of coastal dunes with vegetation and the establishment of estuarine salt marshes with vegetation. Although the thrust of our work is applied, we have conducted basic research into germination, seedling growth, microclimate, and vegetation composition and structure." Numerous citations of research conducted by this group in the two Seashores is to be included in Volume I, Bibliography of Scientific Research at CALO.

S.W. Broome (Professor, Department of Soil Science, North Carolina State University, Raleigh, NC), adds that this group's "only current work... is following changes in vegetation and sand accumulation in the dune and marsh plantings." Professor Broome also participated in a Soil Conservation Service soil survey of the Outer Banks which included both CALO and CAHA.

Vertebrate Fauna

James D. Lazell, Jr. (President, The Conservation Agency, Conanicut Island, RI) writes that he continues research on the vertebrate faunas of CALO, CAHA and CACO. His agency

contains an extensive library.

Biosphere Reserve Status for CALO

Monica Goigel Turner (Institute of Ecology, University of Georgia, Athens, GA, whose research is at Cumberland Island N.S.), served as coordinator of a January 1984 panel on coastal biosphere reserves. The selection panel, chaired by Dr. Dirk Frankenberg, included both CUIS and CALO in its nomination. A report, Selection of Coastal Biosphere Reserves in the Carolinian-South Atlantic Region, U.S.A. (Frankenberg,, et al., 1984), describes the reserve system as "serving as sites for baseline monitoring, ecological research, preservation of genetic resources, and training and education" (p. 4). The report provides a brief summary of past and present research, including "the geology, ecological effects of overwash, vegetation, dune stabilization, ecology of dune strand plants, stabilization of dredge spoil, rates of beach recession, and general barrier island ecology" (p. 23). The panel has compiled an inventory of environmental knowledge about CALO.

Coastal Geology and Geomorphology

Duncan Heron (Professor, Department of Geology, Duke University, Durham, NC) states that he, Dr. Orrin Pilkey, Thomas F. Moslow, William M. Berelson, John R. Herbert, George A. Steele III, and Kenneth R. Susman have carried out NPS- sponsored coastal geomorphology research at Cape Lookout. The articles from this research will be cited in Volume I. He states that they have another article in press (1984) in Sedimentology entitled, "Correlatives between Holocene flood-tidal delta and barrier island inlet fill sequences: Back Sound- Shackleford Banks, NC." In addition, they have submitted a 57-slide set to the Society of Economic Petroleum Mineralogists (SEPM) entitled, "Evolution of barrier island sedimentary sequences: Cape Lookout, N.C." The Duke program has encouraged graduate research at CALO, and Professor Heron has an extensive collection of aerial color slides (including infra-red) and a few U-2 shots.

SCIENTIFIC RESEARCH FACILITIES AND IN-HOUSE DATA COLLECTION

The following pages provide a detailed accounting of facilities available in or near CALO, for use in conducting scientific research. Also included is a summary of CALO-directed data collection efforts. This information was provided by CALO personnel in 1984 in response to the Research Facilities and In-House Data Collection Questionnaire.

RESEARCH FACILITIES QUESTIONNAIRE

The purpose of this questionnaire is to summarize facilities available to researchers at or near the Seashore.

1. Primary contact

Please list the name, address and phone number of the primary contact at the Seashore for questions about availalbe research facilities.

Name: Chief of Operations

Address: CALO, P.O. Box 690

Beaufort, NC 28516

Telephone: 919-728-2121

2. Research labs

a) Are wet or dry lab facilities available at the Seashore? NONE
If so, list location and size:

Location: _____

Size: _____

b) What laboratory equipment is available? List below:

3. Field equipment

a) Please list available field equipment including nets, surveying gear, traps, etc.:

Live traps

Nets - fish

Cameras, slide projectors

Video materials

b) Are boats available on site? If so, list type, size, and location:

NOT AVAILABLE FOR RESEARCHERS - TRANSPORT IS AVAILABLE.

1. type _____ 2. type _____

size _____ size _____

location _____ location _____

c) What type of vehicles are available to outside researchers?

List number and type:

Honda ATC (3)

4. Housing and storage

a) List the location, number of beds, and kitchen and laundry facilities available for temporary housing:

1. Core Banks - Cottages - 10 + people (4 cottages)

2. Coast Guard facility - dormitory - 10 people

3. Portsmouth Village - cottage - 3/4 people

Kitchen facilities and washing machine are at Core Banks. Food and water must be transported from the mainland.

b) Is covered, locked storage available for lab and field equipment? If so, please note location:

Core Banks: at the ranger station or Coast Guard facility

Portsmouth I - ranger station

c) Is secure, outside storage available for vehicles, boats, and gear? If so, note location and size:

Gear - garage at Coast Guard facility - Core Banks

Boats - docks available

5. Herbaria and species collections

a) What collections are available at the Seashore?

Herbaria and insect collection

b) Where are the nearest collections containing significant specimens from the Seashore? Please list institution, location, and type of collection:

There is a list of collections in the Preliminary Resource Inventory, (1977, Mgmt. Rep. #22). Specimen collections from CALO are at: Washington Missionary College (reptiles and amphibians); University of Illinois Museum of Natural History (reptiles and amphibians); North Carolina State Museum (reptiles and amphibians); Duke University (reptiles and amphibians); Museum of Comparative Zoology, Harvard University (reptiles and amphibians); California State University at Long Beach (reptiles and amphibians); University of Kansas (reptiles and amphibians) Chicago Field Museum (reptiles and amphibians); University of Massachusetts at Amherst (mammals).

6. Other facilities

a) Are computer facilities available at the Seashore? Yes

If so, list make and model, available software, and whether connections to a main frame computer are available:

IBM PC - smart modem - basics

b) Is there a library of relevant literature at the Seashore? If so, please identify scope and size:

Located at Harker's Island, the library contains primarily recent material. Available at Harker's Island Library are: Wildlife observation cards; tabulated slide collection; directory of North Carolina libraries; old photographs of islands, Portsmouth Village and renovations; fishing settlements; media clippings, 1975-1983.

c) Are there cooperative agreements between the Seashore and other nearby laboratories, collection, libraries or computer systems which are available to researchers? If so, please list the location, type of facility and restrictions, if any, on use:

Duke Marine Laboratory, Marine Resources Laboratory, NOAA, State Marine Fisheries

IN-HOUSE DATA COLLECTION

Data collection by NPS personnel may prove useful to outside investigators. This questionnaire identifies information collected during the day-to-day operation of the Seashore by NPS staff.

1. Visitation records

For how long have these records been kept? Since 1977

Can you provide a breakdown of the categories of information collected on visitation?

Broken down by recreational activity: fishermen, boaters, overnight visitations

List locations where visitations are recorded:

Harker's Island, Davis, Atlantic, Ocracoke

2. Other

What other types of information are collected regularly, for example, bird censuses, well logs, motorized traffic? Please provide a list, with short explanation for each item:

ORV numbers; water quality logs (monthly) turtle nesting censuses;

stranded and sighted marine mammals; feral cat study, 1977-1978;

censusing of shore birds (Parnell); fire studies, 1977-1978;

preliminary checklists of CALO reptiles, amphibians, birds.

PREPARERS OF THIS REPORT

Editors: Patricia G. Claxon, Dr. Hilary Lambert Renwick

Geology, Hydrology, Soils: Berta L. Schreiber

Coastal Geomorphology: Enid Lotstein, Berta L. Schreiber

Vegetation: Patricia G. Claxon

Invertebrates: Heidi M. Wearne, Richard Paperno, Sharon A. Boeglin

Fish: Craig Liska

Reptiles and Amphibians: Steven D. Garber

Birds: Craig Liska

Mammals: Heidi M. Wearne

Estuarine Ecology: Richard Paperno

Cultural/Historical: Sharon A. Boeglin

Management, Legislation, Recreation, Miscellaneous: Sharon A. Boeglin

Bibliographies: Sharon A. Boeglin

Maps, Charts, Aerial Photographs: Helen F. Dudar

Computerized Data Bases: Patricia G. Claxon

Other materials assembled through correspondence. Fieldwork by Martha Gulick, Caroline Grant, and others, and prepared by Hilary Lambert Renwick. Editorial revisions by Richard Paperno, Sharon A. Boeglin, and Patricia G. Claxon.