Assessment of Environmental Research and Nonmineral Resources Offshore Georgia

Lewis Taylor, James Harding, Vernon J. Henry,
John Kelly and Heather Trulli

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

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ASSESSMENT OF ENVIRONMENTAL RESEARCH AND NONMINERAL RESOURCES OFFSHORE GEORGIA

By

Lewis Taylor, James Harding, Vernon J. Henry, John Kelly, and Heather Trulli

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This report is preliminary and has not been reviewed for conformity with Georgia Geologic Survey editorial standards and stratigraphic nomenclature.

DEPARTMENT OF NATURAL RESOURCES
Joe D. Tanner, Commissioner
ENVIRONMENTAL PROTECTION DIVISION
Harold F. Reheis, Director
GEORGIA GEOLOGIC SURVEY
William H. McLemore, State Geologist

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List of Acronyms

BIOTRANS	Biological Transformation Study
BLM	Bureau of Land Management
CZM	Coastal Zone Management
DOE	Department of Energy
DOI	Department of Interior
EEZ	Exclusive Economic Zone
FLEX	Fall Removal Experiment
GABEX	Georgia Bight Experiment
GIS	geographical information system
MARMAP	Marine Areas Management Program
MMS	Minerals Management Service
NASA	National Aeronautics and Space Administration
NDBC	National Data Buoy Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NTIS	National Technical Information Service
OCS	outer continental shelf
SEAMAP	Southeast Area Marine Assessment Program
SPREX	Spring Removal Experiment
TACTS	Tactical Aircrew Combat Training System (Navy Towers)
TED	turtle excluder device
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

EXECUTIVE SUMMARY

INTRODUCTION

Increasing industry interest in heavy-minerals exploration on the Georgia continental shelf, and the occurrence of large deposits of phosphate, led to the formation of the Georgia-Federal Nonenergy Minerals Task Force in 1986. The Task Force, chaired jointly by the Georgia Geologic Survey and the U.S. Department of Interior Minerals Management Service (MMS), was charged with examining the economic potential of offshore phosphate and heavy-mineral resources, the technologic and economic feasibility of mining, and the environmental constraints to mining offshore Georgia (Amato, 1990).

The Task Force determined a need for creating a database containing a comprehensive inventory of available information on non-mineral resource and environmental studies of areas offshore Georgia, and identifying significant data gaps for those areas. To address those needs, the Task Force sponsored this major study to

- Assess the extent of information that describes the Georgia shelf environment (exclusive of economic-mineral investigations);
- Determine gaps in oceanographic, environmental, and subsurface-environmental data pertaining to the Georgia shelf; and
- Prioritize the areas most critically in need of additional research in order to determine potential impacts of marine mining on offshore non-mineral, natural resources.

To accomplish these objectives, an extensive literature search and review was conducted on the extent of knowledge of non-mineral resources, habitat distribution, and marine mining of the Georgia shelf. This report presents the findings and conclusions of the study and includes a comprehensive bibliography of references that describe the non-mineral resources of the Georgia Bight.

Study Area

The study area encompasses the waters, seabed, and shallow subsurface of the continental shelf, and extends from the mean high-water shoreline to the 200-m isobath, between 32°45′ N (Charleston, South Carolina) and 30°15′ N (Jacksonville, Florida). The study area extends along the Sea Island section of South Carolina, Georgia, and Florida, and is known as the Georgia Bight (Figure 1). The

Georgia Bight is part of a larger geographic area known as the South Atlantic Bight, which extends from Cape Hatteras, North Carolina, to West Palm Beach, Florida.

Study Approach

The literature search and summary encompassed all studies conducted after 1977. The 1977 study published by Texas Instruments, Inc., entitled *South Atlantic Outer Continental Shelf Benchmark Study*[1], was treated as the baseline because it was the first comprehensive study of the Georgia Bight.

To fulfill the study objectives, the study was completed in the three major phases:

- **Information collection and annotation,** which consisted of the literature search and reference collection, annotation of a limited number of references, and incorporation of reference citations to the reference database;
- **Analysis of information,** which consisted of analyses of the extent of information, analyses of models, and identification of data gaps, and research priorities; and
- **Report development,** which included development of the manuscript and the electronic database of references formatted in dBase III.

Copies of references collected during the study are stored at the Skidaway Institute of Oceanography Library in Savannah, Georgia.

Report Organization

The report is organized into several sections according to activity and conclusions.

- Section 1.0 includes the introduction and background information.
- Section 2.0 summarizes the conduct and results of the literature search, and the development of the electronic database.
- Section 3.0 discusses the extent of the environmental information located during the literature search and presents abbreviated summaries of the information.
- Section 4.0 contains a brief analysis of physical/chemical and biological oceanographic models.
- Section 5.0 presents and briefly discusses data gaps in the context of marine mining methods.

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[1]Texas Instruments, Inc. 1979. *South Atlantic benchmark program: Volume I Executive Summary.* Final report prepared for Bureau of Land Management under Contract AA550-CT7-2. Texas Instruments, Inc., Dallas, TX. 5pp.

- Section 6.0 presents research needs and recommendations in regard to non-mineral resources, marine mining and site selection.
- Section 7.0 presents a technical summary.
- Section 8.0 lists the references cited in the report.
- Appendix A presents the comprehensive database bibliography.
- Appendix B presents a list of key words used during the electronic literature searches, a list of information contacts, and a list of key words in the study database.
- Appendix C presents selected annotated citations.

INFORMATION COLLECTION AND ANNOTATION

A comprehensive literature search was conducted to meet the study objectives. Data were identified and recovered from sources such as computer databases, libraries, universities, research facilities, state and federal agencies, resource managers, individual researchers, and environmental organizations. Data collection methods also included telephone surveys, written correspondence, and on-site investigations; these methods recovered a variety of gray literature and unpublished materials that could not be located through electronic-database searches.

The types of collected information ranged from the papers of refereed scientific journals, to the unpublished or gray literature (i.e., technical reports, books, conference abstracts, dissertations, and theses). Over 1600 references were identified and recorded into an electronic database. A reference description [author(s), date, title, source, publisher, and other information necessary to obtaining the reference] was included with each citation, and abstracts were included in the database when available.

The electronic database may be searched through the title and author(s), and by using key words. The database may be expanded and updated on a regular basis by adding new citations and reference descriptions. In this sense, the database may be seen as a starting point or a baseline for the future management and use of resources in the Georgia Bight.

ANALYSIS OF THE EXTENT OF ENVIRONMENTAL INFORMATION

A review of the collected data was conducted after the literature search. The three-step process used to characterize the data analysis was (1) organizing individual references into resource topic categories; (2) reviewing and analyzing the type, nature, and relevance of citations in each topic area; and (3) analyzing of the extent of information.

The references were organized first into four major environmental study areas: physical, chemical, biological, and socioeconomic. Results of the literature search show that approximately 29% of the citations describe the physical and chemical environments, 40% describe the biological environment, and 31% describe the socioeconomic environment. The four areas were further divided into the specific topics listed in Table E-1.

Many interdisciplinary studies were conducted in the South Atlantic Bight under the aegis of the Bureau of Land Management (Outer Continental Shelf responsibilities were given to MMS in 1982). These interdisciplinary studies, which were typically performed as assessments for oil and gas activities, provide baseline data for the region and the study area.

A general summary of the extent of environmental information for each of the four major areas is presented below.

- **Physical Environment** — Dynamic processes from the seafloor through the water column to the sea surface have received thorough study. Movements of water masses, such as circulation patterns, Gulf-Stream intrusions, upwelling, and outwelling are relatively well-defined, especially in regard to the coupling of meteorological activity with water mass motions.
- **Chemical Environment** — Processes of transport, exchange, and transformation of dissolved and particulate constituents in the water column are well described. Baselines are established for concentrations of various trace elements in shelf waters and seafloor sediments.
- **Biological Environment** — Biotic components of shelf environments that are subject to resource management programs are described and understood better than other aspects of biological systems. The biology of several commercially important species of fish and shellfish is documented in detail. A baseline for hard-bottom habitat areas is established for the area, however, detailed site-specific assessments of the live-bottom areas are needed.
- **Socioeconomic Environment** — Research related to fisheries management, including shellfish and finfish, dominate the socioeconomic literature. Few references pertain to the socioeconomic facets of offshore and coastal environments of the study area. Publications on coastal and marine management and public education are more common from South Carolina and Florida than from Georgia. Regulations and legislation concerning ports, navigation, and pollution comprise most of the remainder of work in this area. Archeological resources, primarily shipwrecks, may number in the thousands in offshore areas, but these resources have not been assessed recently.

Table E-1. Resource Topics and Organization of Environmental Information.

PHYSICAL ENVIRONMENT
Meteorology
Physical Oceanography
Water Masses
Waves, Tides and Currents
Geology
Bathymetry and Seabed Morphology
Sediments and Sediment Transport
Aquifers
Geologic Hazards and Environmental Studies
Stratigraphy and Shallow Structures
CHEMICAL ENVIRONMENT
Water Column
Geochemistry
BIOLOGICAL ENVIRONMENT
Microbes
Macroalgae
Phytoplankton
Zooplankton
Upwelling and Productivity
Outwelling
Nektonic Invertebrates
Benthic Invertebrates
Fish
Birds
Threatened and Endangered Species
Sea Turtles
Whales and Other Marine Mammals
Benthic Habitats
Hard grounds
Artificial reefs
SOCIOECONOMIC ENVIRONMENT
Commercial Shellfish and Crustacean Fisheries
Commerical Finfish Fisheries
Recreational Fisheries
Resource Management and Use
General Coastal Management
Beaches
Ports and Navigation
Pollution
Cultural Resources

ANALYSIS OF MODELS

Literature relevant to models of physical and biological processes and systems of the Georgia shelf is analyzed. The applicability of selected models is discussed with emphasis on their strengths and weaknesses. These data are of particular interest because of the possible use of models to predict and characterize potential effects of marine mining.

Reviews of models for the South Atlantic Bight were performed as early as 1979, when Jaycor[2] conducted an extensive evaluation of all available physical oceanographic models applicable to the South Atlantic Outer Continental Shelf. Jaycor concluded that highly theoretical models involving ocean circulation were of little use because of the complexity of the water movements in the South Atlantic Outer Continental Shelf, and that the database extant in 1980 was inadequate to define boundary conditions or to drive any of the models beyond a diagnostic state. This report supports the critical need for final verification in all the models to support realism in the predictive models.

A comprehensive review was recently completed for MMS that discusses the use of predictive models to forecast dynamic events and their effects with regard to marine mining activities[3]. The review concluded that the only models that adequately address sediment-plume dispersion are those designed by the U.S. Army Corps of Engineers to describe plumes generated during dredged-material disposal.

The biological models located and reviewed during the present study provide insight into forces affecting the Georgia-shelf ecosystem, and highlight critical features that should be considered by modeling efforts concerning environmental effects of marine mining. However, none of the models could be directly applied to the study of a potential biological effect of marine mining on the Georgia shelf; instead, question-specific models must be developed. For example, none of the models addressed major concerns to be considered when predicting potential effects such as perturbations of the benthic and demersal-fish communities, and the interactions of particle fields with the biological environment.

Therefore, reviews of the model studies accessed by the literature search indicated a low degree of applicability between the models and any site-specific mining activities that might occur on the Georgia

[2]Jaycor. 1980. *Physical oceanographic model evaluation for the South Atlantic OCS Region.* BLM Report No. BLM/YM/ES-80/10. National Technical Information Service, Department of Commerce, Springfield, VA. 327pp.

[3]Continental Shelf Associates, Inc. 1993. Synthesis and Analysis of Existing Information Regarding Environmental Effects of Marine Mining. OCS Study MMS 93-0006. Minerals Management Service, Herndon, VA. 392pp.

continental shelf. The models may, however, highlight key areas that should be considered when developing models for the Georgia-shelf environment.

IDENTIFICATION OF DATA GAPS IN THE LITERATURE

For this study, a data gap is defined as a lack of documented information within a specific area of research or current understanding of environmental resources and processes. This report identifies gaps in

- Geologic, biologic, physical, and chemical processes on the shelf and in the shelf subsurface;
- Distribution of known and potential non-mineral resources on the shelf;
- Habitat distribution relative to shelf topography and oceanography;
- Environmental data for marine mining impacts, methods, and site-selection processes; and
- Information relevant to socioeconomic concerns.

Nineteen data gaps were identified relating to marine mining activities and the physical, chemical, biological, and socioeconomic environments of the Georgia shelf, and 41 additional data gaps were identified for the non-mineral resources in general (Table E-2). Eleven data gaps pertaining to site-specific mining activities are listed also in Table E-3.

Five significant gaps in the U.S. literature database regarding environmental effects of mining were identified by the recent Continental Shelf Associates, Inc., study (1993[4]). Those data gaps that may be relevant to the Georgia shelf environment are

(1) Water quality modeling of the generation and dispersion of particulate and dissolved materials in the water column, based on, or at least confirmed by empirical data acquired from marine mining operations;

(2) Effects of significant alterations of the seabed on adjacent coastlines;

(3) Characteristics, behavior, and recolonization response of organisms in various mine sites under the stress of production operations;

(4) Effects of processing discharges from onshore mines on coastal biota; and

(5) Relationship between mining activities and other natural processes and man-induced activities.

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[4]See footnote 3 on previous page.

Table E-2. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979]

Physical Environment

(1) Projections of potential effects of climatological change on the centers of high-pressure fields.

(2) Effect of northeasters/extratropical cyclones on nearshore sediment dynamics, water column processes, and water masses.

(3) Post-storm effects of hurricanes on physical, chemical, and biological processes across the shelf.

(4) Regional response of water masses/currents to large-scale wind forcing.

(5) Relationship between density-driven, wind-induced circulation in the inner-shelf frontal zone and the means by which circulation confines near-bottom particles and dissolved materials to the inner shelf.

✓ (6) Role of bottom currents on patterns, dynamics, and sediment-transport mechanisms across the shelf over broken bottoms and planar bottoms, and effects of sediment fluxes on benthic communities.

(7) Inwelling/advection studies of shelf-to-estuarine transport of organics and sediments, and interaction of estuaries with continental shelf circulation.

(8) Further quantification of levels, transport, and input of particulate and dissolved organic matter from rivers and estuaries to the shelf, including definition of sinks and sources of lignin with regard to shelf biological processes.

✓ (9) Fluxes in turbidity levels for periods of sediment suspension due to episodic events, such as storms, as compared to ambient conditions.

✓ (10) Hydrogeology, depth, and areal extent of the offshore Floridan Aquifer System.

✓ (11) Detailed imagery, bathymetry, and seabed characterization of the Georgia shelf.

(12) Degree and frequency of Gulf Stream intrusions into the central portion of the South Atlantic Bight shoreward of the 20-m isobath.

(13) Exchange rates and particle transformations through the life cycles of Gulf Stream intrusion events on the outer shelf.

(14) Processes responsible for cross-shelf diffusion of freshwater in autumn.

(15) The position, extent, and ages of relict shorelines of former sea-level stillstands since the late Pleistocene.

(16) The role of oxic sand sediments in the biogeochemistry of the shelf system.

✓ (17) The fate of high, suspended-particle loads in inner-shelf waters, especially in regard to the alongshore and cross-shelf transport mechanisms.

Table E-2. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979] *(continued)*

__Chemical Environment__

(18) Transport and chemical exchange across the atmosphere/water/ sediment boundaries.

(19) Biogeochemical cycling within and between the water column and the sediments.

✓ (20) Chemical exchange processes associated with resuspension of sediments during normal (ambient) and high energy (storm) conditions.

(21) Levels, fluxes, and fates of point and nonpoint sources of organic and inorganic pollutants in coastal and shelf waters.

(22) Atmospheric contribution of particulate matter (organic material and trace elements) to the Georgia Bight.

(23) Significant trace-metal concentrations in the biota, sediments, and water column.

__Biological Environment__

✓ (24) Detailed investigations of shelf and shelf-edge live-bottom/hardground habitats.

(25) Sediment-microbial interactions regarding productivity, metabolic activities, and substrate relationships.

✓ (26) Laboratory modeling studies regarding turbidity effects on selected indicator biota.

(27) Population distribution and fluxes of microbes in water-column and benthic environments in response to physical and chemical factors, particularly after periods of disturbances.

(28) Benthic biological productivity on the shelf relative to substrate characteristics.

(29) Inwelling of larvae of commercial species from nearshore areas into estuaries, including abundances of larvae offshore versus abundances of adults in estuaries.

(30) Relationships between primary production and higher pelagic trophic levels.

(31) Effect of Gulf Stream intrusions and associated upwelling on primary and secondary productivity and offshelf transport.

(32) Quantification and relative importance of benthic ("new") production.

(33) Coupling mechanisms between the systematics and ecology of benthic invertebrates on the shelf and their role in sediment water column exchanges and processes.

(34) Regulation of population biology by meteorology and physical circulation.

Table E-2. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979] *(continued)*

<u>Biological Environment (continued)</u>

(35) Relationships between tidal fronts and abundances of marine turtles.

(36) Effect of tidal outwelling of organic carbon and fine particles to photosynthesis in the inner shelf.

✓ (37) Migration route(s) of right whales from the northwest Atlantic to the Georgia Bight.

✓ (38) Responses of right whales to noise from shipping traffic, mining operations, etc.

✓ (39) Studies of other marine mammals, especially bottle-nosed dolphins and pygmy sperm whales.

✓ (40) Movements, distribution, and abundance of juvenile and sub-adult sea turtles.

✓ (41) Status of species of concern, including endangered and threatened species, commercial/recreational species, species-in-decline, and indicator species.

✓ (42) Data management system (Geographic Information System/electronic clearinghouse) to integrate information from different disciplines.

✓ (43) Long-term, process-response studies of the ecology of hard-bottom communities in inner-, middle-, and outer-shelf areas (e.g., effects of sedimentation).

(44) Ecology of macroalgal communities in inner-, middle-, and outer- shelf areas regarding rates of productivity, annual recruitment vs. year-round, multi-year populations.

(45) Stock status of sharks, including coastal and large pelagic species.

(46) Population size, distribution, and life history of whelks in nearshore habitats and for other shellfish species that may be targeted for new fisheries.

(47) Composition, distribution, transport, and fate of ichthyoplankton in shelf waters.

(48) Life history aspects for important commercial and recreational finfish species, and reef fish complexes, especially the snapper-grouper complex.

(49) Movements, distribution, population fluxes (breeding/transient), and ecology of pelagic seabirds and coastal marine birds.

✓ (50) Identification of unique and/or critical habitats for rare and depleted finfish species, especially in regard to designation of marine reserves.

(51) Harvest levels of offshore finfish species.

Table E-2. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979] *(continued)*

<u>Socioeconomic Environment</u>

✓ (52) Most probable locations for prehistoric habitation sites on the shelf and development of site-selection criteria.

✓ (53) Determination of maximum levels of exploitive activities, such as mining and fisheries, to be allowed in order to maintain sustainable development.

(54) Socioeconomic responses to the decline of commercial and recreational fishing industries.

(55) Social research on the offshore recreational and commercial fisheries industries.

(56) Educational materials regarding offshore resources of the Georgia Bight to be used by the general public, planners, legislators, educators, etc.

✓ (57) Management mechanisms for addressing conflicts between mining and non-mineral resources.

(58) Management structure for resolving resource-use conflicts between neighboring states.

(59) Assessment and prediction of cumulative effects of numerous individual development actions (planning, resource management, and permitting).

✓ (60) Coastal ocean management policies and regulations for the State of Georgia.

Table E-3. Data Gaps Relative to Potential Site-Specific Mining Impacts.

(1) Detailed information concerning the depth, areal extent, and hydrogeology of the Floridan Aquifer System.

(2) Distribution and abundance of live-bottom habitats.

(3) Effects of habitat modification on benthic communities.

(4) Recolonization of benthic areas after cessation of the mining operations.

(5) Effect of turbidity plumes on benthic and water-column biota.

(6) Effect of turbidity, acoustics, and pollution on marine mammals and reptiles.

(7) Predictive models for marine systems to forecast ecological impacts of mining.

(8) Effect of nearshore mining on beach erosion.

(9) Methods and mechanisms for resolving conflicting uses of mineral and non-mineral resources (e.g., mining, commercial and recreational fisheries).

Only two existing mining techniques — excavating and fluidizing — are likely to be used on the Georgia shelf. The excavating technique, which uses a cutter-head suction dredge, creates an open pit on the seafloor, thereby significantly disrupting the benthic communities on the seafloor. The technique also produces a sediment plume during the overboard-disposal of tailings by the surface vessel; the plume would likely affect the water quality in the mining area.

The fluidizing bore-hole mining technique will minimally impact the shelf environmental because the technique produces little turbidity or disruption of the seafloor. However, the technique has not been fully tested offshore.

Recent studies suggest that economically accessible middle-Miocene phosphate deposits are present on a sub-bottom feature known as the Outer Shelf High, located 70-100 km off the Georgia coast, and also in the vicinity of the Savannah Light Tower. Constraints to mining exist in these areas because live bottoms occur in both areas. In addition, the Oligocene-age sediments that comprise the aquiclude of the Floridan Aquifer System are only 15 m below the seabed at the Savannah Light Tower.

There is no prior experience, except by analogy, on which to base data gaps and correlative research needs that relate specifically to mining in the study area. With the exception of navigation-channel dredging and beach nourishment, no mineral resources mining or petroleum production has ever occurred in either the Georgia Bight or the South Atlantic Bight. Based on current levels of knowledge, the hard minerals of potential economic value on the Georgia shelf are phosphate and, to a lesser extent, sand and gravel.

RESEARCH NEEDS AND RECOMMENDATIONS

The existing research for the Georgia Bight does not adequately address all areas of interest to environmental and resource management. The ten most significant research needs identified by this study concerned the water column; biota (including endangered species); substrate (sediments, habitat, and the aquifer); and mining-related activities (site selection, impacts, constraints, and mitigation) (Table E-4). As additional research efforts increase the understanding of offshore systems and processes, other data gaps may become evident.

The research recommendations within the study report pertain to both the enhancement of the study database (literature characterizing non-mineral resources), the potential impacts of marine mining, and site-selection criteria. The advent of mining of phosphate and other minerals in the marine environment may be decades away and, in the meantime, many studies will be initiated or completed.

**Table E-4. Considerations When Selecting a Mining Site.
[Adapted From South Atlantic Fishery Management Council (1990)]**

(1) Identify potential impacts to the Floridian Aquifer System.

(2) Prohibit mining on or closely adjacent to live-bottom habitat or other special biological resources.

(3) Design facilities associated with mining exploration, development, and transportation to avoid impacts on coastal wetlands and sand-sharing systems.

(4) Avoid migration routes of the northern right whale and other marine mammals.

(5) Identify site-specific fishery resources, including both pelagic and benthic communities, that inhabit, spawn, or migrate through the potential site.

(6) Identify on-site species described as endangered, threatened, or of special concern, i.e., shortnose sturgeon, striped bass, blueback herring, American shad, sea turtles, marine mammals, pelagic birds, and all species regulated under a Federal Fisheries Management Plan.

(7) Determine impacts on fisheries resources of all pre-mining exploratory and developmental activities and actual mining operations prior to approval of mining permits.

(8) Characterize the proposed site in terms of physical oceanographic and geological condition prior to approval of mining permits.

(9) Study potential impacts by noise, turbidity, smothering, cavern collapse, fuel spills, and incidental impacts.

TECHNICAL SUMMARY

STUDY TITLE: An Assessment of Environmental Research and Non-Mineral Resources Offshore Georgia

REPORT TITLE: An Assessment of Environmental Research and Non-Mineral Resources Offshore Georgia

CONTRACT NUMBER: MMS Agreement No. 14-35-0001-30496

SPONSORING ENTITIES: Georgia Department of Natural Resources, Georgia Geologic Survey; U.S. Department of the Interior Minerals Management Service

COMPLETION DATE OF REPORT: July 1, 1994

CUMULATIVE COST: $85,000

PROJECT MANAGER: Ms. Heather Trulli

AFFILIATION: Battelle Ocean Sciences, 397 Washington Street, Duxbury, Massachusetts 02332

PRINCIPAL INVESTIGATORS: Mr. Lewis Taylor, Dr. James Harding, and Dr. Vernon J. Henry (Independent Consultants), and Dr. John Kelly and Ms. Heather Trulli (Battelle Ocean Sciences)

KEY WORDS: Georgia Bight, South Carolina, Georgia, Florida, literature review, environmental assessment, data gaps, research priorities, oceanography (physical, chemical, biological), socioeconomics, non-mineral resources, marine minerals, mining.

BACKGROUND: The Georgia-Federal Nonenergy Mineral Task Force was established in response to industry interest in potential mining for large phosphate deposits and potential deposits of heavy minerals offshore Georgia. Subsequent to investigations of the engineering and economic feasibility of such mining, it was determined that a study and assessment of environmental research on non-mineral resources offshore Georgia was necessary to obviate potential concerns regarding deleterious environmental effects of mining. This study was designed to address such concerns and conflicts.

OBJECTIVES: The major objectives of this study were to (1) assess the existing literature of the Georgia shelf waters and subsurface geology relative to non-mineral natural resources, habitat distribution, and marine mining; (2) determine basic data gaps in oceanographic, environmental, and subsurface knowledge of the shelf (exclusive of economic mineral investigations) relative to shelf processes, habitat distribution, non-mineral natural resources, and marine mining; and (3) prioritize the most critical areas of future research relative to conserving non-mineral natural resources.

DESCRIPTION: The study area extends west-to-east from the mean high water line on coastal beaches to the 200-m isobath, and north-to-south from Charleston, South Carolina, to Jacksonville, Florida. Because the literature search was very broad in scope, material was excluded from consideration if the writings pertained to economic marine minerals or if a reference predated 1977, the baseline date for the study.

The literature search investigated several sources including computer databases, research facilities, universities, libraries, resource management agencies, and individual researchers. Search methods utilized computers, telephone surveys, correspondence, and on-site investigations. Collected information included journal papers and gray literature, such as technical reports and unpublished items (i.e., cruise reports). These materials form an electronic database in which each reference is annotated with a description of the resource, research methods, location of work, and summary. Reference citations of each item were created for a bibliography.

The extent of environmental research relative to non-mineral resources offshore Georgia was determined through analysis of the collected literature. Separate analyses were conducted for major categories of physical, chemical, biological, and socioeconomic resources. All collected references that pertained to models of processes or systems were analyzed for their significance and any constraints. This information provided the foundation for further analyses of data gaps in the existing work and for recommendations for future research.

Data gaps are identified by category in the text and tables of this report. A review of the extent of research, as well as a survey of selected researchers and resource managers, facilitated this effort. The primary data gaps for the non-mineral environmental resources were assessed in separate summaries for each resource category. Data gaps regarding specific mining techniques and site selection are highlighted separately with emphasis on resources likely to be affected by mining.

Priorities for future research are identified in regard to the need for filling data gaps prior to the initiation of any mining activities. Typically, data gaps in areas of critical concern were addressed by the suggested research efforts. Research priorities considered the type of resource, objectives, methods, project length, locations of the work, approximate costs, and justification for the research relative to the environment, affected resources, and mining. The research priorities are reported individually by project.

SIGNIFICANT CONCLUSIONS: The information describing the study area is dominated by gray literature typically collected by State and Federal natural resource management agencies. Sixty data gaps, of which 11 relate to mining, are identified for the offshore resources. Ten research priorities are recommended to fill data gaps and allow assessment of potential impacts of marine mining, and aid in site selection. Research priorities include the Floridan Aquifer System, sediment dispersal, and distribution of live-bottom and benthic communities. Site-specific investigations are necessary regarding marine mining, but shelf-wide work is ideal.

STUDY RESULTS: Over 1600 references were accepted for inclusion in the project database. The majority of the material consists of gray literature from resource management agencies and research facilities. Approximately one-quarter of the collected literature is comprised of journal articles. A substantial amount of unpublished data was also located.

The physical and chemical processes are relatively well-defined for water mass movements and for the transport, exchange, and transformations in the water column. Regional studies associated with oil and gas exploration provided baseline data for the physical and biological aspects of the Georgia Bight. Research by various researchers and agencies provides a relatively well-defined base of information for many of the resources, but several major systems and processes have not been investigated. In general, a paucity of collected material appears to be evident for the following resource areas: bathymetry and seabed morphology, aquifers, macroalgae, sediment and water column chemistry, benthic invertebrates, seabirds, coastal and marine management, and cultural resources.

Sixty data gaps were identified in the non-mineral database for the study area. One-third of these gaps exist for the physical and chemical environments, particularly for processes at the sediment-water boundary, the Floridan Aquifer System, and seabed morphology, especially in regard to hard-bottom areas. The 27 data gaps identified for the biological environment pertained to the benthic environment, especially in regard to the distribution of resources and habitat areas. Whereas some resources, such as the seabirds, have received little study, better-documented resources may be considered to be a higher priority because of the potential impacts of marine mining. Gaps in the socioeconomic database pertain to the management of coastal and marine resources, however, cultural resources, archeological research in particular, is perhaps the least-researched field for the entire study area. Eleven of the data gaps were highly relevant to marine mining. Areas in which additional research is needed prior to the advent of marine mining include aquifers, sediment transport, and benthic environments including live-bottom areas.

Ten research projects were recommended in order to address the data gaps relative to marine mining and site selection. Proposed research priorities include the Floridan Aquifer System, effects and/or feasibility of mining methods, fluxes in turbidity and sediment dispersal, right whale migrations, live-bottom areas, seabed morphology, coastal management, and data collection and management.

STUDY PRODUCTS: Taylor, L, J. Harding, J. Henry, J. Kelly, and H. Trulli. 1994. An Assessment of Environmental Research and Non-Mineral Resources Offshore Georgia. Final Report prepared by Battelle Ocean Sciences under contract to the State of Georgia Department of Environmental Resources, Georgia Geologic Survey. MMS Agreement No. 14-35-0001-30496. Project Report No. 21. 160pp. + appends.

1.0 INTRODUCTION

Increasing industry interest in offshore, heavy-mineral exploration on the Georgia continental shelf, and the known occurrence of large phosphate deposits underlying the shoreline and inner shelf, led to the formation of the Georgia-Federal Nonenergy Minerals Task Force in 1986. The Task Force, chaired by the Georgia Geologic Survey and the U.S. Department of Interior Minerals Management Service (MMS), was charged with examining the resource potential of offshore phosphate and heavy minerals, the technologic and economic feasibility of mining, and the environmental constraints to offshore mining (Amato 1990). In 1988, a study was contracted to determine the economic and engineering feasibility of mining on the Georgia Shelf. The report concluded that additional geological and geophysical information is needed (Zellars-Williams Company 1988).

Following the acquisition of additional geologic data, the Task Force determined the need to establish a database of all existing information on non-mineral resources and environmental studies in the area as well as to identify significant gaps in the database. To this end, the Task Force contracted with Battelle Ocean Sciences (Battelle) to prepare an assessment of the current status of environmental research relative to the non-mineral resources and the effects of offshore mining.

1.1 Objectives

This study is intended to meet three major objectives:

- Identify, review, and summarize the existing literature regarding the Georgia shelf waters and subsurface geology relative to non-mineral natural resources, habitat distribution, and marine mining.
- Determine gaps in oceanographic, environmental, and subsurface geological data of the shelf relative to shelf processes, habitat distribution, non-mineral natural resources, and marine mining.
- Prioritize the most critical areas of future research relative to conserving non-mineral natural resources on the shelf.

1.2 Scope of Study

The study area encompasses the waters, seabed, and shallow subsurface of the Georgia continental shelf extending from the mean high water shoreline to the 200-m isobath; and between 32°45′ N (Charleston, South Carolina) and 30°15′ N (Jacksonville, Florida) (Figure 1). The study area essentially

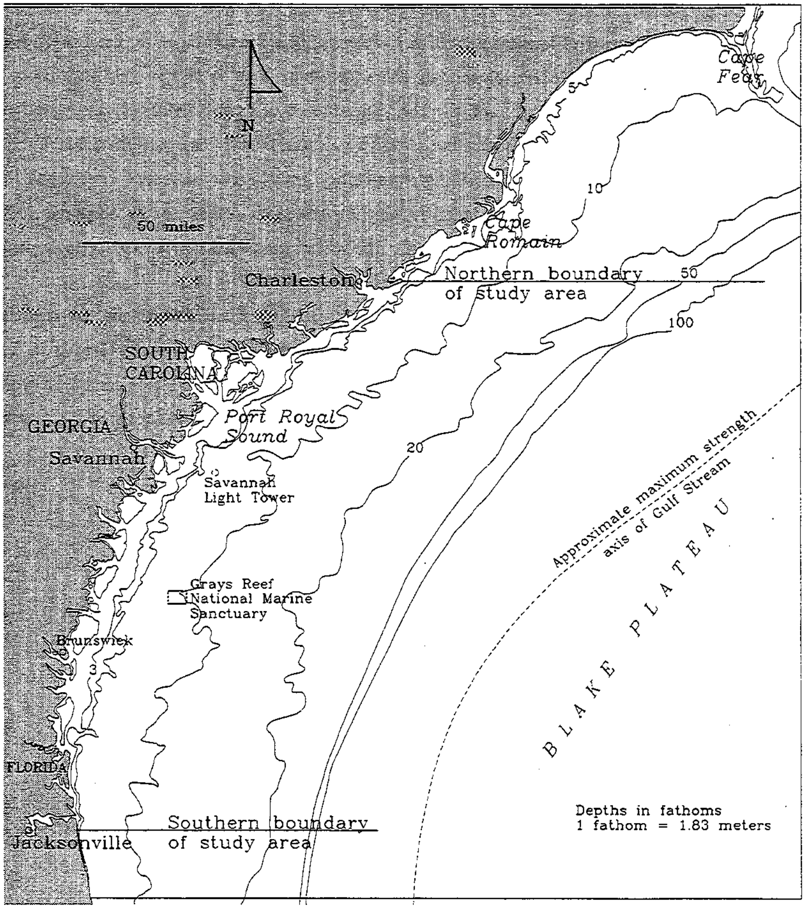

Figure 1. The Georgia Bight and Study Area.

includes the Sea Island sections of South Carolina, Georgia, and Florida. Together with the adjacent shelf, this area is known as the Georgia Bight. Much of the reviewed literature includes regional studies of the South Atlantic Bight, which is the broad embayment extending from Cape Hatteras, North Carolina, to West Palm Beach, Florida. The Georgia Bight an integral part of the South Atlantic Bight.

Rather than provide a database on which to recommend new baseline studies, a major focus of this study is to identify data necessary to determining if, when, where, and how mining operations can be conducted on the Georgia shelf. Although a broad range of topics are investigated during the study, literature on economic minerals of the shelf concerning topics such as mineral potential and exploration efforts is excluded. References for minerals studies are included only if they relate to environmental aspects of the shelf. Additional topic areas that are not considered by the study include studies of the subsurface strata below the Eocene, human histories of the study area, and research on nutritional values, storage, and preparation of seafood. The study begins with the South Atlantic Benchmark Program (Texas Instruments, Inc., 1979a-e) which, along with earlier baseline studies and environmental inventories, provides an excellent foundation upon which to build this study.

1.3 Methods and Approach

The study objectives and major tasks guided the methods and approach for the study. The study was conducted in three phases: (1) information collection and annotation, (2) analysis of information, and (3) production of a report and electronic database.

Information collection and annotation preceded the other two phases of the study. The database of pertinent information was assembled through a literature search. Material was identified and recovered by a variety of techniques including searches of computer databases; on-site investigations at research, education, and resource management facilities; and correspondence with agencies and colleagues working in the area. Copies of references collected during the study are stored at Skidaway Institute of Oceanography in Savannah, Georgia.

All pertinent reference citations were compiled to create a comprehensive study bibliography, and selected references were annotated with details about the nature, location, and contents of the research. All citations are entered into the study database. Section 2.0, Literature Search and Reference Citations, details the information collection and data management methods.

The analysis of information included several tasks in which the collected literature was reviewed and evaluated. The extent of environmental knowledge of shelf resources was defined by summarizing the data according to the general field of research and the resource topic. Models of biological and physical processes and systems were described separately, and model type, strengths and weaknesses and relative significance were highlighted.

Data gaps in the existing literature were identified for each resource, especially regarding marine mining and site selection. Recommendations of research needs were based on the analyses.

1.4 Report Organization

The report is organized according to the requirements of the Georgia Geologic Survey, as described briefly below.

- Section 2.0, Literature Search and Reference Citations, discusses collection of information, preparation of reference citations, and description of the references, and reviews the products of the study, including the electronic database.
- Section 3.0, Analysis of Extent of Environmental Information, summarizes the results of the literature search according to topic category.
- Section 4.0, Analysis of Models, contains an analysis of physical- and biological-oceanographic models for the Georgia shelf.
- Section 5.0, Identification of Data Gaps, discusses significant deficiencies in the current knowledge of Georgia shelf environments and processes.
- Section 6.0, Prioritization of Research, recommends specific research to precede site selection or marine mining.
- Section 7.0, Summary and Conclusions, contains a brief technical summary of the report.
- Section 8.0, References, presents the complete citations for all references cited in the text.
- Appendix A, Key Words and Information Contacts, includes an index of common terms that used during the literature searches, a list of individuals from whom information was obtained, and a lit of key words in the electronic database.
- Appendix B, Bibliography of Citations, contains a complete listing of references included in the study database.
- Appendix C, Annotated Citations, contains annotations for two references that are representative of each resource topic.

The Program Manager for this study is Ms. Heather Trulli of Battelle. Ms. Trulli provided liaison with the Georgia Geologic Survey and MMS, managed individual tasks, and provided technical guidance and editorial assistance during report preparation. Mr. Lewis Taylor, Dr. James L. Harding, and Dr. Vernon J. Henry, hereafter known as the Georgia authors, were responsible for performing all research, technical work, and report preparation (except Section 4.3) under subcontract to Battelle. Dr. John R. Kelly of Battelle authored the analysis of biological models in Section 4.3. Mr. Thomas Nitroy of Battelle was responsible for constructing the final electronic database (dBase III). Ms. Nancy Padell of Battelle provided editorial assistance during the draft and final report preparation.

This report provides a means to assess or plan research in the Georgia Bight. The electronic database is a valuable reference tool that may be updated and expanded in the future. In addition to providing guidance in regard to potential marine mining, this study is expected to benefit resource managers, planners, and researchers concerned with the offshore environments of the Georgia Bight. Educators, legislators, and conservation groups may also find the report and database useful to their investigations.

2.0 LITERATURE SEARCH AND REFERENCE CITATIONS

A literature search was conducted to establish the database for review and analysis in the study. Excluded from consideration were references pertaining to resources of areas outside of the study boundaries, publication dates prior to 1977, mineral resources, and subsurface features below the aquifer. Essentially, all other data pertaining to the Georgia Bight were included in this study. The broad scope of this study required a comprehensive literature search.

2.1 Information Collection

The Georgia authors identified the potential sources of data in coordination with the MMS, the Georgia Geologic Survey, and Battelle. The data sources included computer databases, libraries, universities, research facilities, state and Federal agencies, individual researchers, resource managers, and environmental organizations. Appendix A contains a list of data sources that were contacted.

2.1.1 Methods and techniques

The comprehensive literature search was guided by word identifiers, or key words, specific to major resource topics (Table 1). These key words were identified by Battelle with suggestions from the authors, the Georgia Geologic Survey, and MMS. The key words provided starting points from which to launch literature searches of electronic and printed databases. Resource topic titles of Section 3.0, Analysis of the Extent of Environmental Information, are based on these key words.

Complementary methods were employed to locate, identify, and recover information. The main procedures included searches of computer databases, telephone contacts, written correspondence, and on-site investigations. Efficient collection of large amounts of data was accomplished by the computer-database searches. Personal communication with select individuals, however, was effective in identifying and recovering unpublished data, technical reports, and other such material, hereafter referred to as gray literature.

2.1.1.1 Computer-database searches

The major sources of data were several electronic databases of information relevant to the study topics. Extensive searches of some databases on CD-ROMs (Computer Disk-Read Only Memory) were

Table 1. Resource Topics and Organization of Environmental Information.

PHYSICAL ENVIRONMENT
- Meteorology
- Physical Oceanography
  - Water Masses
  - Waves, Tides and Currents
- Geology
  - Bathymetry and Seabed Morphology
  - Sediments and Sediment Transport
  - Aquifers
  - Geologic Hazards and Environmental Studies
  - Stratigraphy and Shallow Structures

CHEMICAL ENVIRONMENT
- Water Column
- Geochemistry

BIOLOGICAL ENVIRONMENT
- Microbes
- Macroalgae
- Phytoplankton
- Zooplankton
- Upwelling and Productivity
- Outwelling
- Nektonic Invertebrates
- Benthic Invertebrates
- Fish
- Birds
- Threatened and Endangered Species
  - Sea Turtles
  - Whales and Other Marine Mammals
- Benthic Habitats
  - Hard grounds
  - Artificial reefs

SOCIOECONOMIC ENVIRONMENT
- Commercial Shellfish and Crustacean Fisheries
- Commerical Finfish Fisheries
- Recreational Fisheries
- Resource Management and Use
  - General Coastal Management
  - Beaches
  - Ports and Navigation
  - Pollution
- Cultural Resources

conducted on-site in the library at the Skidaway Institute of Oceanography (Savannah, Georgia). Three databases on CD-ROM, Aquatic Science and Fisheries Abstracts, Biosis Reviews (Biological Abstracts), and Selected Water Resources Abstracts, are in the library collection at Skidaway. A fourth database on CD-ROM, Dissertation Abstracts, was searched at the University of Georgia library (Athens, Georgia). Additional CD-ROM databases that were searched on-site include the Bibliofile Intelligent Catalog of bibliographic records in the National Oceanic and Atmospheric Administration (NOAA) libraries and the LS-2000 system of the Savannah District of the U.S. Army Corps of Engineers. Some information requests to agency libraries were filled through the searches of library and agency databases by each agency librarian.

The computer databases were also accessed on-line through DIALOG Information Services, Inc., at the library of the Skidaway Institute of Oceanography. Simultaneous, comparative searches of several databases produced comprehensive, non-repetitive results. Appendix A (Table A-1) includes a list of key words used during the computer database searches.

Data collected from the DIALOG computer databases were downloaded for storage in electronic files before entry into the study database. Raw data were manipulated by editing and organizing the information into formats suitable for transfer to the study database. Data management is described in Sections 2.3 through 2.5. The following electronic databases were accessed during the literature search: Aquatic Sciences and Fisheries Abstracts, Biosis Previews (Biological Abstracts), Dissertation Abstracts, GeoRef, Life Sciences Collection, National Technical Information Service (NTIS), Oceanic Abstracts, Pollution Abstracts, and Selected Water Resources Abstracts.

2.1.1.2 Telephone surveys and correspondence

Information was gathered through telephone surveys and through correspondence with universities, state and Federal agencies, research facilities, and colleagues. The telephone surveys identified and recovered publication lists for agencies and organizations, manuscripts by individuals, and technical reports. Requested investigations of libraries, files, and data banks at several research, education, and management facilities aided in recovering much of this literature and in locating much unpublished data. A list of individuals contacted is presented in Appendix A (Table A-2).

Telephone surveys were conducted throughout the study to determine the extent of available information. Occasionally, follow-up calls and letters were necessary to prompt responses and to obtain additional data. The literature search plan was expanded and modified in response to the information gleaned from telephone surveys. The telephone survey also aided in locating additional researchers and identifying studies.

Written correspondence typically followed contacts by telephone or facsimile. In comparison with time invested in telephone surveys, very little effort was given to written requests in the initial phases of the study. Written correspondence was usually effective in reinforcing or amending requests made during telephone surveys. Several responses included information about unpublished data, current projects, and other information sources.

2.1.1.3 On-site investigations

Whereas data collection by using computer searches and telephone surveys proved to be most effective, the investigations of some data sources were best accomplished through site visits. For unpublished data sets and resource management projects, the only source of such information was usually the facility where the original research was conducted. Likewise, progress reports and annual reports for projects typically were available only through the sponsoring agencies. The labor-intensive, on-site investigations recovered reports and unworked data that otherwise would have remained in researchers' files.

Public libraries in the coastal region and private libraries of resource management and research facilities were the most productive sources for these on-site investigations. Gray literature that was not recovered through other methods was often located in this manner.

2.1.2 Effectiveness of methods

Evaluating the effectiveness of information-collection methods may be based upon ease of implementation, scope of application, labor intensity, numbers of recovered citations, and relative efficiency. In this study the searches of computer databases through an on-line service such as DIALOG was an effective means for recovery of data. The searches of the individual computer databases on CD-ROM were also effective. Because cost and time limits on use of the CD-ROMs did not apply as strictly as for the on-line services, CD-ROM searches generally were more extensive.

The type of data recovered by computer searches differed from data types that were located by telephone, letters, or on-site visits. The latter methods generally recovered unpublished data and some types of gray literature. On-site investigations required a greater amount of effort and time compared to surveys by telephone and letter. All of the methods needed to be used in concert in order to conduct an effective search of the literature.

2.1.3 Modifications in methods and techniques

Modifications to the scope of the study and to the key words list were the first changes to affect the literature search. In July 1992, the open-sound regions were eliminated from the study area, which, consequently, also removed most estuarine-related papers from consideration. The list of key words used in the literature searches (Appendix B, Table B-1) was expanded to include a few additional categories. These changes affected the literature-search strategies.

Although the study guidelines for information collection established relatively straightforward parameters for acceptance or rejection of a specific reference, many citations were difficult to accept or reject based only upon the title, key words, and abstract. To create a standard for data assessments and to reduce bias, the Georgia authors developed indices for evaluating both the reliability and applicability of collected citations. The applicability scale, which incorporated these guidelines, allowed for the relevance of citations to study objectives to be determined. Peripheral citations were assessed by the applicability scale for inclusion into the database. The reliability scale allowed for the significance and relative importance of a citation to the body of data to be determined. The parameters of this index also guided decisions for including peripheral data in the database. The parameters and variables considered in the indices are noted in Table 2. Many of these parameters were used in assessing citations for the extent of data analysis and for identification of data gaps.

2.2 Results of Literature Search

2.2.1 Profile of collected data

The sources of collected information included refereed scientific journals and the gray literature of technical reports, books, dissertations, and theses. The bulk of journal papers were located through searches of computer reference databases and review of bibliographies of current scientific publications.

Approximately 25% of the citations in the database are from peer-reviewed journals. The remainder of the collected references comprised various forms of gray literature. These references are primarily technical reports of both state and federal resource management agencies. Technical reports and data reports from the scientific community also comprise much of the gray literature. Conference-

Table 2. Guidelines for Evaluating References.

Parameter	Variables
RELIABILITY INDEX SCALE	
Type of Source	Refereed journal Non-refereed publication Unpublished material
Significance of Research	
Area of Study	Relative significance within the specific field of research
Author(s)	Experience and contributions to the field of study
Cited Documentation	Strength, nature, and extent
Methods and Techniques	Application, validity, strength
Best Professional Judgement	Georgia authors
APPLICABILITY INDEX SCALE	
Location of study	Within the study area Possibly within the study area Outside the study area
Topic of study	Included on topic list Tangential to items on topic list Not on topic list
Nature of Work	Studies major systems/processes Addresses facet of one of the above Narrowly-focused or minor study
Relevance to Marine Mining	
Best Professional Judgement	Georgia authors

paper abstracts do not contain much information, however, they do provide information on the types of research being conducted. Theses and dissertations comprise a small portion of the gray literature.

A total of over 1600 individual references comprise the study database. Table 3 presents the numbers of references in each resource topic area, excluding biological and physical models that are considered in Section 4.0. [*Note:* Because Table 3 is 20 pages in length, it is presented at the end of Section 2.0, beginning on page 16.]

Information collected during the literature search was stored in an electronic format. Whether entered manually or downloaded in ASCII format from a computer database, the data were stored in WordPerfect®5.1 files prior to entry into the database. Initially, all recovered data were organized into the structure used by the Compact Cambridge Aquatic Sciences and Fisheries Abstracts database. The citations were eventually transferred to Citation Utility, a database software format designed by Battelle specifically for this study. This intermediate database format allowed for data transfer into the dBase III database format and subsequent transmittal to MMS and the Georgia Geologic Survey. Key words were also incorporated into the database (Appendix A, Table A-3).

2.2.2 Peripheral data

Many peripheral citations were excluded from the database after review or evaluation by using the reliability and applicability scales. Although several peripheral citations were inappropriate for consideration because of the date or topic, many referred to resources of the study area. The following are estimates for the number of citations that were not accepted during the literature search:

- Pertain to geographical areas adjacent to study boundaries: 142 references.
- Describe economic minerals (oil, gas, phosphates, etc.): 25 references.
- Deep stratigraphy (below level of aquifer): 25 references.
- Predated the 1977 South Atlantic Benchmark Program Study (Texas Instruments, Inc., 1979a-e): 101 references.

Field research and laboratory work that was conducted outside the study area, even if applicable to processes or systems within the study area, were also excluded.

2.2.3 Unpublished data

Unpublished data are typified by observations that are not analyzed, synthesized, and published. In some cases, only portions of the data may have been reported formally. The locations of some of the unpublished data are mentioned under "Comments" in Table 3. The unpublished data includes meteorological data, biological data on turtles, and observations of hard-ground habitat and fauna. In the future a more thorough investigation may be necessary to assess the extent, significance, and value of the unpublished material. Citations for unpublished data references are incorporated into the study database.

2.3 Reference Citations and Bibliography

A complete citation was prepared for each reference in the database. The citation includes the publication date, author, title, volume and series numbers, page numbers, and publisher. A standard format is used for each type of citation — journal article, book or technical report, thesis, and map. Citation contents and format differ slightly between the different types of references. These citations are not characterized by lengthy comments, as in an abstract or by key identifiers for the contents of the references.

The database bibliography (Appendix B) includes citations for all of the pertinent references identified during the literature search. The bibliography is arranged alphabetically by author, and comprises the extent of research efforts in the Georgia Bight since 1977. The format is based upon that used in *American Scientist*.

2.4 Reference Descriptions/Annotations

The data collected during computer-database searches were usually in a format suitable for entry into the study databases. Generally, the abstracts collected during computer searches were entered *verbatim*. The geographical coordinates, sponsor(s), and contract number(s) for the research are also included when available. Data were collected, stored on disk, and electronically transferred into the database. When hard copies of documents were obtained, the abstracts and conclusions were entered manually. The hard copies are stored at Skidaway in Savannah, Georgia.

Due to the unexpectedly large number of references located during the literature search, the preparation of annotations (i.e., descriptions) for each reference was discontinued at the midpoint of the study. However, descriptions were added to the study database in cases where they were included in the searched electronic databases.

Selected annotated citations were included in Appendix C to illustrate the range of types, sources, and content of the collected references. Each annotated citation includes the basic citation information as well as the type of resource studied, the method(s) of research, the location of the research, and a summary of the abstract and/or conclusions from the reference description. The contents of the annotated citations are the same as the contents of reference descriptions in the database, except the annotated citations include an abbreviated abstract/summary.

2.5 Electronic Database

Electronic storage files were created after collecting the raw data. The initial database of edited raw data was maintained as WordPerfect® 5.1 files in a format based upon the structure of the Compact Cambridge Aquatic Sciences and Fisheries Abstracts database. Subsequently, the WordPerfect® files were loaded into the Citation Utility database that served as a way station for transfer into dBase III.

The structure for the records in the study database was developed by Battelle based upon the study objectives and scope. The key words in the database, presented in Appendix A (Table A-3), are identifiers that may be used to locate and retrieve references from the database.

The electronic database was designed to be flexible and comprehensive, and provides a valuable tool for resource management, research, planning, and education in the Georgia Bight. The electronic database can be expanded and updated regularly through the addition of new citations and reference descriptions. The final study database in dBase III format is compatible with the MMS Minerals/Mining database. By using this reference database, MMS and the Georgia Geologic Survey will be better able to anticipate conflicts and needs regarding potential marine mining offshore.

Table 3. Extent of Data Collected During the Literature Search.

Primary Topic (No. References)	Content	Comments
METEOROLOGY		
Tropical Cyclones (24)	Historical reviews; data sets; storm tracks; storm surges; hindcasting; forecasting errors; effects of storms	Meteorological or climatological data encompassing all atmosphere-related subjects. ***Types of Citations:*** Technical reports, progress reports, journal articles. ***Sources of Studies:*** National Climatic Data Center, National Data Buoy Center, National Hurricane Center (National Weather Service); U.S. Army Corps of Engineers; BLM; DOE; Environmental Protection Agency; South Carolina Water Resources Commission; Skidaway Institute of Oceanography. ***Unpublished Data:*** Meteorological and hydrological measurements by offshore weather buoys are available as data sets and also summarized infrequently by the National Data Buoy Center in "Climatic Summaries for NDBC Buoys and Stations." Atmospheric data is compiled as unpublished measurements by the National Hurricane Center and the National Climatic Data Center. ***Areas of Overlap:*** Studies of effects of wind stress, atmospheric pressure, and storms on sea-surface flux, currents, circulation, and exchange. Also Baseline Studies and Pollution.
Winds (7)	Surface fields; historical reviews; data sets; data buoy and Savannah Light Tower records; reports of DOE studies [e.g., Genesis of Atlantic Lows Experiment (GALE)]	
Air-Sea Interactions (13)	Wind stress/atmospheric forcing of patterns, currents, and circulation; data sets	
Miscellaneous (3)	Forecasting of fog and stratus; transport of pollutants; haze; rainfall	
WATER MASSES		
River Discharges (16)	Freshwater transport on shelf; estuarine plumes of freshwater and nutrients; coastal frontal zones at inner and mid-shelf regions; DOE-funded studies such as the Spring Removal Experiment (SPREX) and the Fall Low Salinity Experiment (FLEX); tracing origin of freshwater runoff to shelf (piedmont vs. coastal plain)	These citations include studies of the processes, events, and dynamics of water masses that move onto and over the shelf. Various research fields, from physical to chemical to biological, are involved in these significant interdisciplinary studies. ***Types of Citations:*** Journal articles; technical reports; progress reports; dissertations; theses. ***Sources of Studies:*** Skidaway Institute of Oceanography; Rosenstiel School of Marine and Atmospheric Sciences of University of Miami; University of North Carolina and Old Dominion University; NOAA ***Unpublished Data:*** Data may exist from DOE-funded projects at sites of original research. *(continued)*
Gulf Stream Intrusions (15)	Effects on physical processes and shelf waters by upwelling, eddies, meanders, and filaments; vertical vorticities	

Table 3. **Extent of Data Collected During the Literature Search.** *(continued)*

Primary Topic (No. References)	Content	Comments
Circulation, Forcing and Exchange Processes (34)	Progress reports of DOE-funded studies such as SPREX and FLEX; transport and fate of pollutants; mixing; frontal zones on inner and mid-shelf regions as affected by atmospheric forcing and water masses; influence of wind and Gulf Stream on water masses; deflections of Gulf Stream due to changes in bottom topography (Charleston Bump); models	*(continued from previous page)* ***Areas of Overlap:*** Meteorology, Currents, Water Column, Outwelling, Upwelling and Productivity.
Miscellaneous (22)	Reports of hydrographic conditions during cruises funded by NOAA and DOE since the 1970's; shelf circulation; surface flux; general shelf processes; oceanographic research programs and plans; hypsometry; sea level flux; post-Hurricane Hugo conditions	
WAVES, TIDES, AND CURRENTS		
Waves (4)	Nearshore - direction; production of longshore currents; Kings Bay/Cumberland Island/St. Mary's River inlet area monitoring; Deepwater - archival data sets; hindcasts; extreme and climatic wave estimates; scattering due to bottom topography; satellite imagery; birds associated with oceanic waves	Citations in this category pertain primarily to studies in nearshore and inner shelf areas of the dynamics of waves, tides and currents. Offshore wave action is also included for consideration as are tidal actions and selected current movements over the mid- and outer-shelf areas. ***Types of Citations:*** technical reports; conference papers; journal articles ***Sources of Studies:*** U.S. Army Corps of Engineers; U.S. Navy; NOAA; University of Florida; University of Georgia; Skidaway Institute of Oceanography ***Unpublished Data:*** Weather buoy data from the National Data Buoy Center and National Climatic Data Center, beach erosion control monitoring surveys by the U.S. Army Corps of Engineers and various consulting firms, and archival data sets by U.S. Army Corps of Engineers. The Physical Oceanography Division of the National Ocean Service compiles and maintains databases of *(continued)*

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
Tides (5)	Tidal regime of South Atlantic Bight; influence of shelf width on tidal range; tide tables, current tables and charts; tidal mixing of shelf waters	*(continued from previous page)* oceanographic information on tides that are available in different formats. ***Areas of Overlap:*** Water Masses (current data), Sediments and Sediment Transport, and Beaches, Baseline studies, Models.
Currents (4)	Longshore currents in littoral zone; measurement at Grays Reef of velocity and direction; distribution of currents offshore	
BATHYMETRY AND SEABED MORPHOLOGY		
Bathymetry (10)	Historical reviews of changes in bathymetry and mean high water shoreline positions; nautical charts; bathymetric maps	This category evaluates citations that pertain to bottom features, bathymetry, and seafloor morphology. ***Types of Citations:*** journal articles; technical reports; maps; charts ***Sources of Studies:*** NOAA; U.S. Geological Survey; Geology Departments of the University of Georgia and the University of South Carolina ***Unpublished Data:*** Unpublished data sets of relevance may be at the Coastal Resources Division of Georgia Department of Natural Resources; the Marine Resources Research Institute of the South Carolina Department of Wildlife and Marine Resources; the Marine Resources Division of the Florida Department of Natural Resources; and U.S. Geological Survey. The National Ocean Service of NOAA compiles and maintains a digital hydrographic database of bathymetric data from NOS surveys of coastal waters. The maps or blueprints of unpublished bathymetric information may be obtained through NOAA also. ***Areas of Overlap:*** Stratigraphy and Shallow Structure, Geologic Hazards and Environmental Studies, Hard Grounds (Hard-Bottom Areas), and Resource Management and Use. The amount of research on seabed morphology, therefore, is more extensive than indicated above.
Seabed Morphology (5)	Topographical features and bathymetrical changes associated with the Charleston Bump area; in-place indicators of Pleistocene Age sea level stands; local elevation changes on the SC shelf region	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
SEDIMENTS AND SEDIMENT TRANSPORT		
Nearshore Transport (11)	Estuary-shelf exchange; inlet processes; longshore drift in littoral zone; storm-induced transport	Citations within this section deal primarily with the characteristics and dynamics of seafloor sediments, sediment structure and type, distribution and abundance, and transport, and deposition. ***Types of Citations:*** technical reports; conference papers; journal articles; books; theses ***Sources of Studies:*** U.S. Geological Survey, U.S. Army Corps of Engineers, DOE, University of Georgia; Old Dominion University; Skidaway Institute of Oceanography; Emory University ***Areas of Overlap:*** Data on sediment and sediment transport is also in references on Water Masses, Currents, Geologic Hazards and Environmental Studies, Geochemistry, Beaches, Pollution, and Baseline Studies.
Composition and Distribution (12)	Petrologic analyses; nearshore heavy mineral distributions as indicators of transport processes; general properties; sedimentation history; sediment cover	
Bottom Transport (Offshore) (10)	Bottom current processes and sediment mobility; transport patterns	
Miscellaneous (1)	Sedimentation at ocean dredge spoil disposal site	
AQUIFERS		
Nearshore (14)	General and specific data on coastal aquifers and groundwater resources; descriptions of the hydrogeology and the hydrogeochemistry of aquifers areas at nearshore/island boundary; surveys of Cumberland Island, GA/Fernandina Beach, FL area; Hilton Head/Port Royal Sound, SC area; Savannah, GA region	Attributes of offshore extensions of the Floridan Aquifer and groundwater are the subject of papers evaluated in this category. Mainland studies of the aquifer or of groundwater use and management were not collected for consideration by the literature review. Work that occurred on barrier islands, and which could be extrapolated to apply to offshore areas is considered. ***Types of Citations:*** technical reports; journal articles; conference papers; theses ***Sources of Studies:*** U.S. Geological Survey, Georgia Geologic Survey, South Carolina Water Resources Commission; Georgia State University Department of Geology; National Ocean Service; U.S. Navy ***Areas of Overlap:*** Some data which concern the offshore aquifers are considered in the Stratigraphy and Shallow Structure category. Model studies of flow regimes in the aquifer are discussed in Section 4.0.
Offshore (6)	Hydrologic data from drill sites for oil-test wells; data re: salinity levels in the offshore aquifer; offshore extension of the aquifer; saltwater-freshwater interface of the offshore Floridian Aquifer	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

<table>
<tr><th>Primary Topic (No. References)</th><th>Content</th><th>Comments</th></tr>
<tr><td colspan="3">GEOLOGIC HAZARDS AND ENVIRONMENTAL STUDIES</td></tr>
<tr><td>Oil Lease Block Surveys (13)</td><td>Geophysical surveys for geologic hazards; in GA and FL; prepared for Exxon, Tenneco, Getty Oil and Transco</td><td rowspan="3">This category considers references to the geological investigations for oil and gas resources in the South Atlantic Bight. The publications are directed more towards identification and description of geologic hazards to proposed work than towards assessment of energy resources. This work provides additional data on the seafloor and subsurface.
Types of Citations: technical reports; geophysical survey reports; conference papers and abstracts; maps
Sources of Studies: U.S. Geological Survey; consulting companies; BLM; MMS
Areas of Overlap: Contents of this section are related closely to citations in Stratigraphy and Shallow Structure and in Bathymetry and Seabed Morphology.</td></tr>
<tr><td>Geologic Hazards (18)</td><td>Geological and environmental papers regarding oil and gas lease sales 43, 56 and 90; maps</td></tr>
<tr><td>Environmental Studies (11)</td><td>Geological research by U.S. Geological Survey in the South Atlantic Bight; fiscal year reports and products; Environmental Impact Statements</td></tr>
<tr><td colspan="3">STRATIGRAPHY AND SHALLOW STRUCTURE</td></tr>
<tr><td>Shallow Seismic Stratigraphy (45)</td><td>Shallow seismic stratigraphy: Neocene structures; Tybee Trough area; Southeast Georgia Embayment; development and structure; vibracores; phosphate deposits</td><td rowspan="5">The references concern Tertiary and Quaternary shallow seismic stratigraphy and associated geological structures in the upper 1-200 m of sub-bottom deposits.
Types of Citations: journal articles; technical reports; conference papers; maps; dissertations; theses
Sources of Studies: U.S. Geological Survey; Georgia Geologic Survey; University of Georgia Marine Geology Program; Louisiana State University; South Carolina Geological Survey
Areas of Overlap: References with data on Stratigraphy and Shallow Structure are considered in Geologic Hazards and Environmental Studies, Bathymetry and Seabed Morphology, and Aquifers.</td></tr>
<tr><td>Navy Towers (TACTS) Area Data (14)</td><td>TACTS Area Data: seismic stratigraphy; phosphates</td></tr>
<tr><td>COST GE-1 Well Site (10)</td><td>Data reports on lithology, stratigraphy, and petrography</td></tr>
<tr><td>Foraminifera (16)</td><td>Stratigraphic distribution; identification; depth occurrences; recurrent groups; biotopes; taphonomy</td></tr>
<tr><td>Miscellaneous Field Studies Maps (5)</td><td>Miscellaneous Field Studies Maps: seismic reflection profiles; isopach and contour maps</td></tr>
</table>

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
WATER COLUMN		
Trace Metals (12)	Geochemical composition; sources, cycles, budgets, concentrations; physical processes causing flux; types of flux; transport and fate in sediment-water, estuary-shelf, plankton uptake; measurements of levels for aluminum, arsenic, copper, iodine, lead, mercury, zinc	References in this category deal with the chemical and physical constituents and dynamics in the water column offshore. Research papers on the sources, concentrations, fluxes, transport and fate of materials are considered within this category. The materials investigated include dissolved and suspended, organic and inorganic materials, such as trace metals, sediment, radioisotopes, and nutrients. ***Types of Citations:*** journal articles; technical reports; progress reports; books; conference papers ***Sources of Studies:*** Skidaway Institute of Oceanography; Old Dominion University Research Foundation; DOE; U.S. Geological Survey; BLM; University of South Carolina; University of South Florida ***Areas of Overlap:*** Some references in this category contain data that are also applicable to Water Masses, Sediment, Geochemistry, Upwelling, and Pollution.
Seston (9)	Components; description; fluxes; pathways; turbidity; interstitial solutions of sediment (sediment-sediment flux)	
Radioisotopes (4)	Concentrations; measurement of; fluxes (estuary-shelf, water-sediment); Ra 224; Ra 228	
Miscellaneous (4)	Alkalinity; sulfides; hydrography; nutrients	
GEOCHEMISTRY		
Trace metals (15)	Natural concentrations of Al, As, Co, Cr, Cu, Cd, Fe, Hg, Pb, Mn, Ni, Zn; distribution; chemistry; cycling, transport and release of arsenic; fluxes; DOE-funded studies; in burrow walls of *Callianassa* sp.	Research that pertains to the chemistry of sediments, as well as to geochemical processes of flux at the sediment-water boundary layer, are considered in this section. The literature survey did not collect papers on marine minerals; however, the references on non-economic aspects of minerals are considered.
Radioisotopes (4)	Presence of barium in sediments; tracers indicative of marine origin of estuarine sediments; Pb-210	***Types of Citations:*** journal articles; technical reports; books; conference papers ***Sources of Studies:*** DOE; Skidaway Institute of Oceanography; U.S. Geological Survey; BLM. *(continued)*

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
Miscellaneous (5)	Sediment-water interactions; pore fluids and formation fluids; hydrocarbons in sediments; chemical analysis of TACTS cores.	*(continued from previous page)* *Areas of Overlap:* Sediments, Water Masses, Water Column, Outwelling, Stratigraphy, and Pollution.
MICROBES		
Metabolic Activities (13)	Recycling of nutrients (mineral); uptake of amino acids; synthesis of proteins; biomass production; rates of growth; productivity; respiration; decomposition of organic materials (detritus, feces)	This category considers references to the microbial inhabitants of the water column and sediments, such as bacteria, protozoa, yeast, and fungi. Papers on phytoplankton and zooplankton are considered elsewhere. *Types of Citations:* journal articles; progress reports; conference papers; books *Sources of Studies:* Sapelo Marine Institute, Institute of Ecology, and Department of Zoology of the University of Georgia; Skidaway Institute of Oceanography; DOE *Areas of Overlap:* Sediments and Sediment Transport; Water Column; Phytoplankton; Zooplankton; Outwelling; Productivity
Trophic Relationships (6)	Heterotrophic-autotrophic interactions; protozoans in food webs; zooplankton consumption of protozoans	
Sediment-Microbial Relationships (4)	Fluxes of materials; production	
Miscellaneous (11)	Distribution and abundance; taxonomy; measurements; biodegradation of pollutants; pathogenic bacteria; shell-boring Protista	
MACROALGAE		
Various (10)	Floristics, characteristics and taxonomy; benthic species; new species; overview of macroalgal flora of Georgia Bight (69 total species as of 1986); reproductive morphology; seasonal variations in flora; profile of communities of nearshore, rock jetties, Grays Reef and deepwater	References to macroscopic marine plants, macroalgae, are considered in this category. *Types of Citations:* journal articles; conference papers *Sources of Studies:* Marine Biology Department of Savannah State College; Department of Botany at Duke University; Harbor Branch Foundation; BLM *Areas of Overlap:* Hard Grounds; Artificial Reefs; Baseline Studies.

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
PHYTOPLANKTON AND ZOOPLANKTON		
Phytoplankton Metabolic Activities (7)	Respiration; measurements; consumption of nutrients (nitrates, phosphorus, organics); nutrient fluxes	These categories consider papers on the biology, ecology, and dynamics of planktonic organisms. The DOE funded much of the work in these areas. ***Types of Citations:*** Phytoplankton - journal articles; progress reports; conference papers; PhD dissertations. Zooplankton - journal articles; progress reports; technical reports ***Sources of Studies:*** Phytoplankton - Skidaway Institute of Oceanography; Institute of Ecology and Department of Zoology at University of Georgia; University of Rhode Island; Old Dominion University; Zooplankton - Skidaway Institute of Oceanography; South Carolina Department of Wildlife and Marine Resources ***Areas of Overlap:*** Water Column; Microbes; Productivity; Outwelling; Baseline Studies.
Phytoplankton Distribution and Abundance (6)	Measurements; general descriptions	
Physical Processes Affecting Phytoplankton (5)	Irradiance flux; eddies; advection; turbidity and seston flux	
Chlorophyll Pigment Concentrations (9)	Controlling processes; ratios of chlorophyll a to chlorophyll b; distributions; variability; CZCS (Coastal Zone Color Scanner) satellite imagery measurements	
Miscellaneous Phytoplankton (7)	Productivity; estuarine influences; progress reports of DOE-funded studies (BIOTRANS, FLEX)	
Zooplankton Trophic Relationships (9)	Food webs; feeding behavior; feeding rates; diets; sources of food; predator-prey interactions	
Zooplankton Populations (4)	Abundance and distribution; structure of; larval	
Miscellaneous Zooplankton (5)	Progress reports on biological processes in water column of the SAB; concentrations; catch levels	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
UPWELLING, PRODUCTIVITY, AND OUTWELLING		
Physical Components (6)	Eddies; shelf and Gulf Stream dynamics; circulation; temperature flux and spatial variations; nutrient transport	Each category refers to the dynamic physical processes and biological processes that effect transport of water masses and nutrients onto the shelf through different input and transformation mechanisms. Upwelling occurs at the shelf break; outwelling originates from the estuary to the inner shelf. The nutrient inputs from each process stimulate rates of productivity. *Types of Citations:* Upwelling - journal; progress reports; books; conference papers; Outwelling - journal articles; conference papers; books; progress reports *Sources of Studies:* Upwelling - Skidaway Institute of Oceanography; Sapelo Marine Institute and Institute of Ecology at University of Georgia; DOE; BLM. Outwelling - Institute of Ecology and Sapelo Marine Institute of the University of Georgia; Skidaway Institute of Oceanography; DOE *Areas of Overlap:* Water Masses; Water Column; Plankton
Biological Components (4)	Food chains; plankton productivity; fish distribution	
Estuarine Export of Organic Material (11)	Salt marshes as sources; transport processes; composition; distribution of organics; concentrations; progress reports for DOE studies (SPREX, FLEX)	
Organic Materials in Shelf Waters (5)	Nitrogen cycling; composition and stability; transport of particles by bubbles	
Miscellaneous (5)	Estuary-shelf interactions; outwelling descriptions	
PELAGIC INVERTEBRATES		
Mollusca (6)	Squid biology; squid distribution; octopus biology and pelagic fishery potential in SC	References to pelagic invertebrates are considered in this category with the exception of those concerning aspects of commercial shellfish and crustacean fisheries. *Types of Citations:* journal articles; books; conference papers; technical reports; PhD dissertations; cruise reports *Sources of Studies:* Institute of Ecology and Marine Institute of the University of Georgia; Skidaway Institute of Oceanography; South Carolina Wildlife and Marine Resources Department; U.S. Fish and Wildlife Service; NMFS; South Carolina Sea Grant Consortium; University of South Carolina; Florida Department of Natural Resources *(continued)*
Cnidaria (6)	Guide to common jellyfishes; taxonomy; life history of *Stomolophus* sp.; *Physalia*	
Crustacea (12)	Parasitic copepods and isopods on other crustaceans; diseases and toxic responses; metabolism; distribution; abundance; taxonomy; guidebooks and keys for identification	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
Chordata-Urochordata (8)	Distribution and abundance of *Thaliacea*; feeding rates and behavior; growth rates for *Dolioletta* and *Thaliacea*; seston production; epizoan communities	*(continued from previous page)* ***Areas of Overlap:*** Commercial Shellfish and Crustacean Fisheries; Baseline Studies.
Miscellaneous (6)	Parasites of dolphin, *Pomocanthus*, squid and fish; descriptions and inventory lists for the phyla Rhyncocoela, Entoprocta, and Ctenophora in SC	
BENTHIC INVERTEBRATES		
Communities (10)	Recruitment and development; seasonal cycles; grazing rates (on bacteria and diatoms); nutrient and oxygen fluxes; inventories and surveys; computer analyses; jetty assemblages	References to marine invertebrates which inhabit bottom environments of the shelf, the benthos, are in this category. ***Types of Citations:*** journal articles; technical reports; conference papers; cruise reports; books; M.S. thesis ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Department; Georgia Department of Natural Resources; University of South Carolina; Marine Institute and Institute of Ecology at the University of Georgia; Skidaway Institute of Oceanography; Savannah State College; NMFS; BLM; Smithsonian Institution ***Areas of Overlap:*** Sediments; Fish; Hard Grounds; Pollution; Baseline Studies.
Cnidaria (5)	*Renilla reniformis*; biochemistry of bioluminescence	
Annelida (7)	Polychaete mats on shelf; polychaete metabolism; taxonomy	
Mollusca (10)	Taxonomy; populations and growth of *Busycon* whelks; range; species profiles	
Crustacea (12)	New species; seasonal populations; population size; inventories and surveys; lobsters - identification, behavior; studies of Marine Areas Management Program (MARMAP) and Southeast Area Marine Assessment Program (SEAMAP)	
Echinodermata (3)	Feeding on microbes; morphology; new species	
Miscellaneous (11)	Taxonomy; biota checklist; densities; effects of nutrient inputs; surf zone fauna; nematodes; bryozoans; pycnogonids	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
FISH		
Populations (34)	Size; distribution and abundance; range and habitat; structure; seasonal variations; fluxes	These references concern the biology and ecology of fish in the Georgia Bight. References to aspects of commercial and recreational fisheries and the associated industries are considered in other categories. Also, references to fish communities of hard grounds and artificial reefs are considered in other categories. Table 3.3 lists fish species and topics of collected citations. ***Types of Citations:*** journal articles; technical reports; conference papers; M.S. theses; data reports; books ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Department; NMFS labs; Georgia Department of Natural Resources; University of Georgia; U.S. Fish and Wildlife Service; U.S. Army Corps of Engineers; College of Charleston; NC Department of Natural Resources; Rutgers University; University of South Florida ***Areas of Overlap:*** Hard Grounds; Artificial Reefs; Commercial Finfish Fisheries; Recreational Fisheries; Baseline Studies.
Life Cycles and Biology (35)	Reproductive biology; mortality; age and growth; food sources; trophic relationships; ecology; cruise reports; surveys and inventories	
Larval and Juvenile Stages (25)	Transport; distribution; abundance; SEAMAP cruise reports; Boothbay ichthyoneuston net test results; age and growth	
Taxonomy and Morphology (14)	Descriptions and records of rare species and of new species; anatomy; length and growth; sex ratios	
Miscellaneous (21)	Synopses of biological data for individual species; bibliographies and literature reviews; species profiles; general overviews; information sources	
BIRDS		
Nearshore Species and Shorebirds (7)	Nesting and colonial birds (terns, gulls, pelicans); distribution and abundance; surveys; feeding behavior; population structure; parasites	This category considers studies of seabirds of offshore areas and references to coastal species common to nearshore areas and ocean beaches. Studies of birds that are primarily estuarine were not collected. ***Types of Citations:*** journal articles; technical reports; books; PhD dissertation ***Sources of Studies:*** Department of Zoology of University of Georgia; U.S. Fish and Wildlife Service; BLM; Skidaway Institute of Oceanography ***Areas of Overlap:*** Water Masses; Baseline Studies.
Marine and Pelagic Seabirds (8)	Regional survey; management and status of populations; interactions with offshore physical processes (upwelling, frontal eddies); distribution and abundance; petrels; shearwaters	

Table 3. **Extent of Data Collected During the Literature Search.** *(continued)*

Primary Topic (No. References)	**Content**	**Comments**
THREATENED/ENDANGERED SPECIES — SEA TURTLES		
Populations (11)	Distribution (leatherback, Kemp's ridley); habitat; genetic variance; population model (loggerheads)	This category considers all references to the species of endangered sea turtles of the GA Bight - Kemp's ridley turtle *(Lepidochelys kempi)*, loggerhead turtle *(Caretta caretta)*, leatherback *(Dermochelys coriacea)*, green turtle *(Chelonia mydas)*. ***Types of Citations:*** conference papers and abstracts; journal articles; technical reports; data reports; M.S theses; books; PhD dissertations ***Sources of Studies:*** Institute of Ecology at University of Georgia; Georgia Department of Natural Resources; South Carolina Marine and Wildlife Resources Department; NMFS; U.S. Army Corps of Engineers; National Park Service; Florida Department of Natural Resources; U.S. Fish and Wildlife Service. ***Unpublished Data:*** Island-based projects; Institute of Ecology, University of Georgia ***Areas of Overlap:*** Shellfish and Crustacean Fisheries citations concerning TEDs
Adult Loggerheads (22)	Status reports; movements; life history; winter surveys; morphology; mortality	
Nesting Loggerheads (48)	Tagging project reports; aerial surveys of nesting activity and nest distribution; overlap in regard to island nesting sites and migration patterns; clutch size; incubation length variations; heavy metals in eggs; role of temperature in nest in affecting sex and site; mortality from predation and rain; genetic variability; hatchlings - movement in response to lights; offshore migration; success rates	
Adult Mortality (31)	(1) incidental catch by shrimp trawlers - annual reports; mortality data; development of Turtle Excluder Devices (TEDs); federal regulations on use of TEDs by shrimpers; (2) strandings - state and national reports of sea turtle stranding network on numbers of dead sea turtles found washed ashore beaches; (3) entrainment - intake of turtles by dredges in Kings Bay navigation channel; (4) sea turtles and oil	
Miscellaneous (8)	Status reports on the conservation and management of sea turtles (leatherback, Kemp's ridley, green and loggerhead); sea turtle conservation workshop proceedings	

Table 3. **Extent of Data Collected During the Literature Search.** *(continued)*

Primary Topic (No. References)	Content	Comments
THREATENED/ENDANGERED SPECIES — WHALES AND OTHER MARINE MAMMALS		
Right Whale Populations (16)	Population biology; calving; migration; distribution; identification of individuals; monitoring efforts; species recovery plan	References to the right whale *(Eubalaena glacialis)* are considered in this category. A few papers concern other marine mammals that occur in the area. ***Types of Citations:*** journal articles; conference papers ***Sources of Studies:*** New England Aquarium; NMFS; International Whaling Commission; MMS; U.S. Fish and Wildlife Service; Georgia Department of Natural Resources; University of Rhode Island; Institute of Ecology at University of Georgia. ***Unpublished Data:*** Cumberland Island National Seashore; Institute of Ecology at University of Georgia; monitoring reports by dredging companies to the NMFS
General Right Whale (9)	Speciation; heavy metal concentrations; mortality; status reports and overviews	
Miscellaneous (8)	Overviews of marine mammals and endangered species; pilot whales - heavy metal concentrations, strandings; humpback whales - species recovery plan; ecology of dolphins	
HARD GROUNDS		
Surveys (15)	Mapping methods and maps; morphologic and bathymetric features; abundance/extent; distribution; identification and measurements of sites; descriptions of biota; geophysical surveys	References to physical and biotic components of hard ground environments are considered in this category. These areas are also referred to as hard bottoms and live bottoms, but hard ground regions may be planar with little topographic relief whereas live bottom areas may be characterized as reef-like. ***Types of Citations:*** journal articles; technical reports; conference papers; PhD dissertation; books. ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Dept.; NMFS; Georgia Department of Natural Resources; Marine Geology Program at University of Georgia; Continental Shelf Associates, Inc.; University of South Carolina; U.S. Geological Survey; BLM; MMS; Savannah State College Marine Biology Program; SEAMAP.
Reef Fish (22)	Population inventories and stock assessments; habitat; population structure; communities; species associations; range in regard to physical conditions; distribution; food; feeding habits; trophic relationships	

(continued)

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
Reef Invertebrates (7)	Community descriptions and development; surveys and inventories; community metabolism; nutrient cycling; community size, extent and distribution; sponge-coral habitat	*(continued from previous page)* ***Unpublished Data:*** Jacksonville University (data for offshore northeast Florida gathered by Reef Research Team); Florida Institute of Technology (invertebrates collected by SEAMAP survey offshore northeast Florida); Natural History Museum, University of Georgia (invertebrate collection of Milton Gray from Grays Reef); Coastal Resources Division of Georgia Department of Natural Resources (data gathered offshore Georgia); Marine Resources Research Institute of South Carolina Wildlife and Marine Resources Department ***Areas of Overlap:*** Currents; Bathymetry and Seabed Morphology; Stratigraphy and Shallow Structure; Microbes; Macroalgae; Benthic Invertebrates; Fish; Fishery categories; Artificial Reefs; Resource Management and Use; Baseline Studies.
ARTIFICIAL REEFS		
Biota (7)	Fish - population sizes, community structure, food and feeding behavior, effects of Fish Aggregation Devices (FAD). Invertebrates - communities, site colonization, abiotic factors	All references to artificial reefs are in this category, however, overlapping references are considered in the related categories noted below. ***Types of Citations:*** technical reports; journal articles; conference papers; books; maps; brochures ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Department; University of Florida Sea Grant Program; South Carolina Sea Grant Consortium; Georgia Department of Natural Resources; NMFS; Rutgers University; Savannah State College Marine Biology Program; Florida Department of Natural Resources; University of Georgia Sea Grant Program. ***Unpublished Data:*** NMFS regional office (annual reports of managers of each state program); State natural resource agency management programs (data reports) ***Areas of Overlap:*** Benthic Invertebrates; Fish; Fishery categories; Hard Grounds; Resource Management and Use
Management (15)	Maps and lists of sites in Florida, Georgia, and South Carolina; construction - materials, procedures, permits, plans; economic benefits and effects; management considerations	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
COMMERCIAL SHELLFISH AND CRUSTACEAN FISHERIES		
Crustacean Fishery-Management (22)	Industry profiles; economic analyses; Fisheries value of landings; incidental catch; efficiency of trawl nets; effects of Turtle Excluder Devices on catch; management plans	References in this category pertain to the commercial fisheries for shellfish and crustaceans in offshore waters with an emphasis on the monitoring, management and economic aspects of industries. Papers on the biology and ecology of the organisms in these fisheries are considered in separate categories. ***Types of Citations:*** technical reports; journal articles; conference papers; management plans ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Department; Georgia Department of Natural Resources; NMFS; South Atlantic Fisheries Management Council; University of South Carolina; Marine Extension Service of University of Georgia; University of Florida Sea Grant Program; North Carolina Sea Grant Program; Georgia Coastal Area Planning and Development Commission ***Unpublished Data:*** Annual statistics on landings of the shellfish and crustacean fisheries are maintained in databases at the natural resource management agencies for each state. ***Areas of Overlap:*** Benthic Invertebrates; Pelagic Invertebrates; Models
Crustacean Fishery-Landings (15)	Annual data reports; statistics; stock assessments; distribution; surveys; populations	
Shellfish Industries (16)	Potential for octopus (*Octopus vulgaris*) fishery; profile and history of whelk (*Busycon* sp.) fishery; squid (*Loligo* sp.) fishery; scallops; pollutant concentrations; diseases and parasites; publications list; shrimp baiting fishery	
COMMERCIAL FINFISH FISHERIES		
Cruise Reports (78)	MARMAP trawls; SEAMAP trawls; cruise reports of R/V *J.W. Fanning* and R/V *GA Bulldog* on finfish projects; survey results; data reports; landings data on size, composition	References in this category pertain to the commercial fisheries for finfish in offshore waters of the study area with an emphasis upon the monitoring, management and economic aspects of the industries. Papers on fish biology and the recreational fishery are considered in separate categories. All citations on fish and fisheries are shown by species in Table 3.3. ***Types of Citations:*** journal articles; technical reports; management plans; conference papers; cruise reports; books; annual reports; maps; brochures. *(continued)*

Table 3. **Extent of Data Collected During the Literature Search.** *(continued)*

Primary Topic (No. References)	**Content**	**Comments**
Fisheries Management and Gear (16)	Management - Federal and State regulations, management plans, economic analyses; fishing gear - tests of efficiency, nets, gill nets, finfishing with shrimp boats, bottom longlining	*(continued from previous page)* ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Department; NMFS; South Atlantic Fisheries Management Council; Atlantic States Marine Fisheries Commission; Georgia Department of Natural Resources; University of Georgia Marine Extension Service/Sea Grant Program; National Coalition for Marine Conservation; Florida Department of Natural Resources; University of Florida Sea Grant Program; Marine Areas Management Program (MARMAP); Southeast Area Marine Assessment Program (SEAMAP). ***Unpublished Data:*** Statistics on annual landings, stock assessments and other data are maintained by the natural resource management agencies for each state. ***Areas of Overlap:*** Fish; Hard Grounds; Artificial Reefs; Recreational Fisheries
Fish Biology (9)	Recruitment; mortality; guide to fishes; by-catch; feeding behavior; stock assessments; distribution	
RECREATIONAL FISHERIES		
Fishery Industries (12)	Charterboats and headboats, economic analyses, landings; sports fishing tournaments; marine bait industry; pier fishing industry	This category contains references that pertain to the recreational, or sports, fisheries with emphasis upon economic, management and educational materials. Commercial fisheries and fish biology are considered in separate categories. ***Types of Citations:*** technical reports; education reports; data reports; journal articles; conference papers ***Sources of Studies:*** South Carolina Wildlife and Marine Resources Department; South Carolina Sea Grant Consortium; Georgia Department of Natural Resources; NMFS; South Atlantic Fishery Management Council; Atlantic States Marine Fisheries Commission; National Coalition for Marine Conservation; University of Florida Sea Grant Program; University of Georgia Marine Extension Service ***Areas of Overlap:*** Fish; Commercial Finfish Fisheries; Hard Grounds; Artificial Reefs
Populations (13)	Populations: fishery surveys of landings; dynamics; models	
Fishery Management (39)	Management plans and amendments; impact statements (regulatory) and assessments (environmental); laws and regulations; proceedings; use conflicts	
Miscellaneous (8)	Maps and guides to fishing; flounder; sea trout	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	Content	Comments
GENERAL COASTAL MANAGEMENT		
Coastal Zone Management (17)	Program plans; regulations; legislation; environmental impact statements; ocean and coastal law and policy; beach recreation	References in this category pertain to natural resource management policies and practices in coastal and offshore areas, Some estuarine and terrestrial data are included, however, due to the general scope of coastal zone management references. *Types of Citations:* management plans; environmental impact statements; technical reports; annual reports; conference papers; journal articles *Sources of Studies:* NOAA Office of Coastal Zone Management; National Academy of Science; Savannah State College Marine Biology Program; University of Florida Sea Grant Program; Atlantic States Marine Fisheries Commission; Georgia Geologic Survey; South Carolina Sea Grant Program; Georgia Coastal Regional Development Commission; Florida Department of Environmental Regulation; South Carolina Coastal Council *Areas of Overlap:* Commercial Finfish Fishery; Recreational Fishery; Beaches; Hard Grounds; Pollution
Miscellaneous (16)	Marine resource use and conflicts; marine economics; SEAMAP annual reports and master plans; Grays Reef National Marine Sanctuary management plans; Geographic Information System (GIS); Exclusive Economic Zone (EEZ) use; marine fishery reserves	
BEACHES		
Shoreline Changes (24)	Historical reviews; data records; transport of sediment; Hugo-induced; effects of sea level rise; surveys of statewide (GA, SC) and island-specific (Seabrook, Kiawah, Hilton Head, Tybee, etc.) shoreline changes	These references include data specific to the measurement and the monitoring of rates of change, to coastal engineering methods of beach erosion control, and to the processes of shoreline change. *Types of Citations:* technical reports; journal articles; conference papers; PhD dissertation; M.S. theses; environmental impact statements; books *(continued)*
Inlets (21)	Ebb-tidal deltas; sediment transport; shoreline changes; variability and cycles; morphology; processes; stabilization	

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	**Content**	**Comments**
Erosion Control and Coastal Engineering (21)	Historical reviews; feasibility studies; environmental impact studies; beach nourishment projects; management options; hurricane protection studies; Sites - Nassau County and Duval County (FL); Glynn County, Wassaw Island, Tybee Island (GA); Hilton Head, Seabrook Island, Folly Island (SC)	*(continued from previous page)* ***Sources of Studies:*** University of South Carolina; U.S. Army Corps of Engineers; University of Georgia; Skidaway Institute of Oceanography; University of Florida; Duke University; consulting firms; Georgia State University; South Carolina Sea Grant Program; South Carolina Geological Society ***Areas of Overlap:*** Sediments and Sediment Transport; Bathymetry; Waves, Tides, and Currents
PORTS AND NAVIGATION		
Kings Bay Reports (17)	Monitoring studies of dredging; environmental impact statements; biological and physical effects of dredging	This category considers references to ports, navigation, and shipping activities in the study area. The major ports are Charleston, Savannah, Brunswick, and Jacksonville; however, most references specific to these sites were not collected due to the location of the ports outside of the study area boundary. Most uncollected information about ports refers to the tonnage and economics of the shipping industries at the port site. The inshore references to navigation likewise were often inapplicable. ***Types of Citations:*** environmental impact statements; technical reports; conference papers ***Sources of Studies:*** U.S. Navy; National Ocean Service; Institute of Ecology of the University of Georgia; National Park Service ***Unpublished Data:*** Kings Bay Naval Base; Institute of Ecology of the University of Georgia; District offices of U.S. Army Corps of Engineers (Jacksonville, Savannah, Brunswick) ***Areas of Overlap:*** Sediment and Sediment Transport; Bathymetry; Beaches; General Coastal Management; Pollution
Navigation (7)	Channel dredging; project reports (Charleston Harbor, Wando River, Folly River, Savannah River, Brunswick Harbor); Jacksonville port report; Coast Pilot - sea conditions, marine regulations for navigation and legislation on pollution	

Table 3. **Extent of Data Collected During the Literature Search.** *(continued)*

Primary Topic (No. References)	Content	Comments
POLLUTION		
Atmospheric (4)	Regional ozone and haze distributions; transport of pollutants by rainfall over northeast Florida; regulations	This topic includes the sources, transport, distributions, and concentrations of atmospheric and water-borne pollutants in the study area. Regulation and monitoring efforts associated with pollution control are also considered. *Types of Citations:* technical reports; journal articles; conference papers; books *Sources of Studies:* NOAA National Marine Pollution Program; U.S. Army Corps of Engineers; Environmental Protection Agency; South Carolina Wildlife and Marine Resources Department; Savannah State College Marine Biology Program; Skidaway Institute of Oceanography; U.S. Geological Survey; U.S. Fish and Wildlife Service; Sapelo Marine Institute of the University of Georgia; NMFS *Areas of Overlap:* Meteorology; Water Column; Sediments and Sediment Transport; Commercial Finfish Fishery; Commercial Shellfish and Crustacean Fisheries; Birds; Whales; General Coastal Management
Hydrocarbons (9)	Baseline data re: concentrations in shelf waters; transport in oil spills; effects on oil-sensitive marine wildlife; pelagic tar in offshore waters - transport, distribution, effects on environment	
Bioaccumulation (13)	Trace metal concentrations of cadmium, magnesium, selenium, organochlorides, brominated compounds; biological monitoring; in fish, invertebrates, birds	
Ocean Disposal of Dredged Material (12)	Sediment - chemistry, mapping; disposal sites - surveys, designations; regulations; characterization of benthic macrofauna	
Miscellaneous (5)	MARPOL international regulations; federal research; pollution monitoring; marine debris along shoreline	
CULTURAL RESOURCES		
Archeological Surveys (10)	Lease block site surveys; regional study for BLM (1981) re: cultural resources; Folly River - Stono Inlet area survey; National Wildlife Refuge resources in region	Cultural resources in the study area are constituted by archeological artifacts and shipwrecks on the shelf. Historical publications on general maritime history were not collected. The few citations within this category reflect the scant attention given to these topics. *(continued)*

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

Primary Topic (No. References)	**Content**	**Comments**
Shipwrecks (2)	Historical review of wrecks in waters offshore South Carolina and Georgia; hangs and obstructions to trawling offshore Georgia and South Carolina	*(continued from previous page)* ***Types of Citations:*** technical reports; surveys; books ***Sources of Studies:*** U.S. Army Corps of Engineers; BLM; University of North Carolina Sea Grant Program; consulting firms; National Park Service; Sea Research Society ***Unpublished Data:*** *Chatham County, GA, Shipwrecks Survey* in office of State Preservationist, Georgia Department of Natural Resources; database of information compiled by Judy Woods, Savannah District of U.S. Army Corps of Engineers; National Ocean Service Automated Wreck and Obstruction Information System's database of wrecks and obstructions in coastal U.S.; reports of the South Carolina Institute of Archeology and Anthropology on specific offshore wrecks; and, LORAN records of shrimp and fish boats regarding uncharted snags and hangs. ***Areas of Overlap***: Baseline Studies

Table 3. Extent of Data Collected During the Literature Search. *(continued)*

3.0 ANALYSIS OF THE EXTENT OF ENVIRONMENTAL INFORMATION

A literature review revealed the nature and scope of information pertaining to the study area. A rigorous and structured analysis was then conducted to assess the current state of environmental research on the non-mineral resources on the Georgia Shelf. This assessment provides the basis for identifying data gaps and research priorities. In addition, defining the current knowledge and research allows for comparisons with similar historical evaluations.

The data was collected and analyzed by using a three-step process: (1) organizing individual references into resource topic categories; (2) reviewing and analyzing the type, nature, and relevance of citations in each category and the extent and scope of work in each category; and (3) summarizing the analysis of environmental information.

3.1 Data Analysis Process

3.1.1 Guidelines

A structural framework that organized the data according to the types of resources guided both the review and analysis process and the subsequent summary. The topic areas presented in Tables 1 and 3 are the non-mineral resources topics into which collected data were grouped for this analysis. Four major environment groups were used for identifying data gaps as described in Section 5.0.

Many citations included a wide range of topics and research fields and could not be placed in a single category. Examples include citations for interdisciplinary studies combining facets of physical, geological, biological and chemical oceanography. Whereas these papers address several topics, they are enumerated in only one category — typically, in the primary area of focus. During the analysis of the extent of information, however, the evaluations of such papers are applied to all appropriate categories. Within the electronic database, these citations may be easily located using key words (Appendix A, Table A-3).

3.1.2 Analytical methods

The references were assessed to determine the extent of available information in specific categories. For each category, the parameters evaluated for each reference included

- Major topics of study,

- Fields of research involved in each study,
- Research methods (i.e., laboratory, field, modeling),
- Scope of the research,
- Geographical location(s) of research work,
- Type of publication (e.g., journal paper, technical report), and
- Relevance of the work to the study.

The subjective nature of the analysis, however, could not be completely avoided or eliminated. To reduce bias, the work of each author was reviewed by the other authors. Discussions regarding points of contention also served to shape consensus on the extent of knowledge.

3.1.3 Structure of the discussion

The following summaries of the extent of information are presented within the same framework in which the references were initially grouped for analysis (Table 1). Major interdisciplinary research efforts, baseline studies, and environmental inventories for the region are discussed in Section 3.2. An overview of the extent of information according to environment - physical, chemical, biological, and socioeconomic - is presented in Section 3.3. The extent of knowledge in each resource topic is discussed in Section 3.4.

3.2 Regional and Baseline Studies

3.2.1 Environmental studies program

The U.S. Department of Interior's Bureau of Land Management (BLM), the Outer Continental Shelf (OCS) Environmental Studies Program in 1973 began to conduct studies to predict, assess, and manage impacts on the human, marine and coastal environments, and nearshore areas that may be affected by activities associated with oil and gas production (Wilson 1993). In May 1982, the newly-created Minerals Management Service (MMS) assumed responsibility for the OCS program. Most of the regional, long-term, comprehensive, and topical studies that are pertinent to this report were conducted in either of two formats: baseline studies or environmental inventories. BLM defined baseline studies as "multidisciplinary field studies designed to produce a statistically valid benchmark against which the impacts of the Outer Continental Shelf (OCS) activities could be measured" (Wilson 1993). Conversely, it defined environmental inventories as "a compilation of existing information into an original concise format, that contain an identification of data gaps in the published and unpublished literature, and make recommendations for studies designed to fill identified data gaps" (Wilson 1993).

3.2.2 Major baseline studies

Table 4 lists, in chronological order, the title and objectives of the most pertinent baseline studies and environmental inventories conducted in the study area. BLM and, later, MMS sponsored all but two of these studies. The two exceptions are (1) a study of the ecology of the South Carolina and Georgia coastal regions, which was sponsored by the U.S. Fish and Wildlife Service (McKenzie and Barclay 1980), and (2) a multidisciplinary program concerning Southeast United States continental shelf, which was sponsored by the U.S. Department of Energy (DOE) (Menzel 1993). The latter program produced more than 220 journal articles and 100 technical and miscellaneous reports that were synthesized into a single, multi-author volume. This publication provides the most comprehensive and pertinent discussion of the physical, chemical, and biological processes and interactions in the South Atlantic Bight to date. The major experiments conducted during these DOE studies are listed in Table 5. Citations of all relevant journal publications and reports resulting from each of the above studies are included in the electronic database and are considered in the analysis in Section 3.4. Descriptions of the BLM/MMS studies are detailed by Fritz (1986), Continental Shelf Associates, Inc. (1990), and Wilson (1993).

3.2.3 Extent of the baseline studies

The bulk of the references in the study database have a relatively narrow focus regarding study topic, scientific field, type of research, and geographical location. Conversely, most of the baseline studies, such as the South Atlantic OCS Benchmark Program of 1977 (Texas Instruments, Inc. 1979a,b), create broad-based descriptions of many resources in the study area. Some studies were literature surveys that characterized resources and research, as in *A Summary and Analysis of Environmental Information on the Continental Shelf and Blake Plateau from Cape Hatteras to Cape Canaveral* (Center for Natural Areas 1979a,d). Other studies focused on a specific field of research for the entire region, as in the South Atlantic OCS Physical Oceanography Study (Science Applications, Inc. 1980a-c, 1981a-g, 1982a-d, 1983a-c, 1984a,b).

Although some studies provide regional baseline data for many fields, others synthesize earlier research to develop their conclusions. These studies are considered in Sections 3.3.1 and 3.4.

Table 4. Baseline Studies and Environmental Inventories Conducted in the Georgia Bight Study Area.

Title and Products	Objectives
South Atlantic Benchmark Program, Fiscal Year 1977 Study (Texas Instruments, Inc. 1979a-e)	
Vol. 1: Executive Summary Vol. 2: Technical Program and Management Vol. 3: Results of Studies of Georgia Bight of North Atlantic Ocean Vol. 4: An Atlas of Normal Histology and Histopathology of Benthic Invertebrates and Demersal fish Vol. 5: South Atlantic OCS Geological Studies Vol. 6: Appendices	• To determine concentration of high molecular weight hydrocarbons and selected trace metals in water, sediment, zooplankton, and selected macroepifauna; • To evaluate natural variation in benthic and zooplankton communities; • To enumerate heterotrophic microorganisms of surface film, near surface, and sediments and examine the relationship to hydrocarbon presence; and, • To measure and describe water chemistry.
South Atlantic Hard Bottom Study (Continental Shelf Associates Inc. 1979)	
Final Report	• To determine whether geologic hazards survey records would be adequate for delineating hard-bottom areas in the Georgia Bight; • To characterize substrates comprising hard bottom through petrographic analyses; and, • To identify epibiota and demersal fishes associated with hard-bottom areas.
Summary and Analysis of Physical and Meteorological Information on the Continental Shelf and Blake Plateau from Cape Hatteras to Cape Canaveral (Environmental Research and Technology 1979)	
Vol. 1: Executive Summary Vol. 2: Final Report	• To identify and assemble recent oceanographic and meteorologic data not available from the National Oceanographic Data Center (NODC) or National Climatic Center (NCC) for the South Atlantic (OCS) region; • To organize the data on tapes in formats that are compatible with NODC/NCC and transmit them to NODC/NCC; • To update a previously prepared National Science Foundation bibliography for the region; • To use recent and previously catalogued data to display, describe, analyze, and interpret oceanographic and meteorological phenomena in the region; and, • To make recommendations for future sampling and buoy sites and programs based on the preceding analyses and review of raw data and unworked samples.

Table 4. Baseline Studies and Environmental Inventories Conducted in the Georgia Bight. *(continued)*

Title and Products	Objectives
Summary and Analysis of Environmental Information on the Continental Shelf and Blake Plateau from Cape Hatteras to Cape Canaveral (Center for Natural Areas 1979a-f)	
Vol. 1, books 1 through 4: Summaries of data on environmental resources of region Vol. 2: Master Bibliography and Index Vol. 3: Appendices A, B, and C	• To update the environmental survey by the Virginia Institute of Marine Science (1974) and provide analysis of all existing biological, chemical, and geological data; • To identify and summarize biological, chemical, and environmental resources of region geological programs in the South Atlantic OCS region; • To identify sources of raw data and unworked samples, and evaluate the role of this material in relation to the total existing data base; and • To identify gaps in the biological, chemical, and geological database and evaluate the extent of gaps.
South Atlantic OCS Geological Studies, Fiscal Year 1976 (Popenoe 1979b,c)	
Executive Summary Report Geology Final Report	• To measure the rate, direction, and forcing mechanisms sediment mobility over the seabed, and monitor resultant changes in bottom morphology or texture; • To determine concentration, distribution, and flux of suspended particulate matter in the water column; • To determine the vertical distribution of trace metals in the near-surface sediment at selected locations; • To evaluate potential geological hazards to oil and gas development due to surficial and intermediate depth structure and mass transport events; and, • To identify and evaluate the distribution and significance of outcrop and reef structures. **Note:** The Final Report is also included in *South Atlantic Benchmark Program Study* as Volume 5.

Table 4. Baseline Studies and Environmental Inventories Conducted in the Georgia Bight. *(continued)*

Title and Products	Objectives
Environmental Geologic Studies on the Southeastern Atlantic Outer Continental Shelf, 1977-1978 (Popenoe 1981a,b)	
Summary Report Final Report	• To determine the sedimentation rates and processes on upper slope and inner Blake Plateau; • To determine the distribution, areal extent, and vertical characteristics of geological features supportive of biological communities; • To monitor transport of bottom sediment across the OCS, to evaluate its possible effect on pollutant transfer along the seabed and the potential of sediment as a pollutant sink, to determine implications of erosion/deposition on pipeline placement, and to aid in the interpretation of chemical, biological & physical data; • To determine the concentration levels of chosen trace metals and silica in three chemically-defined fractions of suspended particulate matter (seston); • To study the shelf edge and slope near areas of oil and gas interest, and northern portion of the Blake Plateau for evidence of slope instability and geologic hazards; • To determine the depth and rate of sediment mixing caused by large storms and/or benthic organisms and to estimate rates of sediment accumulation where possible.
Ecological Characterization of the Sea Island Coastal Region of South Carolina and Georgia (Mathews *et al.* 1980; McKenzie *et al.* 1980; Sandifer *et al.* 1980; Davis *et al.* 1980; McKenzie and Barclay 1980)	
Vol. 1: Physical Features Vol. 2: Biological Features Vol. 3: Socioeconomic Features Characterization Atlas Executive Summary	• To assemble, review and synthesize existing biological, physical and socioeconomic information and establish a sound information base for decision-making; • To identify and describe various components (habitats, subsystems, communities, key species) in the ecosystem; • To describe major physical, biological, and socioeconomic components and interactions; • To describe known and potential ecosystem responses to man-induced changes; and, • To identify major information deficiencies for further study and decision-making needs.

Table 4. Baseline Studies and Environmental Inventories Conducted in the Georgia Bight. ***(continued)***

Title and Products	Objectives
South Atlantic OCS Physical Oceanography Final Progress Report, Year 1 (Science Applications, Inc. 1980a-c)	
Vol. 1: Executive Summary Vol. 2: Technical Report Vol. 3: Data Products Vol. 4: Books 1 and 2 (Appendices)	• To describe water circulation and mixing processes in Georgia Embayment OCS and upper slope region **Note:** A review of the existing literature pertaining to OCS physical oceanography is included in this report.
South Atlantic OCS Physical Oceanography Final Progress Report, Year 2 (Science Applications, Inc. 1981a-c)	
Vol. 1: Executive Summary Vol. 2: Technical Report Vol. 3: Data Products (Parts 1 and 2)	•To understand and document South Atlantic Bight OCS physical oceanography so the various processes can be parameterized and modeled.
A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West (Science Applications, Inc. 1981d-g)	
Vol. 1: Physical Environment Vol. 2: Prehistoric Archaeology Vol. 3: Appendices Vol. 4: Conclusions and Recommendations	• To combine physical environmental and archaeological information to predict distribution, location and concentration of archaeological sites and shipwrecks; • To use the above information in developing workable management schemes.
South Atlantic OCS Living Marine Resources Study, Year 1 (Burrell *et al.* 1981; Van Dolah *et al.* 1981a,b)	
Vol. 1: Investigation of Live Bottom Habitats South of Cape Fear, NC Vol. 2: Investigation of Live Bottom Habitats North of Cape Fear, NC Vol. 3: Appendices	• To characterize invertebrate and fish communities associated with representative live-bottom habitats on the continental shelf offshore the southeastern U.S.; • To characterize food habits of selected fish species of commercial or recreational importance; • To conduct a limited assessment of bottom topography substrate type; and, • To evaluate potential impacts of oil- and gas-related activities on live-bottom organisms.

Table 4. Baseline Studies and Environmental Inventories Conducted in the Georgia Bight. ***(continued)***

Title and Products	Objectives
South Atlantic OCS Physical Oceanography Final Progress Report, Year 3 (Science Applications, Inc. 1982a-d)	
Vol. 1: Executive Summary Vol. 2: Technical Report Vol. 3: Data Products (Part 1 of 2) Vol. 4: Data Products (Part 2 of 2)	• To examine and document high and low frequency lateral oscillations of the Gulf Stream western and eastern boundaries; • To continue study of the characteristics and joint response of wind and water level in the South Atlantic Bight; • To collect detailed hydrographic measurements on the North Carolina shelf, with several transects extending well seaward of the shelf break; • To measure subsurface currents; • To determine hydrographic conditions on Blake Plateau; • To predict shelf winds, as part of the study of shelf forcing mechanism; • To develop physically-based mathematical descriptions of important regional circulation patterns; and, • To provide resolution of the multivariable response of the South Atlantic Bight shelf to key forcing mechanisms.
South Atlantic OCS Living Marine Resources Study, Year 2 (Van Dolah *et al.* 1982; Van Dolah and Kirby-Smith 1982; Van Dolah 1982)	
Vol. 1: Investigation of Live-Bottom Habitat Off South Carolina and Georgia Vol. 2: Investigation of Live-Bottom Habitat Off North Carolina Vol. 3: Appendices	• To characterize invertebrate and fish communities associated with representative live-bottom habitats on the continental shelf offshore the southeastern U.S.; • To characterize food habits of selected fish species of commercial or recreational importance; • To conduct a limited assessment of bottom topography substrate type; and, • To evaluate potential impacts of oil- and gas-related activities on live-bottom organisms.
South Atlantic OCS Physical Oceanography Final Progress Report, Year 4 (Science Applications, Inc. 1983a-c)	
Vol. 1: Executive Summary Vol. 2: Technical Report Vol. 3: Data Products	• To document and explain site-specific and regional circulation occurring over a range of temporal and spatial scales; and, • To describe mechanisms producing these circulation patterns.

Table 4. Baseline Studies and Environmental Inventories Conducted in the Georgia Bight. ***(continued)***

Title and Products	Objectives
South Atlantic OCS Physical Oceanography Final Progress Report, Year 5 (Science Applications, Inc. 1984a,b)	
Vol. 1: Executive Summary Vol. 2: Technical Report	• To examine and understand the effects of tides, winds, water mass density and Gulf Stream on the South Atlantic Bight circulation patterns; and, • To document and explain the spatial and temporal variability of hydrographic conditions such as temperature, salinity, density, dissolved oxygen, and selected nutrients.
South Atlantic OCS Living Marine Resources Study, Phase 3 (Van Dolah 1984a-c)	
Executive Summary Vol. 1: Technical Report Vol. 2: Appendices	• To determine short-term and long-term colonization patterns by invertebrates and fishes on artificial hard substrata; • To determine how changes in sediment depth over hard substratum influence the distribution and abundance of large sponges and corals; and, • To describe the food habits of several fishes typically found in hard-bottom areas of the South Atlantic Bight.
Special Literature Analysis Study: Final Report on Benthic Communities in Certain Slope Areas of the South Atlantic Bight (Knot and Wendt 1985)	
	To provide an analysis of information on benthic invertebrate communities of the continental slope in the South Atlantic Bight in water depths ranging from 80-200 m off north Florida to 200-2000 m between Brunswick, GA and Cape Fear, NC.
Ocean Processes: U.S. Southeast Continental Shelf (Menzel 1993)	
	To synthesize results of research conducted from 1977 to 1991, the purpose of which was to describe and to quantify processes controlling inputs, distribution, cycling and fate of materials produced in and entering the South Atlantic Bight.

Table 5. Experiments Conducted in the South Atlantic Bight for DOE Studies [Adapted from Menzel (1993)].

Title of Experiment	Overview	Dates
Preliminary studies of intrusion processes on the Georgia Shelf	Identification of physical processes that control interactions of waters of shelf with water offshore	4/77-4/79
Front FLUX I and II	Investigate exchanges of heat and salt across nearshore frontal zone during tidal cycles	FLUX I, 11/79 FLUX II, 4/81
GABEX (Georgia Bight Experiment) I and GABEX II	Investigate interactions of waters of shelf and Gulf Stream in seasons when well-mixed vertically (GABEX I) and when stratified (GABEX II)	GABEX I, 2/80-6/80 GABEX II, 5/81-10/81
SPREX (Spring Removal Experiment) I and SPREX II	Determines effects of cross-shelf exchange on biological and chemical processes during springtime meteorological conditions	SPREX I, 3/84-6/84 SPREX II, 2/85-6/85
BIOTRANS (Biological Transformations)	Study on inner- and middle-shelf areas of biological transformations of materials and energy	8/85-1/88
PreFLEX and FLEX I (Fall Removal Experiments)	Study processes of alongshore and cross-shelf exchange on chemical and biological processes and distribution of materials during autumn with prevailing winds from the north	PreFLEX, 9/86-11/86 FLEX I, 8/87-11/87
Bottom Boundary Layer Experiment	Define vertical structure of horizontal currents in a nearshore front	9/89-10/89
Winter 1990	Study effects on rate processes and material distribution offshore Charleston, SC in winter by cross-shelf exchange processes on outer shelf	12/89-3/90

3.2.4 Relevance of baseline studies to environmental assessment

Baseline studies were de-emphasized following a recent National Research Council (NRC) (1992) review of the Environmental Studies Program. The NRC concluded that such studies "were not providing timely and appropriate information for leasing decisions." In addition, the scientific community advised MMS that "natural variability in the marine environment was too great to establish a statistically valid baseline within a reasonable length of time" (Wilson 1993). However, the baseline studies provide valuable information on the physical processes, systematics and ecology, and environmental conditions of the OCS that directly relate to impacts by all anthropogenic activities, including mining, commercial fishing, and point- and nonpoint-source pollution. In general, the regional studies provide a foundation for other research in the study area. The relative importance of such regional efforts, however, cannot supplant the contributions of the large number of other references within the database.

3.3 Extent of Environmental Information

Resource categories are organized into four environmental groups - physical, chemical, biological, and socioeconomic. A brief summary of information available for each environmental group is presented below, and detailed summaries are presented in Section 3.4.

The literature overview followed two approaches. The first approach considered the number of citations for each resource group (Table 1); 29% of the citations described the physical and chemical environments, 40% the biological environment, and 31% the socioeconomic environment. Many citations are for interdisciplinary studies and the percentages are not necessarily accurate.

The second approach provided a more effective means to assess the extent of environmental information. In this case, each reference is reviewed and analyzed for content, scope, and significance. These analyses were combined and synthesized to qualitatively assess the extent of information for each of the four environments. These summaries are presented below.

The scales at which such analyses are conducted determined the apparent extent of knowledge for each area. Although extensive information is available for a specific topic category, the need for additional information will always exist. In general, some physical and chemical processes and the biological systems of shelf environments appear to be widely studied in regard to character, structure, and function. However, additional investigations are needed to fill data gaps before the potential effects of marine mining can be evaluated and an acceptable site selected.

3.3.1 Physical environment

The dynamic processes that affect the physical environment, from the seafloor through the water column to the sea surface, are subjects of considerable study through research sponsored by the BLM/MMS and by the DOE. In particular, general circulation patterns, Gulf Stream intrusions, upwelling, and outwelling are subjects of considerable study. The coupling of atmospheric activity and meteorological events with water-mass motions is one area of study that contributes to the understanding of forcing mechanisms, transport processes, and general circulation patterns. This research originates from concerns over the potential consequences of contamination by oil spills or radioactive contaminants. Geophysical surveys of the seafloor associated with offshore oil and gas exploration established a broad baseline on the stratigraphy, bathymetry, and seabed morphology of the shelf. The direct application of this research is often limited by temporal (seasonal) and/or spatial (site-specific) factors. The physical aspects of shelf environments needing further study include the Floridan aquifer, bottom currents and sediment transport, boundary layer dynamics, and detailed bathymetry and imagery.

3.3.2 Chemical environment

Considerable information was found that describes the processes of transport, exchange, and flux of dissolved and particulate chemical constituents in the water column. The associated data establish broad baselines for determining the concentrations of various trace elements in shelf waters and seafloor sediments. The general nature of the chemical environments of the water column and of the seafloor sediment are better understood than fluxes at the air-sea boundary layer and at the sediment-water interface.

3.3.3 Biological environment

Biotic components of shelf environments of particular interest to resource managers are described and understood better than other biological components. Sea turtles and marine mammals, such as the right whale, have received special attention due to their endangered-species status, but their offshore habits and movements are not well understood. The biology of several commercially important species of fish and shellfish is documented in detail. A broad baseline for hard-ground-habitat areas is established for the area; however, detailed assessments of live-bottom areas are needed. The contributions and functions of phytoplankton, zooplankton, and microbes are typically studied regarding shelf productivity and trophic structures. Additional facets of biological systems needing investigation include the fluxes between biological components and chemical and physical components; and the structure and distribution of macroalgal, benthic, and seabird communities.

3.3.4 Socioeconomic environment

References related to managing finfish, shellfish, and crustacean fisheries dominate the socioeconomic literature. With the exception of a substantial body of work on shoreline erosion and erosion-control projects, few references pertain to the socioeconomic facets of offshore and coastal environments in the study area. Florida and South Carolina, states that participate in the federal Coastal Zone Management (CZM) program, have produced a considerable body of literature pertaining to coastal zone management and offshore resources. Only a few of these types of publications for Georgia exist because Georgia has not yet joined the CZM program. In addition, Florida and South Carolina have produced more public education materials pertaining to coastal and offshore resources than has Georgia. References to regulations and legislation about ports, navigation, and pollution comprise most of the remainder of the work in this area. Archeological resources (primarily shipwrecks) may be numerous on the shelf, but existing literature is limited.

3.4 Analysis of Environmental Information by Resource Topic

As noted earlier, material collected during the literature search was grouped into environments and resource topics based on the non-mineral resource discussed. Because many references were interdisciplinary studies, the evaluations in Section 3.4 may not represent the breadth or total number of references that describe each resource. To account for this overlap, related resources are cross-referenced at the end of each section.

The following section discusses the extent of environmental information for non-mineral resources according to environmental groups and resource topic. Appendix C contains annotated citations (two citations per resource topic) that represent the types of references currently available.

3.4.1 Physical environment

References describing the physical environment of the study area are organized according to three major topics:

- Meteorology, which concerns atmospheric dynamics and events;
- Physical oceanography, which concerns the movements, dynamics, and characterization of shelf waters; and
- Geology, which concerns aspects of the seabed and sub-bottom environments.

The complex nature of the offshore physical environment is reflected by the interdisciplinary nature of many references.

3.4.1.1 Meteorology

The majority of the meteorology references concern hurricanes. Reports from the National Weather Service present the history of tropical cyclones in the North Atlantic, including descriptions of individual storms and storm-track data (Neumann 1990; Neumann and Pryslak 1981). Cardone (1986) hindcasts the most intense tropical storms and hurricanes of the 20th century. Technical reports by the South Carolina Water Resources Commission and various journal articles document the storm surges, storm damage, and sea states caused hurricanes, such as Hugo in 1989 (Purvis 1985; Davis *et al.* 1991). Few references are available, however, for more typical atmospheric weather conditions and events, with the exception of one each regarding rainfall, mesoscale weather events, and the development of fog and stratus (Lyons and Calby 1986; Ricks 1981). Mullins (1978) presents the atmospheric transport over and geochemistry of trace metals in the Georgia Bight.

Air-sea interactions in the form of wind stress and atmospheric forcing receive considerable study regarding seasonal variations in currents and circulation of water masses on the shelf (Blanton *et al.* 1989b; Blanton *et al.* 1985; Schwing *et al.* 1988). Weber and Blanton (1980) establish seasonal and monthly mean-wind fields for the South Atlantic Bight based on over 300,000 marine weather observations. Several of the references analyze and interpret data routinely collected at the Savannah Light Tower which is located 15 km off the Georgia coast (Blanton and Chandler 1978; Blanton *et al.* 1979; Schwing *et al.* 1985). These data, consisting of wind, barometric pressures, sea temperatures, and water movements, are combined with data from other sources and are used to predict the behavior of the coastal water masses and their effects on the physical and biological processes.

The BLM-sponsored studies serve as a partial data baseline of data describing meteorological conditions in the South Atlantic Bight (Environmental Research and Technology, Inc. 1979a-c). Meteorological data are collected, compiled, and stored routinely by the National Oceanic and Atmospheric Administration's (NOAA) National Data Buoy Center (NDBC), the National Climatic Data Center, and National Hurricane Center. Weather and sea conditions in the study area are recorded at three offshore weather buoys (Stations 41.003, 41.004 and 41.005) and at the Savannah Light Tower. Data from these buoys are compiled in a database and are reported most recently in *Climatic Summaries for NDBC Buoys and Stations: Update 1* (Gilhouson *et al.* 1990). Unpublished, often electronic, data on historical climate conditions and short-term weather events for the study area also are stored at these facilities.

Because weather is a short-term phenomenon and climate connotes a much longer span of time, the degree to which both have been investigated in the South Atlantic Bight is only adequate at present. However, in the event of marine mining, more site-specific data will be needed.

3.4.1.2 Physical oceanography

References describing physical oceanography are evaluated according to two topics: (1) water masses, and (2) waves, tides, and currents. The first category concerns Gulf Stream eddies and intrusions, riverine and estuarine discharges, and continental shelf circulation, and the second category concerns localized, typically nearshore, phenomena. Many of the physical oceanographic models discussed in Section 4.2 are applied to the physical processes and systems within this topic.

The physical (and chemical) oceanography in the South Atlantic Bight has been studied extensively. The large interdisciplinary studies sponsored by the BLM (Table 4) and the DOE (Table 5) establish a baseline of information regarding the dynamics of the shelf environment, and the interaction of physical, chemical, and biological processes on the shelf.

Water Masses. Studies of water masses range in topic, from discharges of freshwater and estuarine plumes through the inner shelf, to the dynamics of a coastal frontal zone, to both localized and general circulation patterns over the entire shelf, including advection of waters onto the shelf from the continental slope during upwelling. The references evaluated in this section represent perhaps the best-integrated, most complete work for any of the shelf environments.

Many references are progress reports on long-term studies sponsored by DOE, NOAA, National Aeronautics and Space Administration (NASA), and other Federal agencies, as well as cruise reports by various oceanographic institutions. Studies of the physical oceanography, and water mass dynamics in particular, of the South Atlantic Bight have been sponsored by the BLM and MMS (Table 4).

These large-scale studies, combined with other site-specific studies, indicate that the physical aspects of the water column over the continental shelf are well-known. Even though the time-specific nature of the investigations must be considered, a significant portion of the data can be extrapolated and applied to present and future endeavors. For instance, data from the Georgia Bight Experiment (GABEX), consisting of mooring cruises offshore Savannah and Cape Romain, are correlated with other hydrographic and interdisciplinary cruises (Lovingood *et al.* 1986; Pietrafesa 1980).

Numerous studies address the processes and dynamics offshore Georgia that affect the transport and fate (and buoyancy) of low-salinity water discharged from rivers (Blanton 1980; Blanton and Atkinson 1983). These processes are investigated extensively as a result of the Spring Removal Experiment (SPREX) sponsored by the DOE in the mid-to-late 1980's (Chandler *et al.* 1987; Chandler and Atkinson 1988). Blanton and Chandler (1978) and Blanton *et al.* (1989a) investigate the coastal frontal zone that prevents the seaward transport of fresh water to midshelf areas.

Environmental effects associated with the behavior of the western frontal edge of the Gulf Stream are discussed in many references (Oey *et al.* 1987; Singer *et al.* 1980). The irregularities of bathymetric features are shown to affect the flow of boundary currents along the continental margin (Bane 1983; Brooks and Bane 1978). Gulf Stream- and wind-induced current variability on the continental shelf offshore Georgia and northeastern Florida is discussed by Lee and Atkinson (1982, 1983). The formation, dynamics, and effects of Gulf Stream intrusions on the shelf environment are also studied.

Much of the research on the dynamics of water masses is applied to the development of numerical predictive circulation models for the South Atlantic Bight (Blumberg and Mellor 1983; Kantha *et al.* 1986). A detailed discussion of these models is presented in Section 4.1.

DOE sponsored a comprehensive literature review of studies conducted from 1977 to 1991 of the ocean processes in the South Atlantic Bight (Menzel 1993). The document should be a guide for future research endeavors. A chronological list of the major DOE-sponsored experiments in the South Atlantic Bight during this period is in Table 5.

Due to the wide range of topics included within this section, considerable overlap exists with other resource topics. Additional information may be found below and in the following sections of this report: Meteorology (Section 3.4.1.1), Water Column (Section 3.4.2.1), Upwelling (Section 3.4.3.5), Outwelling (3.4.3.6), and Physical Models (Section 4.1).

Waves, Tides, and Currents. These water movements described in this section concern the effects of localized phenomena, typically coastal processes that affect sediment movement in nearshore areas. Applicable references include several studies of nearshore and deepwater waves. A few studies of only tides and tidal currents exist, but much tide data are found within more comprehensive cruise reports and large-scale studies.

Many studies of waves are technical reports by the U.S. Army Corps of Engineers (Brooks and Corson 1984; Corson *et al.* 1981, 1982). A large number of the reports are hindcasts of wave information from along the Atlantic coast, including some that are specific to storm-generated wave heights (Corson and Tracy 1985). The monitoring of the direction, height, and period of nearshore waves is the subject of other such studies (Corson and McKinney 1991; Gorman 1991). A technique was developed for measuring ocean waves using synthetic aperture radar; the technique compares favorably with direct measurements to provide information about sea waves that is otherwise not available from other instruments (McLeish *et al.* 1980). The radar image can show refraction effects of the bottom on sea waves as they move into progressively shallower water.

The tidal regime in the study area is characterized by diurnal tides with the greatest amplitudes on the East and Gulf coasts of the United States. The large tidal range and associated tidal currents affect transport processes and dynamics throughout the inner shelf and beyond. Pietrafesa *et al.* (1985) describe the tidal regime of the South Atlantic Bight. The barotropic flow of the tides across the shelf is modeled numerically regarding tidal effects upon shelf circulation (Battisti and Clarke 1982; Blanton 1981a, 1984; Wang *et al.* 1984). Blanton (1980) and Blanton and Atkinson (1978) describe the effects of tidal currents upon fresh-water transport offshore Georgia, and upon subsequent mixing processes. Several references discuss the role of tidal currents in sediment transport processes (Hubbard 1977).

Estimates of tidal energies (i.e., times, ranges, and current velocities) and directions in inlets and nearshore areas from Jacksonville, Florida, to Charleston, South Carolina, are presented in tidal current tables, charts, and diagrams prepared by the National Ocean Service (1993). The Physical Oceanography Division of the National Ocean Service compiles and maintains a database of unpublished oceanographic data for use by researchers and managers in predicting tides and currents (National Ocean Service 1992).

Other references that consider tidal cycles in offshore waters are discussed in other topics, such as Water Masses (earlier in this section), Sediments and Sediment Transport (Section 3.4.1.3), Beaches (Section 3.4.4.4), and Physical Models (Section 4.1).

Data on nearshore and offshore and surface and bottom currents are collected typically during interdisciplinary studies. Many references describe nearshore currents that transport sediment in the littoral zone of tidal inlets and beaches. Schwing *et al.* (1983) report the nearshore circulation of coastal currents along the 10-m isobath offshore South Carolina. Current generation, velocity, direction, and bottom stress also have been reported. The surface current movements offshore the Atlantic coast of north Florida are described by the Florida Atlantic Coastal Transport Study (FACTS) (Maul and Bravo 1989).

References concerning offshore bottom currents may be found in Table 5 and also under several other topics, such as Water Masses (Section 3.4.1.2), and Sediments and Sediment Transport (Section 3.4.1.3). Nearshore transport processes that effect shoreline change and beach erosion are also addressed under Beaches (Section 3.4.4.4). Other current-related references are evaluated under discussions of Upwelling and Productivity (Section 3.4.3.5) and Outwelling (Section 3.4.3.6).

3.4.1.3 Geology

References on the geologic nature of the study area are considered under five resource topics. These topics are (1) bathymetry and seabed morphology; (2) sediments and sediment transport; (3) aquifers; (4) environmental and geologic hazard studies; and (5) stratigraphic and shallow structural features on the continental shelf.

Bathymetry and Seabed Morphology. The study area is characterized by a shallow, sloping continental shelf with the relatively featureless seafloor punctuated by scattered geologic features (e.g., rock outcrops, sand waves, buried channels) and localized topographical rises, or hard grounds. Surveys by the National Ocean Service have determined the bathymetry of the region primarily for navigation purposes. The primary references that describe bathymetry are nautical charts and bathymetric maps (National Ocean Service 1986; National Ocean Survey 1976).

Geophysical surveys of the seafloor in lease block sites identify and describe geologic features such as sand waves, rock outcrops and hard grounds, areas of scour, and buried river and stream channels (General Oceanographics Inc. 1978; Gettleson *et al.* 1982). Most of these papers were produced for oil companies, whereas others are products of studies by the U.S. Geological Survey and the BLM. The distribution of hard grounds was studied and identified by several researchers who concluded that most of these features are localized to three roughly-defined, sub-parallel bands located approximately 50-55 km , 90-100 km, and 130-140 km from shore (Ross *et al.* 1987; Barans and Henry 1984). These hard grounds are important biotopes for nektonic and benthic fauna and are also referred to as live bottoms.

Emery (1979) estimates the volume of seawater over the continental shelf through production of sets of hypsographic curves for the eastern U.S. coast. References pertaining to seabed morphology include studies of bottom topography and morphology of the seafloor in the Charleston Bump area, and local elevation changes off South Carolina (Popenoe and Pinet 1980).

Many references that include data on the morphology of seabeds are evaluated also under Geologic Hazards and Environmental Studies and Stratigraphy and Shallow Structures (both discussed later in Section 3.4.1.3), and Benthic Habitats (Section 3.4.3.12).

Sediments and Sediment Transport. Information on sediments in the study area is extensive. The data include details on the texture, mineralogic composition, and trace metal content of the sediments, as well as details on sediment transport and distribution and the kinds and amounts of suspended sediments in the near-bottom waters. Additional references include those on the historical development of the sediment cover, sediment-faunal relationships, and numerical sediment transport models.

Generally, the sediments reflect subaerial weathering, and erosion (or non-deposition) over and near hard grounds and broken bottoms, admixed with the production of biogenic carbonates (Brown *et al.* 1980). In addition, other processes, such as bioturbation and water-mass movements, have some affect on the nature of the sediments (Knebel 1981).

Several studies use side-scan sonar to delineate details on the nature of the sedimentary cover (Popenoe 1980a, 1981b; Popenoe and Meyer 1983; Henry and Foley 1981). The sediments comprising the majority of the continental shelf surface between Charleston, South Carolina, and Brunswick, Georgia, are sand-sized, interrupted in places by hard-bottom areas. East of Charleston, the sediments are coarser and the hard bottom areas are more extensive. The biological and physical processes mix the largely relict, non-carbonate sand with the much younger carbonate fraction. For the most part, this admixture of relict clastic and recent carbonate bioclastic debris represents the only sedimentary material on the continental shelf surface (Pilkey *et al.* 1979).

Little or no clastic material is currently discharged into the sea by the river systems. There are, however, shallow water areas where the surficial sands have a higher carbonate content, such as the belt of carbonate-rich sand lying off the entrances to Altamaha and Doboy Sounds. These abnormalities are thought to mirror a high production of carbonate by organisms, as well as current and wave reworking of oyster shell deposits in the nearshore area (Frey and Pinet 1978). The nature of the fine fraction of the sediment cover is investigated by research of clay mineralogy of the nearshore-bottom muds and clay provenance (Pinet and Morgan 1979).

References on sediment transport address three areas — tidal inlets, beaches, and offshore. Nummedal (1979) and Oertel (1979) discuss tidal inlet transport and dispersal of sediment from estuaries to the inner shelf. Sediment transport studies along ocean beaches, typically in association with beach erosion studies, are more frequent than other types of transport studies (Nummedal and Fisher 1979; Kana 1989; Stapor 1984; Stapor and May 1983). Details on sediment distribution and sediment transport routes in the nearshore are determined by using certain heavy minerals, such as hornblende and epidote, as tracers (Schmitter 1986; Schmitter and Freeman-Lynde 1988). Studies of sediment transport processes offshore are reported by U.S. Geological Survey investigations in the South Atlantic Bight (Butman *et al.* 1980a,b). The dynamics of the sediment cover offshore are not understood as well as sediment dynamics along the beaches.

Aquifers. The onshore hydrology of the Floridan Aquifer system has been studied and monitored over the last two decades. The bulk of work on groundwater resources and on aquifers of the mainland results from work by the U.S. Geological Survey, the Georgia Geologic Survey, and the South Carolina Water Resources Commission. The areas of investigation include physical characteristics, levels of groundwater use, potentiometric surfaces, predevelopment flow, and management of groundwater resources (Clarke *et al.* 1990; Krause and Randolph 1989; Randolph and Krause 1984).

Few details are known concerning the offshore nature of the Floridan Aquifer, the aquiclude, or the saltwater-freshwater interface beneath the inner-continental-shelf waters off the South Carolina-Georgia-Florida coasts. Extrapolation of work conducted on barrier islands may provide information. Some of the only field data for offshore aquifers in the study area are derived from well sites and from offshore stratigraphic sites (Manheim and Paull 1982; Paull and Dillon 1982). The origin of the freshwater under the U.S. Atlantic continental shelf and the presence of relict freshwater under the shelf are reported by some investigators (Kohout *et al.* 1978; Kohout 1982).

Various aspects of the offshore aquifers are discussed. Limestone aquifers, including their stratigraphy and possibilities of offshore extensions, are discussed generally (Paull and Dillon 1979, 1982). Offshore the Georgia-Florida border, the position of the saltwater-freshwater interface is investigated as well as changes of salinity levels in groundwater from nearshore to offshore (Johnston 1980, 1983; Manheim and Paull 1981).

Saline-water intrusion into the freshwater coastal aquifer is studied in South Carolina in the vicinity of Hilton Head and Port Royal Sound, in Georgia near Brunswick and Cumberland Island, and also in Florida near Fernandina Beach (Stone *et al.* 1986; Hughes *et al.* 1989; Herndon and Cofer-Shabica 1991; Fairchild and Bentley 1977). Seawater encroachment of the aquifer resulting from dredging activities in the St. Mary's Inlet is one potential effect of offshore mining activities. Given the importance of the already overstressed aquifer to the viability of coastal communities and economies, the consequences of an aquiclude breach resulting from an offshore mining effort warrants further investigation.

Geologic Hazards and Environmental Studies. During the 1970s and early 1980s, when interest in oil-and-gas drilling on the southeastern Atlantic continental shelf was at its height, many environmental studies were conducted by government agencies and oil companies prior to lease sales in the area (Ball *et al.* 1979; Henry *et al.* 1981; Antoine and Cain 1979; Marlowe 1978; Popenoe 1979b, 1980a, 1981a). These geophysical investigations of seabed morphology, shallow geologic structures, and stratigraphy identify geologic structures such as hard grounds, live bottoms, sand waves, scour, and buried river channels. Similar site-specific environmental surveys are needed if, and when, mining activities are considered.

Stratigraphy and Shallow Structures. References describing shallow structure and stratigraphy of the Georgia continental shelf comprise BLM baseline studies conducted by the U.S. Geological Survey, private firms, and academic institutions (Popenoe 1979c; Dillon 1983). The overall objective of the studies is to provide basic information relevant to offshore oil production impacts. The more recent papers, mostly associated with MMS or joint MMS and Georgia Task Force-sponsored studies, are concerned with assessing hard-mineral resources of the continental shelf and Blake Plateau (Kellam and Henry 1986; Henry and Idris 1992).

Many references address Tertiary and Quaternary shallow seismic stratigraphy and associated geologic structures in the upper 200 m of sub-bottom deposits of the Georgia-South Carolina Shelf (Blackwelder *et al.* 1979; Pilkey *et al.* 1981; Popenoe and Meyer 1983). Several references describe basement structures, such as the Brunswick Magnetic Anomaly; such references, however, were not evaluated for this study due to the depth and pre-Tertiary age of the features. The studies that are considered important to this discussion include those on the Floridan Aquifer/aquiclude system and the phosphate-rich strata, which are of Tertiary age.

3.4.2 Chemical environment

References concerning environmental chemistry and chemical oceanography are divided into two topics, water column chemistry and geochemistry of the sediments and seafloor.

3.4.2.1 Water column

References dealing with water column chemistry describe the chemical and physical constituents and dynamics in the water column offshore. Research on the sources, concentrations, flux, transport, and fate of materials are considered (Bothner 1979; Windom 1990). The subjects include dissolved and suspended organic and inorganic materials, such as trace metals, sediment, radioisotopes, and nutrients (Gardner and Stephens 1978; Moran *et al.* 1991a; Byrd 1988; Moore 1987; Hanson 1988). Some studies introduced tracers to study water movement, whereas others use natural tracers for the same purpose (Willey and Atkinson 1982). Certain properties of the shelf waters are also studied and reported, including the use of alkalinity as an indicator of dynamic mixing processes, seston flux and transport, the cycling of specific elements in the water column to indicate the source of the water mass, the use of particulate aluminum flux across the shelf to predict transport processes, and the pooling of nitrogen-rich waters in nearshore waters off Georgia (Wong 1988; Doyle *et al.* 1981; Windom and Gross 1989; Haines 1979).

DOE-funded experiments and regional studies sponsored by BLM/MMS gathered extensive data on the processes and constituents of the water column. Along with similar oceanographic cruises in the South Atlantic Bight, these investigations are responsible for much of the present understanding of water column dynamics in the study area. Data collected during experiments described in Table 5 and in the studies listed in Table 4 establish baselines of data that describe the hydrochemistry of offshore waters. References discussed under Water Masses (Section 3.4.1.2), Geochemistry (Section 3.4.2.2), and Physical Models (see Section 4.1) also include water-column-chemistry data.

3.4.2.2 Geochemistry of the sediments and sea floor

Several references exist that describe the inorganic and organic chemical characteristics of the sediments and substrates of the nearshore and open shelf areas of the study area (e.g, Sayler *et al.* 1978). Distribution patterns and concentrations of various natural trace metals are the subjects of several investigations (Windom *et al.* 1989a,b; Herring 1989). Estuary-to-shelf exchange of material is discussed under Outwelling (Section 3.4.3.6). The discussion of Sediments and Sediment Transport (Section 3.4.1.3) and the Water Column (Section 3.4.2.1) evaluate some studies of geochemical aspects of suspended particulates.

The U.S. Geological Survey studies in the South Atlantic Bight include research on aspects of geochemistry of bottom sediments and suspended particulates in the water column and dynamics at the sediment-water interface of the benthic boundary layer region (Bothner *et al.* 1980). The DOE-sponsored studies conducted between 1977 and 1991 (Menzel 1993) also discuss the geochemistry in the study area.

3.4.3 Biological environment

Approximately 40% of the references applicable to this study describe the biological environment of the study area. The references focus on zoological aspects, and much of the research relates to the management various fisheries resources. The investigations establish baseline information, often through environmental assessments and surveys sponsored by BLM/MMS and the DOE.

3.4.3.1 Microbes

Studies of trophic relationships and nutrient and energy pathways in salt marshes and estuaries reveal the important role of microbial activity in these systems (Pomeroy 1985). Subsequent investigations of the microbes of shelf waters and sediments indicate that microbial activity in these areas is significant in both scope and function (Fallon *et al.* 1983). Research was conducted by scientists from the Skidaway Institute of Oceanography (Savannah, Georgia), and from the University of Georgia Institute of Ecology (Athens, Georgia) and Marine Institute (Sapelo Island, Georgia).

The metabolic activity of microbes, especially bacterioplankton, is studied regarding nutrient cycling, amino acid uptake and protein synthesis, particulate aggregate formation, and biomass production (Hanson and Robertson 1988; Hanson *et al.* 1990; Hopkinson 1985; Biddanda 1985). Changes in productivity are also delineated with respect to intrusions of water masses and nutrients on the shelf by either river discharges on the inner shelf or upwelling on the outer shelf (Hanson and Wiebe 1977). Investigations of the trophic relationships in plankton food webs define the energy pathways and fluxes (Pomeroy *et al.* 1984). Such studies include the interactions between autotrophic phytoplankton and heterotrophic bacterioplankton and the consumption of bacteria by protozoa. Laboratory studies of the effects of suspended sediments on microbial activity and productivity were conducted by Wainright (1987). The distribution and abundance of amoebae, fungi, and pathogenic bacteria are addressed by various studies (e.g., Benner *et al.* 1986).

3.4.3.2 Macroalgae

Macroalgae, or seaweeds, include a variety of macroscopic plants that inhabit offshore, nearshore, and estuarine habitats. Although some species float at the surface, most are attached to hard substrates. Sessile (attached) species are found on hard grounds, natural and artificial reefs, and structures such as docks, groins, and inlet jetties.

The body of literature describes few investigations of macroscopic marine algae in the coastal waters of South Carolina, Georgia, and northeastern Florida. Although some investigations occurred prior to 1977, macroalgal studies increased with the onset of leasing for oil and gas exploration and with the establishment of the Gray's Reef National Marine Sanctuary off the Georgia coast. Environmental assessments and baseline studies of the South Atlantic Bight (Table 4) describe the macroalgae in the study area (Sandifer *et al.* 1980). Recent research efforts expand upon the early investigations primarily through inventories of macroalgae populations and morphology.

The population surveys, which comprise over half of the references, establish the distribution and abundance of macroalgal species. Some of these papers report upon the discovery of new record species and the identification of new species (Richardson 1985a, 1986). Other references inventory and describe the macroalgae of Gray's Reef and on jetties at the St. Mary's River entrance (Searles 1981; Richardson 1985c, 1991). The remainder of the references describe the morphological and floristic characteristics of various species (Richardson 1985b, 1987; Searles 1983, 1987).

3.4.3.3 Phytoplankton

Phytoplankton (microscopic plants that float in and move with a water mass) research has been conducted over the continental shelf from the littoral zone to the shelf edge. The research encompasses diverse topics, such as limitations in phytoplankton accumulations in Georgia coastal waters resulting from fluctuations in nutrients, and the role played by Gulf Stream frontal eddies in causing phytoplankton patches on the outer shelf (Yoder *et al.* 1981). Seasonal and spatial distributions of blue-green algae are investigated in relation to the overall hydrography of the Southeast Atlantic Bight (Marshall 1981, 1982; Dunstan and Hosford 1977). Pomeroy *et al.* (1983) investigated the relationship of phytoplankton production to suspended sediment distribution offshore Georgia. Nutrient enrichment of coastal waters by dissolved organic and inorganic nitrogen is the subject of laboratory experiments. Studies along a cross-shelf transect offshore Savannah, Georgia, show that phytoplankton abundance varies little with respect to season, except for the effects of non-periodic upwelling events (Bishop *et al.* 1980). Remote sensing is employed to qualify phytoplankton distribution and variability using the Coastal Zone Color Scanner, with the resultant data indexed with data from current meters (McClain *et al.* 1990). The results of DOE-funded studies of phytoplankton (Table 5) are reported by Menzel (1993); these interdisciplinary studies investigate the complex coupling of processes and physical and biological systems.

3.4.3.4 Zooplankton

As with phytoplankton studies, many studies of the zooplankton (microinvertebrates that move with the water mass) in the Georgia Bight and adjacent areas were funded by DOE. A series of progress reports originating from the study report on the processes controlling zooplankton abundance (Paffenhöfer 1985a, 1987, 1989). Associated references include investigations of zooplankton distribution and behavior in response to the abundance and availability of food, water displacement, and other physical factors (Paffenhöfer 1985b; Paffenhöfer *et al.* 1984; 1987). Metabolic activity, feeding behavior, feeding rates, and trophic relationships between omnivores, carnivores, and herbivores are also investigated (Paffenhöfer 1988; Paffenhöfer and Knowles 1978, 1980; Turner 1991). Related references are evaluated under Microbes (Section 3.4.3.1) and Upwelling and Productivity (Section 3.4.3.5).

3.4.3.5 Upwelling and productivity

Upwelling is the upward movement of cold, nutrient-rich water masses on to and over the shelf from the deeps of the continental slope and ocean basin. Studies of the physical process of upwelling and the resultant effects on planktonic biomass and the regional food web are evaluated. Episodic physical events resulting in upwelling in the South Atlantic Bight are described by Atkinson *et al.* (1984). One study indicates that long-shore variations in bottom topography may influence upwelling on the northeastern Florida shelf (Smith 1983). The principal causes of biomass increases along the South Atlantic shelf edge are the Gulf Stream intrusions associated with upwelling events (Lee *et al.* 1991). Studies show that fish aggregations are associated with areas of upwelling (Atkinson and Targett 1983). Several references report on upwelling data from the large-scale DOE-funded studies such as the Fall Removal Experiment (FLEX) and Biological Transformations (BIOTRANS) (Chandler *et al.* 1988). The physical processes that affect nutrient upwelling are described also by some studies discussed under Water Masses (Section 3.4.1.2) and Sediments and Sediment Transport (Section 3.4.1.3),. Other topics that consider upwelling and productivity data are Water Column (Section 3.4.2.1), Geochemistry (Section 3.4.2.2), Phytoplankton (Section 3.4.3.3), and Zooplankton (Section 3.4.3.4), and Outwelling (Section 3.4.3.6).

3.4.3.6 Outwelling

Outwelling is the movement of nutrients in water masses from the coastal areas outward over the shelf. The outwelled material is transported from estuaries and salt marshes to the waters of the inner shelf by river discharges and tidal action (Odum 1980; Kinsey 1981). Organic materials, such as detritus from salt marshes and freshwater wetlands, and inorganic materials in dissolved and particulate forms are exported to shelf waters in this manner (Hopkinson and Hoffman 1984). References pertain primarily to the transport and fate of the organic constituents, especially those associated with nutrient uptake and related productivity on the inner shelf. The role of detritus as a food source in the ecosystem is discussed by Moran *et al.* (1991a,b). The export of suspended organic detritus through coastal waters and its importance to species interactions and ecosystem energetics is described by Hopkinson (1992) and Alberts *et al.* (1990).

Studies of the physical processes associated with outwelling are evaluated in other sections, including Physical Oceanography (Section 3.4.1.2), and Sediments and Sediment Transport (Section 3.4.1.3). Other references are evaluated under Water Column (Section 3.4.2.1), Microbes (Section 3.4.3.1), and Upwelling and Productivity (Section 3.4.3.5).

3.4.3.7 Miscellaneous macroinvertebrates

Zingmark (1978) inventories invertebrates and other organisms of the South Carolina coastal zone using an annotated checklist of the biota. Tripp and Turner (1983) investigate the occurrence of infections and pathologies of several dominant macroinvertebrates of the Georgia Bight, including rock shrimp and squid. The abundance and seasonal composition of decapods and copepods in coastal habitats are subjects of research (Williams 1984). The U.S. Fish and Wildlife Service presents species profiles of life histories, habitats, and life cycles (Larson *et al.* 1989; Muncy 1984).

Nektonic invertebrates are free-swimming invertebrates that move between and independent of water masses; examples include shrimp and squid. Information on nektonic invertebrates pertinent to stock assessments, economic analyses, and management of the regional fisheries (primarily the shrimp industry) is presented in the discussion of Commercial Shellfish and Crustacean Fisheries (Section 3.4.4.1).

3.4.3.8 Benthic invertebrates

The benthic-invertebrate populations inhabit the soft-bottom areas (sand and mud) and the hard-bottom areas (hard grounds, live-bottom areas, artificial reefs) of the Georgia shelf environment. The references that describe soft-bottom benthic assemblages are evaluated in this section, and the references that describe hard-bottom benthic assemblages are evaluated under Benthic Habitats (Section 3.4.3.12).

Seasonal changes in benthic community structure on the inner shelf are investigated by Tenore (1985). Research is reported on the

- Effects of dredging and unconfined disposal of dredged material on macrobenthic communities,
- Distribution of benthic foraminifera,
- Growth history and ecology of the Atlantic surf clam (Jones *et al.* 1983), and
- Benthic community enrichment in the Georgia Bight through infusions of nutrients by Gulf-Stream upwelling and estuarine outwelling (Hanson *et al.* 1981; Tenore *et al.* 1978).

Burrell *et al.* (1981) and Van Dolah *et al.* (1981a,b) discuss problems in assessing community health, as well as the lack of information about the relationships between benthic community structure and the effects by pollution. The development of communities of sessile fouling organisms on the shelf is investigated by the South Carolina Wildlife and Marine Resources Department in an extensive survey of living resources offshore South Carolina (Van Dolah 1981a, 1982, 1984a).

Knot and Wendt (1985) review the benthic community of slope areas in the South Atlantic Bight, including a portion of the study area between the 80-m to 200-m isobath off northeastern Florida. The Florida Department of Natural Resources is conducting a Southeast Area Marine Assessment Program (SEAMAP) project to characterize the benthic communities off northeast Florida (Donaldson *et al.* 1992).

Other investigations of benthic invertebrates are considered under other resource topics. Infauna are considered under Sediment and Sediment Transport (Section 3.4.1.3). The taxonomy and distribution of benthic microfossils (relict foraminifera) are discussed under Stratigraphy and Shallow Structures (Section 3.4.1.3).

3.4.3.9 Fish

Many references discuss fish of the South Atlantic Bight. The distribution and size data on individual species of fish, such as spanish mackerel, black sea bass, red drum, bluefish, vermillion snapper, kingfish, and porgy are presented in numerous references (Horvath *et al.* 1990; Waltz *et al.*

1979; Smith and Wenner 1985). Feeding behavior, age composition, sex ratios, growth rates, fecundity, spawning activity, migratory and local movements, habitats, and general fish biology are the primary topics of other collected literature (Laroche 1977; Collins and Stender 1989; DeVries *et al.* 1990). The types and numbers of these references are shown in Tables 3 and 6.

The U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service species-profile series summarizes commercially, recreationally, and ecologically important fishes of coastal waters. The profiles include data on life cycles, habitat, taxonomy, and ecological distribution (Mercer 1989). NOAA's National Marine and Fisheries Service (NMFS) also produces data synopses for various fish species. Like the former series, the latter synopses present the state of knowledge for each species based upon literature reviews.

Many references are cruise reports that include data on fish of the South Atlantic Bight, particularly fish offshore South Carolina and Georgia. Data from a series of otter trawl investigations are reported for Marine Areas Management Program (MARMAP) cruises; MARMAP is a broadly-based, Federal-state effort coordinated by the Marine Resources Division of the South Carolina Wildlife and Marine Resources Department (Barans and Powles 1977; Wenner *et al.* 1980). Beatty and Wenner (1991) report the results of a series of cruises throughout the South Atlantic Bight during 1991 and 1992 for the SEAMAP. The South Carolina Wildlife and Marine Resources Department collected data on species of commercially-valuable fishes and decapod crustaceans (primarily shrimp), during the Shallow Water Trawl Survey. Annual reports and several cruise reports from other SEAMAP investigations are available (Donaldson *et al.* 1992; Wenner *et al.* 1979). NMFS offices in Beaufort, North Carolina, Charleston, South Carolina, and Panama City, Florida, also have produced several useful reports (Manooch *et al.* 1983; Naughton and Saloman 1984).

Much of the research on fish in the South Atlantic Bight is important to fisheries managers and to the commercial and recreational fishing industries. Many references are primarily concerned with socioeconomic aspects of the commercial and recreational fishing industries (e.g., stock assessments) of fish populations; these references are discussed under Commercial Finfish Fisheries (Section 3.4.4.2) and Recreational Fisheries (Section 3.4.4.3). Fish inhabiting live-bottom areas are discussed under Benthic Habitats (Section 3.4.3.12).

3.4.3.10 Birds

The birds of the Georgia Bight include resident and migratory species of coastal and marine areas. Coastal species, such as shorebirds, waterfowl, and wading birds, inhabit a variety of habitats — beaches,

Table 6. Numbers of Fish Biology and Management References.

Fish Species	Larvae	Adults	Morphology	Range	Habitat	Profiles
Alewife						1
American Shad			1	4		1
Bass: Black Sea, Striped		3		4		2 1
Belted Sandfish		1				
Billfish		1				
Blueback Herring				1		1
Bluefish	2	2		1		2
Croaker		2				
Dolphin	1	2				
Drum: Red, Star, Banded	 1	3		1		3
Eel: American Congrid			1			 1
Gag		4				
Grouper: Snowy, Warsaw, Yellowedge	3	1 1 1 1		3		2
Lamprey		1				
Mackerel: King, Spanish	1 1 3	 5 3	 4 2	3 6 1		6 1 1
Menhaden		3		2		
Miscellaneous MARMAP: SEAMAP Populations	6	1 9	 1	11 15 11	5 9	4
Mullet: Striped, White	1 1		1			
Porgy: Knobbed, Whitebone		1 3				1
Round Scad		1		1		
Scamp		2	1			

Table 6. **Numbers of Fish Biology and Management References.** *(continued)*

Fish Species	Larvae	Adults	Morphol-ogy	Range	Habitat	Profiles
Searobin				1		
Seatrout				1		3
Shark				1	1	
Sheepshead		1				
Shortnose Sturgeon		3				2
Silversides			2	1		
Snapper: Red, Vermillion	1 1	2 6	1 1	4 2		4
Southern Kingfish		1				
Spadefish		3				
Speckled Hind		1				
Spot						2
Summer Flounder			1			3
Swordfish				1		3
Tilefish: Blueline, Golden	 	 4 5		2 1 2	 1 1	1
Tomtate		1		2		
Tuna		1		1		
Tunny		1				
Wahoo		1				
Western Damselfish			1			
White Grunt		1		1		1
White Marlin			1			
TOTAL	**22**	**82**	**18**	**84**	**17**	**46**

nearshore waters, and marsh and estuarine areas. (References on wading birds inhabiting primarily estuarine habitats are not evaluated.) The marine (pelagic) birds are found offshore in the middle-shelf and, more commonly, the outer-shelf regions along the western edge of the Gulf Stream. Pelagic seabird densities in the South Atlantic Bight are the lowest of the U.S. Atlantic coast (Minerals Management Service 1992).

Approximately 2% of the references concern the birds of coastal and marine habitats of the study area. The references comprise literature reviews and status reports, inventories, distributions of populations, habitat studies, investigations into the bioaccumulation of pollutants, and ecological studies of reproductive, feeding, and migratory behavior.

Literature reviews are included in some of the environmental assessments presented in Table 4 (Center for Natural Areas 1979b; Sandifer *et al.* 1980). A three-volume environmental assessment prepared by the U.S. Fish and Wildlife Service reviews the status of seabirds of the southeastern U.S. Atlantic coast, and assesses the possible effects of proposed oil-and-gas exploration (Clapp *et al.* 1982a,b; 1983). This research notes that, although information on populations of breeding species is limited, less is known about pelagic species (Clapp *et al.* 1982a,b).

The references in this category are evenly divided between studies of pelagic birds and studies of coastal species. Studies of coastal species focus on the effects of bioaccumulation of pollutants on nesting success and inventories of populations and nesting birds (Blus and Stafford 1980; Anderson *et al.* 1980; Portnoy *et al.* 1981). Some species studied in individual papers include the brown pelican, laughing gull, least tern, royal tern, sandwich tern, gull-billed tern, and black skimmers.

The distribution and habitat of pelagic seabirds along the western boundary of the Gulf Stream are reported by Haney and McGillivary (1985a). Other researchers investigate the relationship between the occurrence of seabirds and upwelling events, Gulf Stream frontal eddies, and patches of *Sargassum* (Haney 1985, 1986a,b). The ecology and abundance of pelagic species is also reported in Haney (1987). Information on phalaropes, shearwaters, and petrels is also available.

3.4.3.11 Threatened and endangered species

Several animals of the South Atlantic Bight are protected by both Federal and state legislation as either threatened or endangered species. The Endangered Species Act of 1973 and the Marine Mammal Protection Act of 1972 provide the framework for identifying, preserving, and protecting these species. The U.S. Fish and Wildlife Service and NMFS share in the administration and enforcement of each act. Whereas the U.S. Fish and Wildlife Service is responsible for the southern sea otter, sirenians, sea turtles (while onshore), and terrestrial species, NMFS manages the cetaceans (whales), pinnipeds (except for walruses under the Marine Mammal Protection Act), and sea turtles (while in the ocean). The Endangered Species Act is designed to prevent actions by Federal agencies that may jeopardize or adversely affect the habitat of a protected species. The development of recovery plans for certain protected species is also required by the Endangered Species Act (Minerals Management Service 1992). Applicable state laws include Georgia's Endangered Wildlife Act of 1973 and South Carolina's Nongame and Endangered Species Conservation Act of 1976 (Sandifer *et al.* 1980).

Federal legislation includes "threatened species" and "endangered species" designations for species with lowest population levels and greatest threat to their survival. A "rare species" designation provides for identifying and monitoring species that are not yet threatened or endangered (Minerals Management Service 1992). The State of Georgia uses a "rare species" designation to identify species, such as the least tern and Wilson's plover, that are of concern. Species protected by State law may not be on the Federal endangered species list, as in the case of the gull-billed tern in Georgia (Georgia Department of Natural Resources 1993). Table 7 presents the various protected resident or migratory species that frequent the study area.

Sea Turtles. Much emphasis is placed on the protection of sea turtles. Sea turtles are among the most endangered animals in the world's oceans, due in large part to the impact of human activities. All five sea turtle species that occur in the Georgia Bight are protected by Federal and state laws. The endangered sea turtle species are the leatherback *(Dermochelys coriacea)*, the hawksbill *(Eretmochelys imbricata)*, and Kemp's ridley *(Lepidochelys kempi)* turtles; Kemp's ridley is the most endangered sea turtle in the world. The threatened species are the loggerhead turtle *(Caretta caretta)* and the green turtle *(Chelonia mydas)*.

The loggerhead turtle nests along the shores of barrier islands of the study area, and is the subject of more research than the other species. Several island-based turtle-tagging and -hatchery projects annually gather data on the nesting adults and the hatchlings. The references on loggerhead turtles focus on (1) populations, biology, and movement of adults; (2) activity related to nesting and hatchlings; and (3) levels and causes of mortality in adult sea turtles (Nelson 1988; Carr and Carr 1978; Stoneburner 1982; Richardson 1987; Teas 1993). The references also address the biology and life history of loggerheads, population surveys and status reports, nesting parameters, migrations and local movements, feeding behavior, growth rates, mortality levels, conservation efforts, and regulations (Frazer 1983; Hopkins-Murphy and Murphy 1983; Fleetwood 1993; Maley and Harris 1992; Richardson 1990; Thompson 1988). Some references report the development and testing of the turtle excluder device

Table 7. Protected Fauna of the Georgia Bight. [Adapted from Georgia Department of Natural Resources (DNR) (1993)].

Common and Scientific Names	Status
Fish	
Shortnose Sturgeon (*Acipenser brevirostrum*)	Endangered
Reptiles	
Green Sea Turtle (*Chelonia mydas*)	Threatened
Hawksbill Sea Turtle (*Eretmochelys imbricata*)	Endangered
Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)	Endangered
Leatherback Sea Turtle (*Dermochelys coriacea*)	Endangered
Loggerhead Sea Turtle (*Caretta caretta*)	Threatened
Birds	
Least Tern (*Sterna antillarum*)	Rare[1]
Gull-billed Tern (*Sterna nilotica*)	Threatened[1]
Piping Plover (*Charadrius melodus*)	Threatened
Wilson's Plover (*Charadrius wilsonia*)	Rare[1]
American Peregrine Falcon (*Falco peregrinus anatum*)	Endangered
Southern Bald Eagle (*Haliaeetus leucocephalus*)	Endangered
Mammals	
Humpback Whale (*Megaptera novaeangliae*)	Endangered
Northern Right Whale (*Eubalaena glacialis*)	Endangered
West Indian Manatee (*Trichechus manatus*)	Endangered

[1]These species have not received any Federal designation. The designations are by the State of Georgia.

(TED), which was developed to reduce the incidental catch, and subsequent death, of sea turtles in shrimpers' nets (Klima *et al.* 1991).

State natural resource management agencies in South Carolina, Georgia, and Florida monitor the activities of the island-based sea turtle programs. State and Federal (i.e., NMFS) regulatory agencies compile and synthesize data on populations, nesting, and mortality from incidental catches, strandings, and entrainments. Much of the gray literature results from such conservation work, but the published references do not include most of the annual data reports from the island-based projects. Data from those programs are typically compiled and stored by offices of these agencies, and may be obtained directly from natural resource agencies and from individual projects. Unpublished data from some island-based projects may be found at the Institute of Ecology of the University of Georgia.

The published literature contains very few references to other sea turtles that occur infrequently on the Georgia shelf. This research typically pertains to general population overviews (Knowlton and Weigle 1989; Pritchard 1989). The only overlap with similar topics occurs in a few references discussed under Commercial Shellfish and Crustacean Fisheries (Section 3.4.4.1) that evaluate the effects of TEDs on the net efficiency of shrimp catches.

Whales and Other Marine Mammals. Whales that have been reported in waters of the South Atlantic Bight include four endangered species — the northern right *(Eubalaena glacialis)*, humpback *(Megaptera novaeangliae)*, sperm *(Physeter catodon)*, and fin *(Balaenoptera physalus)* whales (Minerals Management Service 1992). Of these species, the right and humpback whales occur most frequently in the Georgia Bight (Schmidly 1981). Another 21 species of nonendangered cetacean species are reported in the waters off Georgia and South Carolina, including several species of dolphin and larger whales. Other reported mammals include the West Indian (Florida) manatee and two pinniped species, harbor seals and sea lions (Neuhauser and Ruckdeschel 1978; Sandifer *et al.* 1980).

Of the 45 references pertaining to marine mammals, all but 16 discuss the biology and ecology of the northern right whale. Fourteen citations refer to the Florida manatee. The following species are discussed in only one reference each — humpback whale, pilot whale, pygmy killer whale, and Atlantic bottlenose dolphin (National Marine Fisheries Service 1991; Irvine *et al.* 1979; Forrester *et al.* 1980; Wursig and Wursig 1979).

Of the two recognized subspecies of the West Indian manatee (*Trichechus manatus*), only one subspecies, *Trichechus manatus latirostris*, is found along the southeastern U.S. coast. Known as the Florida manatee, this mammal ranges as far north as North Carolina as water temperatures rise during summer months. The northern limit for year-round habitation by manatees is the north Florida-south

Georgia coastal area (Zoodsma 1991). Although manatees typically inhabit riverine and estuarine waters along the Georgia coast, some individuals may occur infrequently along beaches in the study area. References include reports of aerial surveys and inventories of populations, overviews and status reports on abundance of manatees, and investigations into manatee ecology (Valade 1980; Beeler and O'Shea 1981; Zoodsma 1991). Potential effects of dredging activity on manatees near Kings Bay, Georgia, are reported by Zoodsma *et al.* (1991).

Right whales occur in all the world's oceans from temperate to subarctic waters. Like most other baleen whales, right whales spend the summer on high-latitude feeding grounds and migrate to warmer waters during the winter calving and mating periods (Winn *et al.* 1986). The northern right whale, *Eubaelana glacialis*, is the most endangered whale on the U.S. Atlantic continental shelf, with a population size estimated at 250 to 350 individuals (Minerals Management Service 1992). The extensive study of this cetacean is due in part because of the critical nature of its endangered status. Right whale research on the Georgia shelf intensified, in response to the identification of its primary calving grounds in waters offshore Georgia and north Florida (Kraus *et al.* 1986). This research on right whales includes aerial surveying and monitoring of movements and distribution; population status reports; species overviews; calving, feeding, and mortality studies; and taxonomy (Kraus *et al.* 1988; Kenney *et al.* 1986; Schaeff *et al.* 1991). In *Endangered Right Whales of the Southwestern North Atlantic,* Kraus *et al.* (1993) summarize sightings and survey data dating back to 1984 in this critically-important area off Georgia and north Florida.

Other Species. Protected fish and bird species are also found in the study area. The endangered short-nose sturgeon, *Acipenser brevirostrum*, is an anadromous species that migrates from shelf waters into coastal rivers to breed. A few studies concern the biology and ecology of the short-nose sturgeon as well as the fishery status and management (Smith 1985; Smith *et al.* 1984). Protected bird species that frequent the area include the bald eagle, peregrine falcon, and piping plover (Sandifer *et al.* 1980; Minerals Management Service 1992).

3.4.3.12 Benthic habitats

The definition and distribution of hard-ground and artificial-reef habitats in offshore environments are major areas of concern for this study. Hard grounds, known also as hard-bottom or live-bottom areas, are the primary habitat areas on the continental shelf in the study area. Although the sandy seabed of most of the shelf is also inhabited by a variety of benthic organisms, hard-ground regions provide natural habitat for large communities of fish and invertebrates. According to VanDolah (1984a), hard grounds often "support dense assemblages of sponges, corals, and other invertebrates. As a result, these biological resource areas attract many important fishes such as black sea bass, porgies, snapper, and groupers."

Both the ecological and economic value of the hard-bottom areas are limited by their distribution. Creation of similar habitats through the construction of artificial reefs is now an effective and popular method for increasing and concentrating populations of certain fish species.

Hard Grounds. The interest in oil exploration on the outer continental shelf during the late 1970's and early 1980's produced many investigations of hard-ground regions in the South Atlantic Bight. Several pre-leasing environmental impact studies included surveys of the hard grounds/live-bottom areas, in part to protect the fishing interests in the region. The Gray's Reef National Marine Sanctuary, thought to represent a typical hard-bottom area within the South Atlantic Bight, was established offshore Sapelo Island, Georgia (National Oceanic and Atmospheric Administration 1980).

Habitat studies in the South Atlantic Bight concentrate on various aspects of fish-seafloor-nutrient interrelationships, including bathymetry, community composition, population densities, bottom topography, fishing-gear methods, stock assessment, and management (Chester *et al.* 1984; Wenner 1983; Gettleson 1981). A regional database of the location and distribution of hard-bottom areas off South Carolina and Georgia is being established by compiling all existing data into a GIS-format for the South Atlantic Area Monitoring and Assessment Program (Idris and Henry 1994).

Most references that describe hard grounds (Wenner *et al.* 1983; Sedberry and Van Dolah 1984; Parker 1990) also discuss Waves, Tides, and Currents (Section 3.4.1.2); Bathymetry and Seabed Morphology, and Stratigraphy (Section 3.4.1.3); Miscellaneous Macroinvertebrates (Section 3.4.3.7); and Fish (Section 3.4.3.9).

A considerable amount of information regarding live-bottom areas throughout the region exists as unpublished data. The Reef Research Team, a volunteer group of SCUBA divers, has compiled a database from studies offshore northeast Florida (White, pers. comm. 1994). The Florida Department of Natural Resources, working with SEAMAP and universities, is collecting data and specimens from the benthic communities of northeastern Florida (Donaldson *et al.* 1992). Additional unpublished data exist about the hard-ground habitats offshore Georgia can be found at the Coastal Resources Division of the Georgia Department of Natural Resources (Ansley, pers. comm. 1993). Unpublished data and collections of marine organisms for Gray's Reef National Marine Sanctuary are located at the Natural History Museum (Athens, Georgia) and at the Marine Extension Service (Savannah, Georgia) of the University of Georgia. In 1993, the South Carolina Wildlife and Marine Resources Division began a study of fish populations at Gray's Reef National Marine Sanctuary for NOAA; however, no reports are published to date (Bohne, pers. comm. 1994).

Artificial Reefs. In the past two decades, artificial reefs have been placed at numerous sites offshore Georgia, South Carolina, and northern Florida. Artificial reefs, constructed of materials such as concrete slabs and blocks, sunken barges, and scuttled Liberty ships, create effective fish spawning and nursery habitats (Loughry 1977). Artificial reefs provide economic benefits through the harvest of fish by recreational and commercial fishermen. The sport diving industry also benefits from the reefs. Coastal natural resource management agencies of the three states operate programs that coordinate the installation, use, and monitoring of artificial reefs. The Georgia program is designed primarily with recreational fishing in mind, and has resulted in the creation of a multitude of reef sites that mirror and supplement functions of natural reef habitats.

Many references deal with management-related topics such as reef construction guidelines and materials, economic benefits of reefs, and use of reef sites (Sheehy 1982; Liao and Cupka 1979a; Myatt 1978; Bell *et al.* 1989). Several studies report on aspects of fish and invertebrates found on artificial reefs, including populations, food and feeding behavior, communities, and site colonization (Low and Waltz 1991; Wendt *et al.* 1989; Gilligan 1987). The construction and use of nearshore, shallow-water Fish Aggregation Devices is also discussed (Rountree 1990). Annual reports are produced by natural resource management agencies that operate artificial reef programs; however, few such reports are published. Some references are discussed also under Miscellaneous Macroinvertebrates (Section 3.4.3.7), Fish (Section 3.4.3.9), Commercial Finfish Fisheries (Section 3.4.4.2), Recreational Fisheries (Section 3.4.4.3), and Resource Management and Use (Section 3.4.4.4).

3.4.4 Socioeconomic environment

The socioeconomic literature concerns aspects of environmental systems relating directly to the societies and economies in coastal plain regions adjacent to the study area. Most of the information pertains to commercial and recreational fisheries. Commercial fisheries references are placed into two categories — Shellfish and Crustacean (Section 3.4.4.1) and Finfish (Section 3.4.4.2). Sport fishing references, including the charterboat and headboat industries, are evaluated as recreational fisheries (Section 3.4.4.3).

Most of the remaining references address management and use of coastal and other marine resources. The references describing Resource Management and Use topics are divided into four subcategories as follows: General Coastal Management, Beaches, Ports and Navigation, and Pollution. The topic Cultural Resources (Section 3.4.4.5) addresses archeological and historical aspects of offshore areas.

3.4.4.1 Commercial shellfish and crustacean fisheries

In the Georgia Bight, the dominant commercial fishery is the crustacean fishery, primarily comprising shrimp and crabs. Of less importance is the molluscan fishery, including clams, oysters, whelks, and calico scallops. Organisms that inhabit estuarine areas — hard clams, oysters, and blue crabs — were not included in the literature search and analyses. Less than 10% of the blue crab catch in Georgia occurs offshore, primarily as bycatch in nearshore beach areas by the shrimp and conch fisheries (Gore, pers. comm. 1993). The shrimp fishery offshore Georgia includes white, brown, and pink penaeid shrimp, as well as rock shrimp (Wenner and Stokes 1984).

Most of the references in this category concern surveys, landings statistics, economic analyses, and management plans of the shrimp fishery (Music 1979; Marsh 1986). The effect of the turtle excluder devices (TEDs) upon shrimp catches is tested and reported by Christian and Harrington (1987). Similar devices are being tested in efforts to reduce the by-catch of fish by shrimp boats (Rulifson *et al.* 1992). The development and status of the whelk fishery is documented by Anderson and Eversole (1984). Other less common organisms of the shellfish fishery, such as octopus, squid, calico scallops, and blood arks are the subject of some investigations (Whitaker *et al.* 1991; Whitaker 1980).

The Coastal Resources Division of the Georgia Department of Natural Resources maintains a database of historical landings for all of these fisheries. The Marine Resources Division of the South Carolina Wildlife and Marine Resources Department and the Florida Department of Natural Resources also maintain databases of historical landings for crustacean and shellfish fisheries.

3.4.4.2 Commercial finfish fisheries

The commercial finfish fishery has developed slowly on the Georgia Bight continental shelf, in part due to the predominance of the shrimping industry and to supply and demand economics. A motivation for developing new fisheries and techniques is to reduce economic impacts of seasonality on shrimpers (Christian and Harrington 1985).

Commercial black sea bass fishermen use fish traps and hydraulic and/or electric reels with baited hook and line (Low 1982). Except for shallow-water shark fishing, most longline fishing is restricted to deep waters beyond the continental shelf. Trawling with roller-rigs has also been employed, but is now prohibited on hard-bottom areas (Van Dolah *et al.* 1987).

The literature in this category pertains to a few topic areas — population/stock assessments, cruise reports and landings data, regulations and management plans, and fishing methods and gear (Huntsman and Waters 1987; Ulrich *et al.* 1979). Most of the references consist of gray literature produced by state natural resource management agencies and by the NMFS. Fishery research by state natural resource agencies sponsored through MARMAP and SEAMAP occurs throughout the study area (Barans 1983; Wenner *et al.* 1980; Stephan 1991; Beatty and Wenner 1991). Management plans for fisheries are produced by the South Atlantic Fisheries Council and by Atlantic States Marine Fisheries Commission. Remaining references describe a range of studies, such as unpublished cruise reports — 60 of which were recovered and abstracted from data sets at the University of Georgia Marine Extension Service Fisheries Research Station (Harding 1993; Rawson 1983). Table 6 lists many references in this category. Related references are also evaluated under Fish (Section 3.4.3.9) and Recreational Fishing (Section 3.4.4.3).

3.4.4.3 Recreational fisheries

Fishing is a popular form of recreation as indicated by the number of marine recreational anglers active in the waters offshore South Carolina, Georgia, and northeastern Florida. The number of saltwater sport fishing enthusiasts grew dramatically over the past two decades, reaching about 35 million nationally (Schmied and Burgess 1987). In the southeastern United States, the recreational catch accounts for a third of the finfish that are caught for food. Furthermore, the economic return to the coastal communities from the sale of supplies, charter of boats, and direct and indirect revenues is substantial, and the economic importance of the saltwater recreational fisheries is significant in all three states in terms of income, employment, wages, and taxes generated (Clepper 1979; Taylor *et al.* 1982). As previously noted, artificial reefs are installed by the states of South Carolina, Georgia, and Florida to serve as habitats for sportfish species.

The references are characterized by gray literature produced by the natural resource agencies of adjacent states as well as by NMFS and associated Federal organizations. The major discussion topics are assessments and descriptions of fishing industries, surveys of landings, fishing guides, management plans, and regulations (Moore 1977; Pafford and Nicholson 1986; Stroud 1982; South Atlantic Fishery Management Council 1990a,b; 1992). References pertaining to the biology and ecology of species important to recreational fisheries are discussed under Fish (Section 3.4.3.9). Some references that discuss commercially harvested species are evaluated under Commercial Finfish Fisheries (Section 3.4.4.2).

3.4.4.4 Resource management and use

References pertaining to the management and use of other marine resources are evaluated in one of the following categories: General Coastal Management, Beaches, Ports and Navigation, and Pollution. The references included under General Coastal Management concern large-scale studies on a state-wide or regional level, such as regulations for coastal resource management. Literature in the Beaches, Ports and Navigation, and Pollution categories is typically site-specific.

Generally, most of the references concern activities that occur in nearshore areas, and estuarine and riverine regions. As such, the significance of many of the references to offshore environments is either limited or not well-defined. These references were not reviewed by this study.

General Coastal Management. Each of the states adjacent to the study area have natural resource agencies responsible for management of the coastal and marine areas within their jurisdiction. State-managed offshore waters extend to 3 nautical miles (nmi) from the shore. Federal jurisdiction, which historically extended to 12 nmi, was recently extended to 200 nm with the creation of the U.S. Exclusive Economic Zone (EEZ) in 1983 (National Research Council 1992). State regulations, therefore, address management of inshore coastal resources more so than the management of offshore resources. Florida and South Carolina participate in the Federal Coastal Zone Management (CZM) program. Georgia is not yet a member, however, and is currently developing a draft CZM plan in an effort to join the Federal program.

General Coastal Management pertains to natural resource management policies and practices in the nearshore zones of states adjacent to the landward boundary of the study area. References in this category include marine, estuarine, and terrestrial topics, and focus on coastal and ocean resource management plans, regulations, and legislation. References include details on the Florida coastal management program, information on the development of marine resources and the subsequent economic impact to the southeastern states, details on the South Carolina coastal program, and the identification of research needs in marine economics (Graber 1986; South Carolina Coastal Council 1979; Christie 1992). Cocker (1993) reports on the development of a geographical information system (GIS) to support data processing in management of Georgia's coastal and marine resources.

The gray literature includes references on managing protected marine areas, primarily Gray's Reef National Marine Sanctuary. Management plans, environmental assessments, and regulations are among the topics of these references (National Oceanic and Atmospheric Administration 1983). Many of the barrier islands and estuarine areas on the landward boundary of the study area are protected by private, state, and Federal management programs. Most references that discuss these islands are not evaluated by this analysis.

The use and protection of coastal resources are the subjects of educational materials produced for the public. Most of these references are specific to activities outside the study boundaries, and, therefore, they are not considered here. A few references, however, pertain to public use and understanding of resources within the study area (Shelander 1977). The number of educational publications produced by Sea Grant programs and by natural resource agencies varies significantly among the three states. South Carolina and Florida programs have produced much more public outreach materials about coastal and marine resources than have Georgia programs.

Beaches. References in this topic pertain to various aspects of beach and shoreline investigations on barrier islands on the western boundary of the study area. References describing tidal inlets and associated processes are also evaluated in this study. Although these references do not relate directly to the concerns of this study, beach-related literature is, at the very least, important to coastal managers. Specific references discuss beach erosion, erosion control efforts, shoreline management policies, sea-level changes, coastal engineering (beach nourishment and bank stabilization), water quality, shore-and-dune protection policies, and use of dredged material for beach nourishment (Griffin and Henry 1984; Anders *et al.* 1990; Kana 1981; U.S. Army Corps of Engineers 1981; Daniels 1992; Clayton *et al.* 1990). Related references are considered under Physical Oceanography (Section 3.4.1.2) and Geology (Section 3.4.1.3).

Ports and Navigation. The major coastal ports of the study area are Charleston, South Carolina, Savannah and Brunswick, Georgia, and Jacksonville, Florida. Navigation-channel dredging in rivers, harbors, and shallow, nearshore-shelf waters is necessary for passage of deep-draft ships into the ports. Due to the shallow slope of the inner shelf, dredged navigation channels, usually over 40 ft deep, may extend offshore for several miles. Many references describe major dredging activities at Brunswick and Savannah. Several United States Navy bases along the coast, such as bases at Charleston, Kings Bay (Georgia), and Mayport, Florida, also require deepening and maintenance dredging of navigation channels. The Kings Bay Trident Submarine Base, in particular, requires dredging activities at the

Georgia-Florida border. Studies of those activities are numerous and are usually funded through the U.S. Navy for implementation by the National Park Service and the U.S. Army Corps of Engineers. The shipping traffic associated with ports and military facilities constitutes a major use of the coastal waters of the study area.

Other references concern managing and maintaining port facilities, navigational access, regulations from local, state and Federal agencies, economic impact of locating military-port facilities in the coastal area (e.g., Kings Bay), waterways, navigable river systems, recreational aspects, shipping statistics, and economic aspects associated with port development and activity (U.S. Army Corps of Engineers 1985, 1986, 1990, 1991; Cofer-Shabica 1991). The U.S. Army Corps of Engineers produces navigation and port-related publications as part of its responsibility to manage and maintain navigable waterways, primarily through dredging projects. The U.S. Coast Guard is responsible for enforcing most of the Federal and some of the international laws that apply to pollution from sea-going ships [e.g., International Convention for the Prevention of Pollution by Ships (MARPOL)] and other hazards to navigation in the region (U.S. Coast Guard 1985). Data on navigation incidents, such as sinkings and collisions, are also compiled and reported by the U.S. Coast Guard. The United States Environmental Protection Agency (EPA) is responsible for managing and monitoring ocean dredged material disposal sites (ODMDS) in the study area (e.g., Noakes 1987, 1991a,b; EPA 1983, 1986, 1988)

Pollution. For this study, pollution is defined as the introduction of anthropogenic materials into the atmospheric and marine environments of the shelf through transport by air and/or water. Measuring and monitoring the processes affecting the transport and fate of pollutants is a major purpose of the DOE-sponsored work in the South Atlantic Bight (Menzel 1993). The BLM-sponsored studies of the late 1970's typically address the potential threat of pollution during the exploration and recovery of oil-and-gas resources. Additional research regarding pollutants in the study area is sponsored by the NMFS, the National Weather Service, U.S. Environmental Protection Agency (EPA), and the U.S. Coast Guard.

Major discussion topics include the atmospheric transport of pollution, hydrocarbons in shelf waters, bioaccumulation in organisms on the shelf, ocean disposal of dredge spoil, monitoring, and regulation (Windom and Smith 1985; Tanaka *et al.* 1980; Lee 1979; Braddon and Sumpter 1981; Gillespie and Harding 1988; Vernberg *et al.* 1981).

Major references address a range of pollution-related topics, such as

- General aquatic pollution problems on the southeastern U.S. coastline (Overstreet 1988),
- Behavior and fate of pollution (overstreet 1988),
- Occurrence and distribution of pelagic tar in shelf waters (Van Dolah *et al.* 1980),

- Modeling of oil spill trajectories (Lanfear and Amstutz 1981), and
- Biological, chemical and biogeochemical monitoring of marine pollutants, including short and long-term ecological effects (Overstreet 1988; Turner 1992).

Other references containing data on the composition, transport, and fate of pollutants on the Georgia Shelf are evaluated under Water Masses (Section 3.4.1.2), Sediments and Sediment Transport (Section 3.4.1.3), and Water Column (Section 3.4.2.1).

3.4.4.5 Cultural resources

Cultural resources within the study area are defined, for this study, as archeological artifacts and historical items located on or within the continental shelf. The few references in this topic indicate the lack of attention paid to such resources in the Georgia Bight.

Environmental impact statements and geophysical surveys associated with oil-and-gas development in the South Atlantic Bight provide sources of archeological data on the shelf (Antoine and Cain 1979; Hudson 1979). Science Applications, Inc. (1981d-g) reports the results of an extensive literature search and survey of cultural resources in the South Atlantic Bight. This BLM-funded study is the most recent regional effort to characterize the archaeological resources offshore in the study area. A similar study by the Virginia Institute of Marine Science (1974) provides an earlier baseline of such information for this region. However, this study is not included in the database due to its pre-1977 date. Refer to Table 4 for information concerning the 1981 archeological survey.

Between ca. 1520 and 1865, approximately 5,000 shipwrecks occurred along the Georgia and South Carolina coasts, including riverine and estuarine areas as well as offshore regions (Spence 1984). Amer (1992) describes a nineteenth-century vintage watercraft found lodged in the sands of Hunting Island beaches. A survey of hangs and obstructions along the southeastern U.S. coast provides recent data regarding possible wrecks (McGee and Tillet 1979).

Much of the coastal archeological research from Georgia and South Carolina remains unpublished. Judy Woods, archeologist with the Savannah District of the U.S. Army Corps of Engineers, maintains a database on underwater archeology, including a report of resources in the waters of Chatham County, Georgia (Woods, pers. comm. 1993). The South Carolina Institute of Archeology and Anthropology produced a few in-house reports regarding wrecks in offshore shelf waters (Amer, pers. comm. 1993). The Automated Wreck and Obstruction Information System, an electronic database of information on wrecks and obstructions in U.S. coastal waters, is maintained by the NOAA National Ocean Service for a variety of users such as fishermen, divers, and researchers.

Archeological research in this region does not focus on offshore areas. Riverine and estuarine shipwrecks receive more attention than marine wrecks because the inshore wrecks are more accessible and more exposed to potential vandalism, than are the offshore wrecks in deeper waters (Amer, pers. comm. 1993). Although archeology is one of the more obvious data gaps identified in the study, the legal need to conduct site-specific archeological surveys prior to commencing any OCS mining activity should address this subject on a case-by-case basis.

4.0 ANALYSIS OF MODELS

Literature describing models of processes and systems of the Georgia shelf environments is analyzed in this section. Regional and site-specific models that have been proposed for the Georgia Shelf are highlighted. The applicability of the models is discussed with emphasis on strengths and weaknesses. Models are of particular interest because of their possible use in characterizing and predicting environmental effects of marine mining activities.

References that describe, create, and/or apply models were located during the comprehensive literature search and also during searches designed specifically to locate models. The applicable references are cited in the study database. However, these references are not tallied or evaluated within the specific topic categories discussed in Section 3.0, and are not considered during the summaries of the extent of information. The following analyses of physical and biological models will aid in the evaluation and identification of data gaps in Section 5.0.

4.1 Guidelines and Methods

The temporal, geographical, and content criteria of this study, as described in Section 1.0, were used to identify and recover the model references. Additional criteria were (1) the type of model, (2) the applications within the paper, and (3) the geographical areas of application. Any reference of consequence regarding the potential effects of marine mining operations is of particular interest.

4.2 Review of Physical Models

Physical models reviewed during this study are summarized in Table 8.

4.2.1 Historical reviews of physical models

Jaycor (1980) reviews the physical oceanographic models and sediment transport models pertaining to the South Atlantic Outer Continental Shelf. After having completed qualitative and quantitative reviews of more than 1200 models, Jaycor concludes that highly theoretical models on ocean circulation are of little use due to the complexity of the water movements in the shelf region. Jaycor also concludes that the database extant in 1980 is inadequate for defining boundary conditions or for driving

Table 8. Summary of Selected Physical Model Studies.

Topic	Reference(s)	Types of Models	Objectives	Experiments
Density Fronts - Formation, Maintenance, Breakdown	Oey (1986)	Two-dimensional, cross-shelf/depth, time-dependent numerical model	To describe winter physical processes that aid formation and maintenance of density fronts by intrusions from Gulf Stream.	Model run 30 days w/forcing by atmospheric conditions of cold air outbreaks and model results determined for shelf break and shelf fronts.
	Oey *et al.* (1987)	Simplified, semi-empirical model derived from Oey (1986)	To describe transient shelf-break upwelling after southward wind event and to correlate wind forcing with the observations.	
	Blanton *et al.* (1989)	Two-dimensional, cross-shelf/ depth, time-dependent numerical model	To illustrate the effects of local wind stress on frontal zones.	Predicts the start of mixing stratification, and offshore advection of low salinity water.
Circulation of Water Masses	Blumberg *et al.* (1981) Blumberg and Mellor (1983) Kantha *et al.* (1986)	General Circulation Model (three-dimensional time-dependent	To characterize circulation in the South Atlantic Bight using numerical models and data and to assess the ability of the models to predict fates of oceanic pollutants.	Used in the diagnostic and prognostic mode to depict flow of Gulf Stream and of currents on shelf using historical data from NOAA and Skidaway.

Table 8. Summary of Selected Physical Model Studies *(continued)*.

Topic	Reference(s)	Types of Models	Objectives	Experiments
Gulf Stream Boundary Conditions and Circulation	Blumberg *et al.* (1981) Kantha *et al.* (1982) Kantha *et al.* (1986)	Characteristic Tracing Model (CTM-81)	To provide the ocean boundary conditions for the General Circulation Model by deducing transport and currents using wind stress fields. To determine total transport in the South Atlantic Bight by integration of geostrophic equation for total transport along contours of constant planetary potential vorticity.	Used in the diagnostic mode in deducing the Gulf Stream and circulation for application in General Circulation Models. Used in the diagnostic mode in calculations of 4 boundary conditions, but wind stress and bottom friction are excluded. Is not accurate on shelf.
Winter Circulation (Tidal)	Wang *et al.* (1984)	Single-layer (vertically integrated) two-dimensional model (w/finite element method). Extends results of Schwiderski (1980), Battisti and Clarke (1982).	To predict flow of tidal-driven currents in the South Atlantic Bight in vertically homogeneous winter conditions. To test earlier findings on shelf transport.	M_2 tide is simulated by model. Simulation of tides for 23 March 1980 is compared with GABEX-I data.
Winter Circulation (Wind)	Kourafalou *et al.* (1984)	Single-Layer (vertically integrated) two dimensional model (w/finite element method) From Wang *et al.* (1984)	To study wind-driven flow in the South Atlantic Bight during winter and predict patterns of flow.	Examined the effect of wind, tides, along-shelf slope forcing by comparison of particle trajectories of each. Evaluate the vertically integrated momentum balances at midshelf.

Table 8. Summary of Selected Physical Model Studies *(continued)*.

Topic	Reference(s)	Types of Models	Objectives	Experiments
Summer Circulation	Lee *et al.* (1982)	Steady-state diagnostic vorticity balance model by Galt (1975) using the finite-element method	To depict mean flow conditions of shelf occurring on time scales of two weeks or more. [Limited to predicting mean flows in mid-shelf region (20-40 m)]	CTD and wind data collected July, 1977 were input to model. Computed the vertical velocity profiles and the volume transport for upper and lower layers.
Summer Circulation (Upwelling)	Lorrenzzetti *et al.* (1988) Lorrenzzetti *et al.* (1987) Lorrenzzetti *et al.* (1986) Lorrenzzetti (1986)	Two-layer finite element model derived from Wang and Connor (1975) Extends results of Kourafalou *et al.* (1984), Lee *et al.* (1982), Galt (1975), Blumberg and Mellor (1983)	To create/test numerical model to describe summer circulation in the South Atlantic Bight. To predict the transport of water borne materials. To improve the understanding of dynamics of region.	Impulsive wind stress re: adjustment time of the South Atlantic Bight and flow. Transient real wind event hindcasting re: sea level, water column layers, shelf currents. Alongshore pressure gradient forcing of deep ocean on shelf currents.

Table 8. Summary of Selected Physical Model Studies *(continued)*.

Topic	Reference(s)	Types of Models	Objectives	Experiments
Freshwater Transport to Shelf	Zhang (1985) Zhang *et al.* (1987)	Steady state, two-layer analytical model	To describe steady flow in an estuary shelf-interaction region with two-layer density stratified flow including plume of freshwater from estuarine area.	Three cases on which model was run were: flat bottom case, sloping bottom offshore (no ambient flow alongshore), for effects of alongshore ambient flow.
	Bush (1988)	Three-source mixing model derived from Hayes (1979)	To determine the sources/relative composition of the waters of the inner shelf re: freshwater from upland vs. ocean waters.	Water samples analyzed for tritium and salinity levels that traced the levels of water from Ogeechee and Savannah Rivers and from the ocean.
Particulate Transport Over Shelf	Windom and Gross (1989)	Simple advection/diffusion model	To determine the distribution and cross-shelf flux of particulate aluminum.	Analytical use on data from SPREX.
Sediment Transport in Inlets and Harbors	Granat (1990) Granat and Brogdon (1991) McNally and Granat (1991)	Numerical modeling system to predict average currents and long-term average maintenance dredging requirements for the King's Bay submarine channel.	To identify the potential areas of sedimentation impact or change associated with Trident channel expansion.	Numerical model predictions of long-term average patterns of cohesive and noncohesive sedimentation in Cumberland Sound for Trident and pre-Trident channels.
Coastal Processes/Sediment Transport Nearshore	Vemulakonda and Scheffner (1987) Vemulakonda *et al.* (1988)	Coastal and Inlet Processes (CIP) Numerical Modeling System using the finite difference method	To determine the effects of dredging the navigation channel of the St. Mary's River inlet upon tides, waves, wave-induced currents, and sediment transport.	Four models are applied to a computational grid for a given set of conditions for tides, waves, wave-induced currents, and transport of sediments.

any of the models beyond a diagnostic state. Perhaps the most important conclusion reached by Jaycor is the need for final verification in all the models to support realism in the predictive mode.

Similar conclusions are reached by the National Research Council (NRC) during 1990 in an assessment of the MMS Environmental Studies Program. The NRC recommended that the MMS continue investigations of the physical oceanographic processes which are poorly expressed by existing models and further states that reliance on those models be curtailed until models are tested and verified in the field (Wilson 1993).

Partially in response to the Jaycor (1980) report, Dynalysis of Princeton was contracted by MMS to prepare an updated, oceanic circulation model covering the Atlantic coast and the Straits of Florida. This model was to be completed by the end of 1993 (Wilson 1993).

A comprehensive review of the use of predictive models to forecast dynamic events and their effects with regard to marine mining activities is provided in a recent report (Continental Shelf Associates, Inc. 1993). This study concludes that the only adequate models concerned with the critically-important aspects of suspended sediment plume dispersion and transport are those designed by the U.S. Army Corps of Engineers. These models describe plumes generated during the dumping of dredged material and are generally analogous to those created during a mining operation.

4.2.2 Review of physical models

A low degree of applicability exists between the models and any site-specific mining activities which might occur on the Georgia continental shelf. The reasons for the poor correlations are (1) either the models are too broad in scope in the case of the numerous shelf circulation models, or (2) if site specific, the location of the model is outside the study area as is the case in the majority of the sediment-related models.

The literature search identified some references for models involving bottom sediments and mass transport. These references include a process-response model for shoreline evolution based on wave refraction dynamics combined with historical bathymetric records (McCants 1980) and a numerical model of cohesive sediment transport (Scarlatos 1981). The latter model utilizes dispersion equations to predict the transport under simultaneous conditions of erosion and deposition.

Most of the reviewed models are of a site-specific nature. For instance, Stapor and Murali (1978) report upon the modeling of sediment transport along barrier island shorelines in South Carolina. Granat (1990) reports on model predictions of sediment redistribution associated with navigation channel expansion in the development of Kings Bay Trident Submarine Base. The latter is a model that was thought to be applicable in the advent of mining in the Georgia shelf, in which case sediments would be placed in suspension in the water column, dispersed with time and current strength and re-deposited over a wide area. Subsequent to the start of this study, however, this model proved to be inappropriate to this study due to verification difficulties.

Most models involving bottom-sediment movement and mass transport depend upon quantifying field measurements such as the critical stress necessary to initiate sediment transport. Understanding sediment transport requires an understanding of fluid dynamics as well as an understanding of the sedimentary environment. In the case of the latter, variables that are considered include grain size, shape, and density; weight of grain in the fluid; settling velocity; particle roughness; bed roughness; etc. Fluid dynamics is also complicated because turbulent flow, as opposed to laminar flow, must be considered (most natural flows that transport sediments are turbulent).

With respect to bottom-sediment transport studies, model development exceeds the state-of-the-art methods for gathering field data with which to drive the models. The greatest difficulty involves accurately measuring near-bottom effects of waves and currents, without which the knowledge of shear stresses at the boundary layer is incomplete. Prior to marine mining, data should be collected on the near-bottom currents in the proposed mining area. Energy fluxes controlling the suspension, entrainment, and transportation of sediments also must be described.

4.3 Review of Biological Models

In general, all of the papers that were examined relative to biological modeling deal directly with some aspect of coastal-shelf ecology in the continental shelf area of the Southeastern United States, if not Georgia waters in particular. The inclusion or use of modeling varies tremendously among these papers.

The modeling element of the studies differs in approach and purpose (i.e., the use and objective of modeling), form, theme, and complexity. The form, or mathematical style, ranges from being a simple empirical regression model to a complex set of coupled differential equations. The themes range from a focus on a selected biological population parameter virtually independent of the abiotic environment, to a focus on fine spatial-temporal scales of interactions between physical water motion and biology of the plankton community). Finally, the models differ in both conceptual and mathematical complexity, especially in the level of biological detail and in the interaction of biotic and abiotic variables.

None of the reviewed papers strongly relate to the environmental impacts that may be caused directly by marine mining activities. Direct environmental impacts would include modification of the immediate and surrounding benthic environment, with transient and long-term redistribution of particulate matter to both water column and bottom sediments. In general, the papers reviewed do not include any explicit interaction between sediment disturbance or modification of the water column particulate field and biological components or processes. Consequently, no models are available for use in assessing likely effects of a mining activity.

4.3.1 Parameters and topical areas considered in the analyses

The reviewed studies thus involve biological/ecological modeling to differing degrees. Moreover, they do not each present a model *per se*. Rather, they either (1) present a mathematical model intended to predict some aspect of a population or facet of ecology; (2) use modeling as a tool to develop greater understanding of the ecosystem of concern; (3) provide an empirical database useful for developing empirical algorithms (models) on selected, significant ecological processes; or (4) review the basis for conceptual, theoretical, and mathematical descriptions of selected, significant ecological processes.

The biological and ecological parameters that are predicted, used, examined, or discussed in the array of papers are numerous and varied. The different studies do not lend themselves to comparative evaluation or any usefulness rating exercise. Each study was examined on merit. A detailed review and critique of each study is not given here, but to aid discussion, the papers are loosely grouped according to four semi-arbitrary topic areas in Table 9. The four topic areas, not necessarily exclusive, are (1) population dynamics, (2) fishery yields, (3) shelf pelagic ecosystem dynamics, and (4) coastal and shelf ecosystem metabolism and material flows. The fourth topic includes modeling or other studies to examine and describe the role of certain biological species (or trophic groups) or biological processes.

For each topic area and reference, Table 9 also provides an overview of the study's theme relative to modeling, the main biological components or parameters, and the environmental features, if any were explicitly included in the analyses or modeling.

4.3.2 Types and functions

In spite of the lack of direct applicability, aspects of different model "types" are considered below to illustrate some salient features. The overview is intended to provide a sense of the modeling analyses that have been performed relative to biological aspects and ecological questions of previous interest and relevance to the study area.

Table 9. Summary of Selected Biological/Ecological Studies.

Topic	Reference(s)	Theme or purpose relative to modeling	Major biological components and/or parameters	Major environmental aspects considered
Population dynamics	Richardson (1982); Crouse *et al.* (1987)	Simulation of a population of sea turtles over time	Loggerhead sea turtles nesting on Little Cumberland Island, GA; fecundity, clutch frequency, clutch size, emigration	None
Fishery yield	Matheson and Huntsman (1984)	Description of growth, mortality, and yield models for two fish species	Speckled hind and snowy grouper off North and South Carolina	None
	Lam *et al.*, 1989	Forecast of shrimp yields by empirical model fit to data	White shrimp landings in South Carolina	Temperature, salinity, rainfall, river discharge
Shelf ecosystem pelagic dynamics	Ishizaka and Hofmann (1988); Hofmann and Ambler (1988); Hofmann (1988)	Simulation of the influence of Gulf Stream frontal eddy and bottom water intrusions on biology	Phytoplankton and zooplankton, productivity, and trophic structure	Water motion, temperature, light, nutrients, detritus
	Ishizaka (1990a-c); McClain *et al.* (1990)	Simulation of chlorophyll distributions in the southeastern Continental Shelf waters	Phytoplankton, zooplankton	Water motion, temperature, light, nutrients, detritus

Table 9. Summary of Selected Biological/Ecological Studies *(continued)*.

Topic	Reference(s)	Theme or purpose relative to modeling	Major biological components and/or parameters	Major environmental aspects considered
Ecosystem metabolism and roles of biology	Pace *et al.* (1984)	Simulation of shelf food web	Phytoplankton, zooplankton, fish, benthos, detritus; energy transfer between components	Dissolved organic matter, detritus
	Newell and Christian (1981)	Prediction of bacterial growth rate from frequency of dividing cells	Bacteria	Temperature, nutrients
	Hopkinson *et al.* (1989)	Simulation of interactions between bacterial food source quality and bacterial production	Microbial heterotrophs, role of microbes in ecosystem metabolism	Nutrients
	Ambler (1986)	Model of food ingestion by zooplankton	Zooplankton (*Paracalanus*), phytoplankton	None
	Hofmann *et al.* (1981)	Model of zooplankton fecal pellet production	Zooplankton, transfer of matter from photic zone	None
	Paffenhöfer (1988)	Review of zooplankton feeding behavior	Zooplankton	None
	Hopkinson (1987)	Benthic nutrient flux measurements	Benthos, role of sediment nutrient recycling in ecosystem metabolism	Temperature

4.3.2.1 Population dynamics studies

Two papers deal with the population dynamics of threatened loggerhead sea turtles that nest in and around Little Cumberland Island, Georgia (Table 9). The two papers involve different formulations to simulate the population size over time. Both use data or assumptions on various population parameters such on fecundity, mortality, and remigration of adults to nesting areas. Crouse *et al.* (1987) offer the more sophisticated and biologically detailed model, based on a common theoretical population model approach, and they use sensitivity analyses of the model to suggest life stages and parameters that may be highly influential in determining population size.

No explicit consideration was given to environmental factors and how they could affect survivorship, fecundity, etc. In principle, if the relationship between environmental factors and such parameters was understood, one might be able to develop a first-order estimate of the potential sensitivity of the population to environmental changes using a model of the type described by Crouse *et al.* (1987). This is not to say that either model has been validated as a predictive tool for the Little Cumberland Island population, but merely that the relative sensitivity to perturbations of different life stages and population parameters could be investigated.

4.3.2.2 Fishery yield studies

Two papers examine aspects of a species' fishery yield. Matheson and Huntsman (1984) use data from landings to derive mortality rates, from which a standard yield-per-recruit model is used to estimate the potential yield of two fish species caught off the Carolina coast. Primarily, their emphasis is on whether the species was being overfished, i.e., fishing mortality was at a level high enough to reduce recruitment to a theoretical level that suggests a declining population will result from overfishing. There is no explicit consideration of environmental factors in this type of modeling. The basic modeling method used is common and rather generic for fisheries, but the Matheson and Huntsman (1984) model is strictly parameterized for the available time series of data on the two species.

Lam *et al.* (1989) develop a stock-recruitment relationship for the white shrimp off an area of South Carolina. Their purpose is to develop harvest (yield) forecasts of the fall white shrimp harvest (the main fishing period) based on spring landings, modified by environmental conditions during the year. Inclusion of salinity (in August) in the model improves the empirical fit of model and data observations. This site- and data-specific type of model is used to provide a simple first-order predictor for future years, but does not address cause-and-effect, nor is it necessarily valid if environmental conditions change from conditions applicable during the period of data observations.

4.3.2.3 Shelf ecosystem pelagic dynamics

Seven papers explore a number of aspects of the physical-biological coupling on the outer southeastern U.S. continental shelf via modeling and data analysis of intensive studies conducted in the Georgia Bight (Table 9). The block of papers represents an extensive, detailed, and varied modeling effort, in general designed to enhance understanding of the relationship between plankton, physical processes, and nutrient fluxes on the continental shelf. The modeling exercises are varyingly used to (1) suggest and roughly quantify the environmental (physical and chemical) and biological influences shaping chlorophyll and phytoplankton distributions over time; (2) simulate how different types and frequencies of upwelling may regulate production and trophic structure of the plankton community, and (3) imply how the shelf ecosystem interacts (geochemically, in terms of nutrient and carbon flows) with inshore and offshore waters. The sophisticated modeling efforts — with their range of subtle differences in model structure, simulation detail, and intent — are too expansive to explore sufficiently under this task. At the risk of overgeneralization and surely without due justice to the effort, a few aspects of the papers are highlighted here.

The series of papers by Ishizaka and Hofmann (1988), Hofmann and Ambler (1988), and Hofmann (1988) are directed toward producing a coupled physical-biological model to investigate the biological response to different upwelling regimes along the outer southeastern U.S. continental shelf that is affected by the Gulf Stream. A physical model of temperature and flow is based on observations from current meter data for the specified region for several months during 1980 and 1981. The intent of the model, which uses an optimal interpretation scheme to derive flow over the whole field from measurements at selected grid points, is to simulate the effect of ocean water circulation on particle movements and trajectories across the outer shelf.

The physical model is coupled with a biological model. The biological model is a system of ten differential equations coupled as are the interactions between biological components (two phytoplankton size groups and several life stages of zooplankton) being simulated, where the components are connected by flows of nitrogen. This physical-biological model is essentially a state-of-the-art mass-balance model, where nitrogen flows between components as a function of a variety of processes (uptake, feeding, sinking, etc.), which themselves are influenced by the environmental conditions such as temperature, light, etc. The mathematical expressions of these interactions are similar to those now commonly used in marine or aquatic simulation models for many areas. As such, the model offers a nice review of how biological interactions in pelagic ecosystems have recently been conceptualized and expressed as mathematical functions. As in all such modeling efforts, the generic formulations must have coefficients defined for the unique application, and many of these are simply specified from field or laboratory experiments. Values for other functions are determined by gauging the time-dependent behavior of the model simulation (under prescribed sets of applied coefficients) relative to observed responses to physical events in the field obtained in other studies. The results of the model allow some fascinating insight into how the frequency and duration of physical upwelling may regulate the patterns of development of plankton patchiness and differences in the plankton community structure.

The coupled physical-biological model investigates spatial and temporal variability of lower trophic levels and the flows of nitrogen and carbon within the outer shelf pelagic ecosystem and between this ecosystem and adjacent offshore and inshore waters. As with the individual models, the simulation results are verified with field observations during the period being simulated. The authors note that the good agreement between model and data (and thus the degree of realism obtained) relates in part to the embedding of actual data (especially physical) in the model. A limitation of the model is its exclusion of the vertical dimension, in that it considers only a latitude-longitude plane at a certain water depth.

Further work with this modeling approach is described in the second series of papers by Ishizaka (1990a-c) and McClain *et al.* (1990). These papers investigate whether the simulation model can reproduce the detail of spatial-temporal variability in chlorophyll patterns that are detectable from high-resolution, synoptic remote-sensing images of chlorophyll patterns. The model is calibrated to observations at a small number of sampling stations, and seeks to enrich these observations by filling space and time gaps between the observations to present a dynamic observation. The modeling and analytical efforts in this series of papers are lengthy and contain many subtle experiments. Two general conclusions may be made: (1) the gross features of the chlorophyll spatial-patterns can be simulated, and (2) both the space and time variability produced by the models are more similar to the observations if the observed data can be assimilated into the model itself, thereby updating results over time.

The final paper (McClain *et al.* 1990) offers some sobering self-introspection regarding the biological models. A comparison of simulation model output with direct analyses of the remote-sensing variability suggests that the two approaches differ in their prediction of the relative (qualitative) significance of various physical and biological processes primarily shaping chlorophyll patterns. The difference is attributed to the propagation of errors in calculations that are introduced as a result of transient features and sharp gradients. In general, the model is less successful in depicting nature's finer details of pattern. Thus, not surprisingly, as the scale of the prediction relative to the scale of the observation increases, the model's faithful capture of pattern variability would seem to increase. Accordingly, the small-scale, site-specific aspects of a highly physically-dynamic environment are most difficult to simulate with confidence. This problem is not peculiar to this model. For example, regional climate (a gross-scale attribute) is easier to predict than weather at a specific location. Moreover, in spite of longstanding efforts to predict weather, probably the best predictor of tomorrow is today's weather, an observation pointing out the basic uncertainty of fine-scale prediction that is inherent with any dynamic system.

4.3.2.4 Ecosystem metabolism and material flow

Papers in this category concern metabolism, carbon, and nutrient cycling that generally focus on a particular biological component, such as microbes, zooplankton, or benthos. In general, these papers focus on specific biological processes, and many provide numerical formulations or tools to describe them (e.g., Newell and Christian 1981). Others use modeling as a pedagogical tool, for example, to demonstrate the importance of a microbial loop in pelagic ecosystem dynamics (Pace and Pomeroy 1984; Hopkinson *et al.* 1989). In total, they offer some valuable insights into some of the critical processes and important aspects of the biological structure that have been identified for Georgia coastal ecosystems. A paper by Hopkinson (1987) provides measurements that could be used to develop mathematical formulations of benthic nutrient flux, but presents no modeling.

With respect to microbial aspects, Newell and Christian (1981) developed a regression model relating several measurements that would in principle enable indirect estimation of bacterial growth rates. Pace and Pomeroy (1984) and Hopkinson *et al.* (1989) use simulation modeling to explain the possible significance of small heterotrophs in energy flow and material cycling.

With respect to zooplankton, Hofmann *et al.* (1981) present an analytical model of the concentration and flux of fecal pellets produced by zooplankton communities on the southeastern shelf. Their conclusion is that fecal pellet production and settling constitute only a very small portion of primary production. The authors suggest that this lack of a significant organic matter linkage between the water column metabolism and the underlying benthos may explain the presence of an impoverished benthos for this region. This type of model, often termed a process model, is also used by Ambler (1986) to derive some explicit formulations related to zooplankton ingestion. Ambler's model is used as a module within the pelagic ecosystem simulation modeling efforts described above. Paffenhöffer (1988) reviews zooplankton feeding behavior and comments on the lack of plasticity allowed by models for the zooplankton feeding response to changing conditions.

In general, the process models, as well as the coupled differential equation simulation models, are indeed rigid. They are deterministic in the sense that the model produces the same result every time it is run with the same conditions. To an extent, inclusion of stochastic elements (assigning a probability of an event actually happening) may provide greater realism. There are few stochastic elements to the models reviewed here.

4.3.3 Strengths, weaknesses, and needs for models and modeling

As suggested by the variety of reviewed studies, the use of biological modeling is varied and can serve different purposes, such as predicting, synthesizing, and integrating. Models may synthesize experimental results into a set of generalized descriptions formulated as mathematical expressions. Models also may integrate data or information from a complex set of interacting components in an effort to provide insight to the natural environment. The strength of the set of papers examined is that they provide a strong understanding of a number of the forces at play in Georgia shelf ecosystems, and thus help identify the critical features to be considered in any modeling effort that examines a specific area or a type of environmental change. Moreover, the different model styles illustrate the possible approaches and identify some of their limits to predict adequately.

As indicated earlier, none of the papers provide an on-the-shelf modeling tool that might be directly applied to an environmental impact resulting from marine mining on the continental shelf. However, some of the generic methodology may be used, depending on the identified application. In this sense, one does not model biology in the abstract, but a question must be posed and an appropriate modeling approach developed. This is precisely the genesis of most of the models reviewed. Some background questions relative to any biological modeling study are:

- Does a model reasonably represent a facet of biological phenomenon?
- What are the appropriate scales (time, space, ecosystem) for its application?
- Is it uncoupled from the complexity of the real world?
- Are its results able to be extrapolated?
- Is it intended as a predictive or an explanatory tool?
- If intended as predictive, what are the bounds of its predictability?

Levin (1988) discusses some of these elements and considers the prospects and challenges for biological modeling.

For the specific case of the Georgia shelf and mining activities, the biological models reviewed do not address some of the main concerns that should be considered with respect to impacts. First, these concerns would include perturbations of the benthic and demersal fish communities as a function of mining. None of the reviewed group of models focus upon these biological components alone, or include interactions with environmental influences. For benthic perturbations, the notions of projected scales of direct impact and the possibility for extended ecological effects must be considered in deciding on any modeling needs. Second, the list presented in Table 9 indicates that few models have explicitly focused on the interaction of particle fields and biology. The pelagic ecosystem simulations (e.g., Hofmann 1988) examined the influence of light on plankton, but a stronger and more wide-ranging consideration of the effects of changes in suspended matter concentration and flux must be included in any biological/ecological model relating to impacts by mining activities.

5.0 IDENTIFICATION OF DATA GAPS

For the purpose of this study, a data gap is defined as a lack of knowledge within a specific area of research or current understanding of environmental resources and processes. This assessment includes data gaps in

- Geologic, biologic, physical, and chemical processes on the shelf and in the subsurface of the shelf;
- Distribution of known and potential non-mineral resources on the shelf;
- Habitat distribution relative to shelf topography and oceanography;
- Environmental data pertinent to marine mining impacts, methods and site selection processes; and
- Information relevant to socioeconomic concerns.

5.1 Procedures and Methods

Section 2.4 described the scope and nature of references and provided the basis from which data gaps are identified and evaluated. The solicited responses of scientists and resource managers currently working on the Georgia shelf provided information useful for identifying specific data gaps. The Bureau of Land Management and Minerals Management Services baseline studies, environmental inventories and summaries cited in Table 4 and included in the study database were excellent frameworks against which to identify regional data gaps.

The identification of a data gap for a certain topic is based, in part, on the number of available references for that topic. A large number of references in any category, however, does not preclude existence of data gaps, because many references (i.e., abstracts, annual reports) may not enhance the state of knowledge. The type and content of the individual references are also analyzed for their applicability to the study. Other important factors which are considered during the data gap analysis are the scope and significance of the research and the pertinence to the study objectives.

5.2 Data Gaps in Research for the Georgia Bight

This study concerns only data published since 1977. The study authors' familiarity with the type and extent of research prior to 1977, however, provides a retrospective evaluation of the earlier research. The environmental inventory compiled by the Center for Natural Areas (1979), entitled *A Summary and*

Analysis of Environmental Information on the Continental Shelf and Blake Plateau from Cape Hatteras to Cape Canaveral identifies 189 data gaps for the South Atlantic Bight, many of which have not been addressed.

The data gaps significant to the assessment of non-mineral resources of the Georgia shelf are presented in Table 10. Each data gap implies a corresponding research need. Because much of the research is interdisciplinary in nature, individual data gaps may apply to more than one non-mineral resource in the study area. Those gaps specific to mining activities or impacts are discussed below.

5.3 Data Gaps Relating to Mining and to Site Selection

The identification of data gaps helps in selecting and setting priorities for specific research efforts needed to address concerns pertinent to potential mining within the study area. Such research efforts may be initiated prior to mining (e.g., site-selection criteria) or may be accomplished contemporaneously with mining (e.g., monitoring activities). Another important function is to gather data relevant to selection of the most appropriate mining technology. Data gaps specifically related to potential site-specific mining impacts are listed in Table 11; they are based on an analysis of the literature and on comments solicited from researchers in the South Atlantic area.

A major factor in identifying significant data gaps applicable to marine mining and site selection is that neither hard-mineral mining nor petroleum production have occurred in the Georgia Bight or the South Atlantic Bight. Therefore, in the study area, no prior experience exists on which to base data gaps and related research needs, except through analogy to other activities such as dredging and dredged-material disposal. The report by Continental Shelf Associates, Inc. (1993) on the synthesis and analysis of existing information regarding environmental effects of marine mining provides some information applicable to the Georgia Bight. That study identifies five major data gaps:

- Water quality modeling of the generation and dispersion of particulate and dissolved materials into the water column, based on, or at least confirmed by, empirical data acquired from marine mining operations;
- Effects to coastlines by significant alterations of the adjacent seabed;
- Understanding of the characteristics, behavior, and recolonization responses of organisms in various mine sites under the stress of production operations;
- Effects on coastal biota of processing discharges from on-shore mines; and
- Understanding the realities of mining in perspective with other natural processes and man-induced activities.

Table 10. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979]

Physical Environment

(1) Projections of potential effects of climatological change on the centers of high-pressure fields.

(2) Effect of northeasters/extratropical cyclones on nearshore sediment dynamics, water column processes, and water masses.

(3) Post-storm effects of hurricanes on physical, chemical, and biological processes across the shelf.

(4) Regional response of water masses/currents to large-scale wind forcing.

(5) Relationship between density-driven, wind-induced circulation in the inner-shelf frontal zone and the means by which circulation confines near-bottom particles and dissolved materials to the inner shelf.

✓ (6) Role of bottom currents on patterns, dynamics, and sediment-transport mechanisms across the shelf over broken bottoms and planar bottoms, and effects of sediment fluxes on benthic communities.

(7) Inwelling/advection studies of shelf-to-estuarine transport of organics and sediments, and interaction of estuaries with continental shelf circulation.

(8) Further quantification of levels, transport, and input of particulate and dissolved organic matter from rivers and estuaries to the shelf, including definition of sinks and sources of lignin with regard to shelf biological processes.

✓ (9) Fluxes in turbidity levels for periods of sediment suspension due to episodic events, such as storms, as compared to ambient conditions.

✓ (10) Hydrogeology, depth, and areal extent of the offshore Floridan Aquifer System.

✓ (11) Detailed imagery, bathymetry, and seabed characterization of the Georgia shelf.

(12) Degree and frequency of Gulf Stream intrusions into the central portion of the South Atlantic Bight shoreward of the 20-m isobath.

(13) Exchange rates and particle transformations through the life cycles of Gulf Stream intrusion events on the outer shelf.

(14) Processes responsible for cross-shelf diffusion of freshwater in autumn.

(15) The position, extent, and ages of relict shorelines of former sea-level stillstands since the late Pleistocene.

(16) The role of oxic sand sediments in the biogeochemistry of the shelf system.

✓ (17) The fate of high, suspended-particle loads in inner-shelf waters, especially in regard to the alongshore and cross-shelf transport mechanisms.

Table 10. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979] *(continued)*

Chemical Environment

(18) Transport and chemical exchange across the atmosphere/water/ sediment boundaries.

(19) Biogeochemical cycling within and between the water column and the sediments.

✓ (20) Chemical exchange processes associated with resuspension of sediments during normal (ambient) and high energy (storm) conditions.

(21) Levels, fluxes, and fates of point and nonpoint sources of organic and inorganic pollutants in coastal and shelf waters.

(22) Atmospheric contribution of particulate matter (organic material and trace elements) to the Georgia Bight.

(23) Significant trace-metal concentrations in the biota, sediments, and water column.

Biological Environment

✓ (24) Detailed investigations of shelf and shelf-edge live-bottom/hardground habitats.

(25) Sediment-microbial interactions regarding productivity, metabolic activities, and substrate relationships.

✓ (26) Laboratory modeling studies regarding turbidity effects on selected indicator biota.

(27) Population distribution and fluxes of microbes in water-column and benthic environments in response to physical and chemical factors, particularly after periods of disturbances.

(28) Benthic biological productivity on the shelf relative to substrate characteristics.

(29) Inwelling of larvae of commercial species from nearshore areas into estuaries, including abundances of larvae offshore versus abundances of adults in estuaries.

(30) Relationships between primary production and higher pelagic trophic levels.

(31) Effect of Gulf Stream intrusions and associated upwelling on primary and secondary productivity and offshelf transport.

(32) Quantification and relative importance of benthic ("new") production.

(33) Coupling mechanisms between the systematics and ecology of benthic invertebrates on the shelf and their role in sediment water column exchanges and processes.

(34) Regulation of population biology by meteorology and physical circulation.

Table 10. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979] *(continued)*

<u>Biological Environment (continued)</u>

(35) Relationships between tidal fronts and abundances of marine turtles.

(36) Effect of tidal outwelling of organic carbon and fine particles to photosynthesis in the inner shelf.

✓ (37) Migration route(s) of right whales from the northwest Atlantic to the Georgia Bight.

✓ (38) Responses of right whales to noise from shipping traffic, mining operations, etc.

✓ (39) Studies of other marine mammals, especially bottle-nosed dolphins and pygmy sperm whales.

✓ (40) Movements, distribution, and abundance of juvenile and sub-adult sea turtles.

✓ (41) Status of species of concern, including endangered and threatened species, commercial/recreational species, species-in-decline, and indicator species.

✓ (42) Data management system (Geographic Information System/electronic clearinghouse) to integrate information from different disciplines.

✓ (43) Long-term, process-response studies of the ecology of hard-bottom communities in inner-, middle-, and outer-shelf areas (e.g., effects of sedimentation).

(44) Ecology of macroalgal communities in inner-, middle-, and outer- shelf areas regarding rates of productivity, annual recruitment vs. year-round, multi-year populations.

(45) Stock status of sharks, including coastal and large pelagic species.

(46) Population size, distribution, and life history of whelks in nearshore habitats and for other shellfish species that may be targeted for new fisheries.

(47) Composition, distribution, transport, and fate of ichthyoplankton in shelf waters.

(48) Life history aspects for important commercial and recreational finfish species, and reef fish complexes, especially the snapper-grouper complex.

(49) Movements, distribution, population fluxes (breeding/transient), and ecology of pelagic seabirds and coastal marine birds.

✓ (50) Identification of unique and/or critical habitats for rare and depleted finfish species, especially in regard to designation of marine reserves.

(51) Harvest levels of offshore finfish species.

Table 10. Data Gaps Relative to Non-Mineral Resources of the Georgia Shelf. Items Checked (✓) Are Most Relevant to Marine Mining Activities. [After Center for Natural Areas, 1979] *(continued)*

Socioeconomic Environment

✓	(52)	Most probable locations for prehistoric habitation sites on the shelf and development of site-selection criteria.
✓	(53)	Determination of maximum levels of exploitive activities, such as mining and fisheries, to be allowed in order to maintain sustainable development.
	(54)	Socioeconomic responses to the decline of commercial and recreational fishing industries.
	(55)	Social research on the offshore recreational and commercial fisheries industries.
	(56)	Educational materials regarding offshore resources of the Georgia Bight to be used by the general public, planners, legislators, educators, etc.
✓	(57)	Management mechanisms for addressing conflicts between mining and non-mineral resources.
	(58)	Management structure for resolving resource-use conflicts between neighboring states.
	(59)	Assessment and prediction of cumulative effects of numerous individual development actions (planning, resource management, and permitting).
✓	(60)	Coastal ocean management policies and regulations for the State of Georgia.

Table 11. Data Gaps Relative to Potential Site-Specific Mining Impacts.

(1) Detailed information concerning the depth, areal extent, and hydrogeology of the Floridan Aquifer System.

(2) Distribution and abundance of live-bottom habitats.

(3) Effects of habitat modification on benthic communities.

(4) Recolonization of benthic areas after cessation of the mining operations.

(5) Effect of turbidity plumes on benthic and water-column biota.

(6) Effect of turbidity, acoustics, and pollution on marine mammals and reptiles.

(7) Predictive models for marine systems to forecast ecological impacts of mining.

(8) Effect of nearshore mining on beach erosion.

(9) Methods and mechanisms for resolving conflicting uses of mineral and non-mineral resources (e.g., mining, commercial and recreational fisheries).

These gaps identified by Continental Shelf Associates, Inc. (1993) are based on a number of mining technologies and mineral species, most of which are not applicable to the mineral and non-mineral resources of the Georgia Bight. Based on current levels of knowledge, the hard minerals of potential economic value on the Georgia Shelf are phosphate (Manheim, 1992) and, to a lesser extent, sand and gravel. Although current market conditions are not favorable for mining these resources in the near future, the need for these commodities is likely to increase as land sources decrease, become environmentally restricted, or, in the case of phosphate, politically strategic. These observations differ from the 1988 Zellars-Williams Company report that indicates a possible market entry for the Georgia phosphate deposits by the year 2000. In addition, the report hypothetically predicts a potential heavy-mineral resource in the mid-shelf region, but recent industry exploration efforts do not confirm this (Henry and Idris, 1992).

5.3.1 Marine mining methods and impacts

A summary of marine mining methods and their environmental effects on a worldwide basis is presented in Table 12. Of the three major mining techniques described, only two — excavating and fluidizing — are likely to be used in the Georgia Bight. Scenarios and descriptions of both methodologies are given in the 1988 Zellars-Williams Company report.

The excavating technique uses a cutter-head suction dredge to create an open pit on the sea floor. This technique significantly disrupts the benthic communities in the mined area. Plumes of suspended sediment created by this technique may significantly impact water-column biota and down-current benthic communities. Overboard disposal of tailings as waste products generated during beneficiation of the ore may also create water-column and seabed impacts. This technique is commonly used in other parts of the world and the potential impacts are reasonably predictable. However, the use and impacts of this methodology on the Georgia shelf are unknown.

The fluidizing, or bore-hole, mining technique has the greatest promise for minimizing environmental impacts because it causes relatively little bottom disruption and turbidity during a properly executed drilling operation. Drill holes are used to penetrate the seafloor and water is then pumped under pressure to fluidize the unconsolidated material into a slurry. This material is then transported to a surface container for beneficiation and ore recovery. The resultant waste material is pumped into the sub-seafloor cavity to prevent, or reduce, subsidence of the overburden. This process

Table 12. Summary of Operational Methods for Marine Mining and Their Environmental Effects [Adapted From Continental Shelf Associates, Inc. (1993) and Cruikshank *et al.* (1987)]

Operational Method	Description	Application	Known or Suspected Environmental Effects
MINING			
Scraping			
Dragline dredges[a]	Large dredge buckets scrape the material from the deposit surface and feed the loosened material into barges. Barges transport the material to shore.	Recover deep seabed phosphorite nodules and slabs; offshore mining; deep seabed sampling; construction.	Fragmentation/collection; turbidity plume; resedimentation; suspended particulates; dissolved substances
Trailing suction hopper dredges[a]	Slurry of bottom water and sediment is pumped through a pipe to the mining vessel/hopper. As sediment accumulates in the hopper, the excess water containing fine suspended material is decanted overboard. Mines while in motion, creating numerous shallow trenches (1-m wide × 0.3-m deep) in the seabed.	Maintain harbor channels; mine sand and gravel in water depths to 45 m	Fragmentation/collection; turbidity plume; resedimentation; suspended particulates; dissolved substances
Continuous line bucket (CLB) dredge systems[b]	Consists of a series of dragline buckets operating in a continuous loop. May operate by one vessel or between two vessels.	Proposed for mining shallow deposits in coastal areas or sheltered waters, and for cobalt crust mining.	Fragmentation/collection; turbidity plume; resedimentation; suspended particulates; dissolved substances
Excavating			
Clamshell buckets	Buckets are mechanically actuated buckets that excavate material from the seabed. Best suited for excavating large-sized granular material where positioning accuracy and cleanup are not concerns.	Used to mine sand and gravel (offshore Japan) and tin (Thailand), and to sample phosphorate (New Zealand).	Excavation scarring; turbidity plume; resedimentation; suspended particulates; dissolved substances

Table 12. Summary of Operational Methods for Marine Mining and Their Environmental Effects [Adapted From Continental Shelf Associates, Inc. (1993) and Cruikshank *et al.* (1987)] *(continued)*

Operational Method	Description	Application	Known or Suspected Environmental Effects
Bucket ladder dredges	Consists of a chain of digging buckets mounted over a supporting arm or ladder. Very efficient for excavating deposits containing boulders, clay, tree stumps, weathered bedrock, etc. Water discharge limited to what is needed to concentrate the placers or deposits. Produces considerable turbulence.	Used to mine gold, platinum, and tin placers, and diamond deposits, and to clear harbors. Used in water depths <20 m.	Excavation scarring; suspended particulates; dissolved substances
Bucket wheel suction dredges	Uses a small-diameter bucket wheel mounted on a suction ladder to excavate material, and combines the best aspects of the bucket ladder and the suction dredge. The combination of simultaneous digging and suction at the seabed provides the option to either treat the ore on the vessel or pipe it into shore.		Excavation scarring; turbidity plume; resedimentation; suspended particulates; dissolved substances
Stationary (anchored) suction dredges	Anchored suction dredges leave deep pits in the seabed.	Used to mine sand and gravel in water depths up to 200 m. Tested in Red Sea to mine metalliferous muds at a water depth of 2000 m.	Excavation scarring; turbidity plume; resedimentation; suspended particulates; dissolved substances
Cutterhead suction dredges	A suction pipe mounted near or in the cutterhead pumps the loosened slurry to the dredge or through a pipeline to a shore-based processing facility. The cutterhead assembly is swung back and forth in an arc; loosening a small amount of material with each swing. Heavy minerals often separate from the disintegrated material and remain on the seabed.	Used to excavate compacted, granular materials in water depths <30 m. Widely used in Thailand to mine cassiterite (tin placers)	Excavation scarring; turbidity plume; resedimentation; suspended particulates; dissolved substances. Significant water discharges containing fine particulate materials. More than 95% of the material retrieved by this method must be disposed.

Table 12. Summary of Operational Methods for Marine Mining and Their Environmental Effects [Adapted From Continental Shelf Associates, Inc. (1993) and Cruikshank *et al.* (1987)] *(continued)*

Operational Method	Description	Application	Known or Suspected Environmental Effects
Fluidizing (Bore-Hole, Solution, or *In Situ* Mining)			
Slurry	Unconsolidated or marginally consolidated mineral deposits are collected as a fluid slurry through drillholes or boreholes that penetrate the seabed. Accomplished by capturing dissolved or suspended deposits (e.g., seawater, hydrothermal-vent fluids, geothermal heat), or slurrying granular deposits.	Mining of sub-seabed sand in shallow waters offshore Japan, and unconsolidated or marginally consolidated mineral deposits such as phosphate (offshore Florida and Georgia) and sulfur. Probably the most efficient method for mining phosphate deposits in the study area.	Subsidence for closed circulation systems. Open circulation would produce plumes and result in resedimentation. With further research, may become the most environmentally-acceptable method for mining phosphates in the study area.
Beneficiation	Extraction process used to beneficiate or upgrade an ore after the ore has been mined. Produces a concentrated-ore fraction and a tailings or waste fraction of excess rock or substrate.		Turbidity plume; resedimentation; suspended particulates; dissolved substances
Platform	Placer processing technology placed aboard floating platforms. Examples of technology include pretreatment, gravity concentration, magnetic separation, and electrostatic separation.	Required when mining placers, pilot plants needed to test tens or hundreds of tons of samples.	
Extractive Metallurgy			
On the platform (speculative)	At-sea processing incorporating self-contained energy systems and closed-circuit processes that will produce saleable products from all ore components and will produce little or no waste.		

Table 12. Summary of Operational Methods for Marine Mining and Their Environmental Effects [Adapted From Continental Shelf Associates, Inc. (1993) and Cruikshank *et al.* (1987)] *(continued)*

Operational Method	Description	Application	Known or Suspected Environmental Effects
TRANSPORTATION			
Bulk Ore Carriers	Vessels used to transport materials such as metalliferous oxides, massive sulfides, or phosphorites. Ores may be transported either in (1) ore-carrier hulls that restrict the centerline cargo hold to a small part of the available hull space, or (2) standard bulk carriers where load-dense ores are carried in only a few cargo holds.		
Slurry Pipelines	Ores hydraulically raised in a slurry from the ocean floor to the lift ship and transferred to the transport ship. Waste water drained after loading to reduce transport weight and to stabilize the cargo.		
WASTE DISPOSAL	Most waste materials from mining operations are in solid form and consist of natural materials from the ore body or from its development. Disposal of these materials may present some unique problems for marine mining operations.		

[a]Conventional mining method in shallow water (existing technology).
[b]Tested mining method in deep water (at a minimum, a prototype has been developed).

eliminates or drastically reduces the suspended sediments in the water column associated with underwater excavation operations. This technique is still in an experimental stage, having been tested only on land, with relatively good results (Zellars-Williams, 1988).

5.3.2 Site-selection criteria and constraints

Studies by Kellam and Henry (1988) and Henry and Idris (1992) concerning the most optimal sites for phosphate mining on the Georgia Shelf suggest that middle-Miocene phosphate deposits are accessible on a subbottom feature known as the Outer Shelf High, located 70-100 km offshore the Georgia coast (Figure 2). This feature extends landward to the Savannah- Georgia/Hilton Head-South Carolina coasts. The Zellars-Williams (1988) study recommends a mining site on this feature approximately 16 km east of Tybee Island near the Savannah Light Tower.

Excavation mining is feasible at the Savannah Light Tower site because the water is relatively shallow and the overburden is thin. Opposite conditions occur at the outer shelf site, with the overburden being thick and water deep. The outer shelf region, therefore, would be the best-suited site for the bore-hole mining technique. Live-bottom areas have been mapped in both areas and are particularly abundant in the Outer Shelf High region. In the vicinity of the Savannah Light Tower, the Oligocene-age sediments that comprise the aquiclude and upper portion of the Floridan Aquifer System are at the shallowest depth (approximately 15m below the seabed) than anywhere else on the shelf (Figure 3). Furthermore, the top of the Eocene-age sediments that comprise the major portion of the Floridan Aquifer System is less than 40m below the seabed in this area. The subbottom depth of the Oligocene and Eocene strata increases southward and seaward.

In addition to the obvious constraints imposed by the Floridan Aquifer System and the presence of live-bottom areas, Table 13 provides other considerations in selecting a marine mining site. Several of the items are adapted from the 1990 South Atlantic Marine Fisheries Commission policy statement concerning future Outer Continental Shelf oil and gas lease sales.

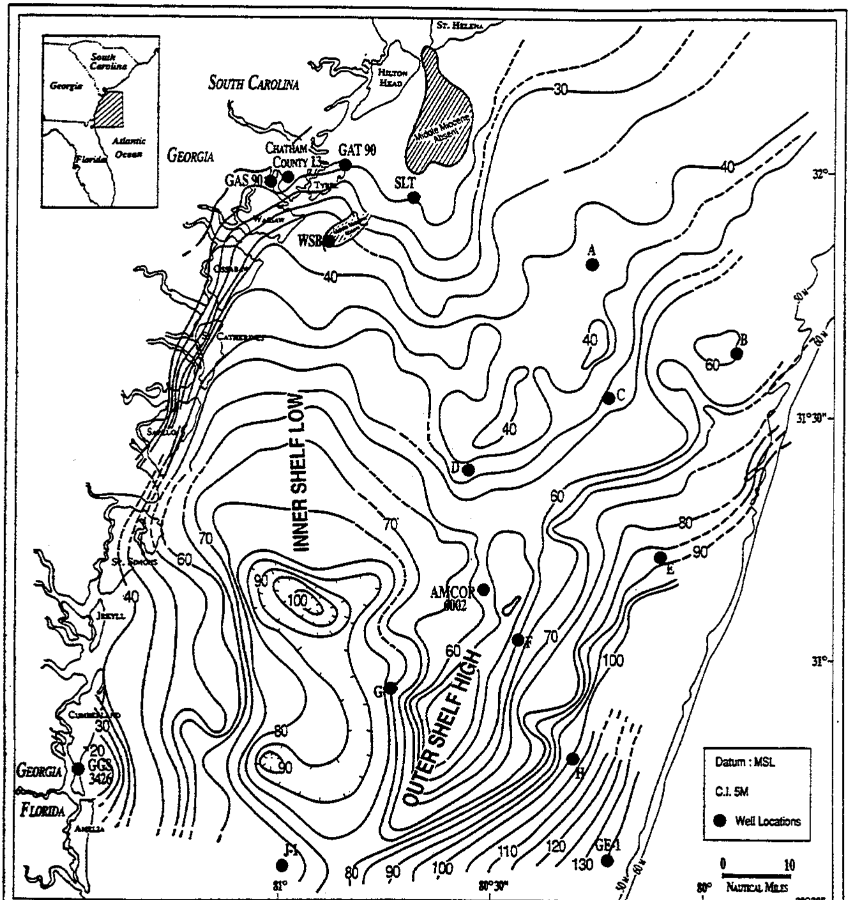

Figure 2. Structure-contour map of top of Middle-Miocene-age sediments. The Savannah Light Tower (SLT) is 16km east of Tybee Island, at a water depth of 15m. (From Henry and Idris, 1992).

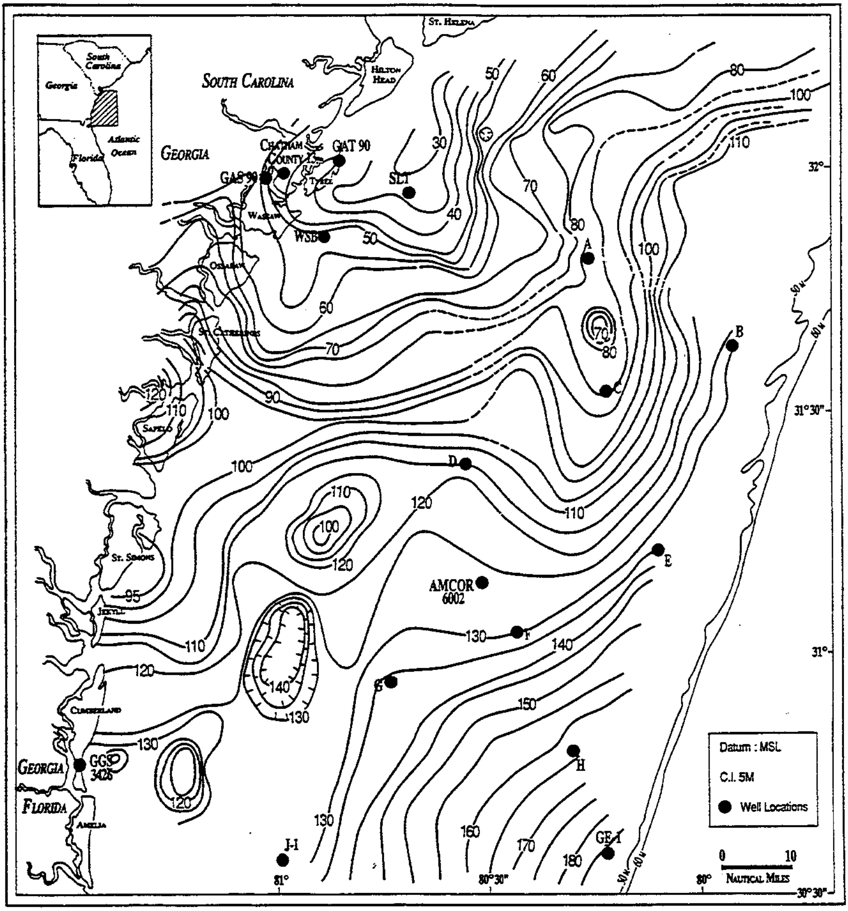

Figure 3. Structure-contour map of the top of Oligocene-age sediments. The Savannah Light Tower (SLT) is 16km east of Tybee Island, at a water depth of 15m. (From Henry and Idris, 1992).

Table 13. Considerations When Selecting a Mining Site.
[Adapted From South Atlantic Fishery Management Council (1990)]

(1) Identify potential impacts to the Floridian Aquifer System.

(2) Prohibit mining on or closely adjacent to live-bottom habitat or other special biological resources.

(3) Design facilities associated with mining exploration, development, and transportation to avoid impacts on coastal wetlands and sand-sharing systems.

(4) Avoid migration routes of the northern right whale and other marine mammals.

(5) Identify site-specific fishery resources, including both pelagic and benthic communities, that inhabit, spawn, or migrate through the potential site.

(6) Identify on-site species described as endangered, threatened, or of special concern, i.e., shortnose sturgeon, striped bass, blueback herring, American shad, sea turtles, marine mammals, pelagic birds, and all species regulated under a Federal Fisheries Management Plan.

(7) Determine impacts on fisheries resources of all pre-mining exploratory and developmental activities and actual mining operations prior to approval of mining permits.

(8) Characterize the proposed site in terms of physical oceanographic and geological condition prior to approval of mining permits.

(9) Study potential impacts by noise, turbidity, smothering, cavern collapse, fuel spills, and incidental impacts.

6.0 RESEARCH NEEDS AND RECOMMENDATIONS

6.1 Research Needs Regarding Non-Mineral Resources

The data gaps concerning non-mineral resources are considered to be correlative to research needs. Each topic would provide information significantly increasing the basic knowledge of the Georgia shelf. Many of the proposed studies broadly involve several disciplines. Examples are the study of the biogeochemistry of sediment/water column interactions and the relationship among Gulf Stream intrusions, upwelling, and benthic/water column productivity. Other studies are quite specific. The studies are not prioritized or ranked according to urgency because the need for marine mining of phosphate and other minerals may be decades away. Meanwhile, many studies will have been accomplished or are in progress. Several studies or actions are identified as being relevant and timely whether or not mining ever occurs.

6.2 Research Needs Related to Marine Mining and Site Selection

The research needs specifically related to mining and site selection are indicated as data gaps in Tables 11 and 13. The most significant research needs concern the (1) water column; (2) biota, including endangered species; (3) substrate, including sediments, habitat, and the Floridan aquifer; and (4) site-specific needs to the mining operation, including site selection, impacts, constraints, and mitigation.

The selection of site-specific research priorities and specific site-selection criteria is tentative, because of (1) the lack of prior mining experience on the Georgia shelf; (2) the yet-to-be proven feasibility of the slurry (bore-hole) mining method; and (3) uncertainties regarding the future phosphate and sand and gravel markets. Therefore, rather than provide a specific list of prioritized research dealing with pre-mining surveys, siting and monitoring criteria, and mitigation plans, the material in Tables 10, 11, and 13 is synthesized into ten research needs and/or actions that provide the most significant information concerning both non-mineral and mineral resources.

6.3 Recommendations for Research and Related Actions

The format for each of the following project descriptions is based on the (1) topic(s) of research; (2) resources that will be affected by mining activities; (3) project objectives; (4) research methods; (5)

area on shelf; and (6) justification of the research. Data gaps from Table 10 that are addressed by the proposed project are also noted.

6.3.1 Hydrogeology of the Floridan Aquifer System under the Georgia Continental Shelf

Resource Affected: The primary coastal groundwater source.

Data Gaps Addressed: Data gap 10 (Table 10).

Objectives: (1) Determine the depth, extent and hydrogeologic character of the aquifer and aquiclude; and (2) prevent/mitigate potential impacts of marine mining.

Methods: Drilling of test wells and use of standard hydrologic techniques, including predictive modeling.

Shelf Areas Covered: Selected inner and outer shelf areas, where mining is most likely to occur.

The Floridan Aquifer System provides the major source of groundwater for both public and municipal water supplies. The aquifer is already stressed by overpumping and is experiencing salt water encroachment. It is critical, therefore, to protect the aquifer from increased salinity that could be caused by breaching of the overlying aquiclude due to mining activities. The offshore portion of the aquifer may provide an additional source of potable water, although little is known of its water quality or quantity.

6.3.2 The economic and environmental feasibility of bore-hole mining on the Georgia Shelf

Resource Affected: Phosphates and biota.

Data Gaps Addressed: Data gaps 1-9 (Table 13).

Objectives: To determine: (1) the feasibility of using the bore-hole technique to mine phosphate on the Georgia shelf; and (2) the potential impacts on biota from bore-hole mining.

Methods: Site-selection procedures, bore-hole mining technology, and monitoring procedures.

Shelf Areas Covered: Outer Shelf High area.

Bore-hole mining is the method of choice to mine phosphate on the outer shelf because of the water depth, overburden thickness and depth to the ore body. Preliminary tests of this technique onshore in Florida suggest that it is the least environmentally destructive of all the present mining techniques. Because the bore-hole method has never been used to mine phosphate offshore, it is necessary to test this technique under actual site conditions. It is assumed that testing will not occur until market conditions dictate.

6.3.3 Fluxes in ambient and episodic turbidity conditions and effects on benthic, planktonic, and nektonic organisms on the Georgia Shelf

Resource Affected: Benthic, planktonic and nektonic organisms, water quality, excavation mining of phosphates.

Data Gaps Addressed: Data gaps 9, 20, 25, and 26 (Table 10).

Objectives: (1) To collect turbidity data appropriate to developing a dispersion model; and (2) to examine the effects of turbidity on benthic and water column biota through field and laboratory studies.

Methods: Field collection/observations and laboratory experiments.

Shelf Areas Covered: Inner shelf.

Both field and laboratory data are needed to develop a dispersion model and to provide the basis for comparison of natural turbidity levels to those created by excavation mining. This information also provides a better understanding of biogeochemical processes related to sediment/water column interactions.

6.3.4 Development of a predictive/dispersion model for the Georgia Inner Shelf

Resource Affected: Phosphate; sand and gravel; sediment; water quality; aquifer; benthic, nektonic and planktonic organisms.

Data Gaps Addressed: Data gaps 9, 20, 25 and 26 (Table 10).

Objectives: To predict and mitigate turbidity plume effects created by excavation mining.

Methods: The use of published and acquired field and laboratory data to develop and test a model.

Shelf Areas Covered: Inner shelf.

Turbidity plumes resulting from mining activities, particularly from excavating techniques, can create severe impacts to benthic and water column biota. A model is needed that accurately predicts turbidity duration and three-dimensional dispersion parameters of suspended sediment plumes. The data also are needed to aid in monitoring and mitigation planning. The model may be applicable to bore-hole mining.

6.3.5 Marine mammal studies

Resource Affected: Marine mammals, both migratory and resident species, such as the northern right whale and the Atlantic bottlenose dolphin.

Data Gaps Addressed: Data gaps 37 and 38 Table 10).

Objectives: To better define the migratory patterns, population dynamics and behavior of marine mammals including response to noises from mining activities and shipping traffic.

Methods: Ship/aerial observations; radio-tagging; sonobuoys and AXBTs.

Shelf Areas Covered: Entire shelf.

The information is needed to protect marine mammals from potential impacts caused by shipping and possible mining activities. The data will also aid in the creation of models to predict areas of greatest mammal density so that avoidance procedures can be developed.

6.3.6 Ecological and process-response studies of selected live bottoms and other critical habitats

Resource Affected: Live bottom communities of benthic and nektonic organisms, including commercial and recreational fish.

Data Gaps Addressed: Data gaps 11, 24, 28, 46, 48, and 50 Table 10).

Objectives: To better understand the systematics, community structure and productivity of rock, sand and mud substrates, and their response to habitat disturbance.

Methods: Field and laboratory studies.

Shelf Areas Covered: Entire shelf region.

Although recent characterization studies of live bottoms have been conducted, further study is needed regarding their systematics, ecology, resident, and transient nektonic community structure, sensitivity to ambient and episodic perturbations, and their role in supporting commercial and recreational fisheries. Much less is known about sand and mud habitats. The mud habitat supports the important nearshore shrimp fishery and the sand habitat may support emerging fisheries for whelk and bivalves.

6.3.7 Detailed bathymetry and imagery of the Georgia Shelf

Resource Affected: Non-mineral and mineral resources including critical habitat, fisheries, and hazards to resource development.

Data Gaps Addressed: Data gaps 11 and 24 (Table 10).

Objectives: To map (in detail) shelf and shelf-edge critical habitat, topographic features, and bathymetry relative to the wise use of coastal and marine resources.

Methods: Seabeam technology, mid- and short-range sidescan sonar, CCTV, SCUBA, and other appropriate techniques.

Shelf Areas Covered: Entire shelf region.

The value of seafloor imagery to coastal and marine resource user groups is analogous to the value and application of air photos, topographic maps, and other imagery to (1) interpretation of land forms; (2) environmental conditions; (3) physical and biological processes; (4) business and commerce; and (5) agriculture and forestry.

6.3.8 Instrumentation of the Navy Towers (TACTS) to measure atmospheric and oceanographic parameters on the mid- and outer-shelf regions of Georgia

Resource Affected: Physical, chemical, and biological systems and processes of the atmosphere, water column, boundary layers, and seabed.

Data Gaps Addressed: All in Table 10

Objectives: To provide an integrated network of atmospheric and oceanographic data-gathering stations.

Methods: To be determined by a consortium of research institutions, state and Federal agencies, and industry.

Shelf Areas Covered: Middle and outer continental shelf.

Instrumentation of the U.S. Navy's Tactical Aircrew Combat Training System (TACTS) towers would provide an unprecedented opportunity to obtain synoptic information on both large and small scale oceanographic processes. The relevancy to understanding, predicting, and monitoring meteorological, physical, chemical, and biological processes and events is significant.

6.3.9 Development of a comprehensive data management system for the Georgia Shelf and coastal zone

Resource Affected: Mineral and non-mineral resources.

Data Gaps Addressed: Data gaps 42 and 56 (Table 10).

Objectives: To develop a comprehensive, interdisciplinary Geographic Information System (GIS) and an electronic clearing-house pertaining to the resources of the Georgia shelf.

Methods: To be determined.

Shelf Areas Covered: Entire shelf.

Ideally, this information system would provide data for a variety of user groups and would include all appropriate information and data from Federal and state agencies, research institutions, industry, and other sources.

6.3.10 Development of a coastal and ocean management plan for Georgia

Resource Affected: Coastal and shelf resources.

Data Gaps Addressed: Data gaps 53, 57, 58, 59, and 60 (Table 10).

Objectives: To develop policies and regulations for the wise use of coastal and shelf resources.

Methods: Joint state/Federal program such as NOAA's Coastal Zone Management program.

Shelf Areas Covered: Coastal zone and shelf.

Among other attributes, a well-conceived plan will facilitate the wise and equitable use of coastal and marine resources by (1) determining the maximum levels of exploitive activities to maintain sustainable development; (2) creating management mechanisms for resolving both intra- and interstate conflicts; and (3) developing action to link planning, resource management and permitting.

7.0 SUMMARY AND CONCLUSIONS

Over 1600 references are included in the project database. The majority of the material consists of gray literature from resource management agencies and research facilities. Approximately one-quarter of the collected literature comprises journal articles. A substantial amount of unpublished data are included.

Sixty data gaps, of which 20 relate directly to marine mining, are identified for the offshore resources. Ten studies are recommended to fill data gaps, allow assessment of potential impacts of marine mining, and aid in site selection. Recommended study topics are:

- Hydrogeology of the Floridan Aquifer System
- Feasibility of Bore-Hole Mining
- Effects of Turbidity on Benthic, Planktonic and Nektonic Organisms
- A Predictive Dispersion Model
- Marine Mammals
- Live Bottom and Other Critical Habitats
- Seafloor Bathymetry and Imagery
- Instrumentation of Navy Towers
- Comprehensive Data Management System
- Coastal and Ocean Management Plan

Some of the above topics are necessarily broad in scope; however, with respect to the onset of marine mining activities, site-specific investigations will be necessary. Regional studies associated with oil and gas exploration provided baseline data for the physical and biological aspects of the Georgia Bight. Research by various institutions and agencies provides a relatively well-defined base of information for many of the resources, but several important systems and processes have received little attention. Numerous studies of physical and chemical processes comprise a baseline of data on water mass movements and on transport, exchanges, and transformations in the water column. A lack of collected material is evident, however, for the following topic categories: bathymetry and seabed morphology, aquifers, sediment and water column chemistry, macroalgae, benthic invertebrates, birds, marine mammals, coastal and marine management, and cultural resources.

Of the 60 data gaps identified from the database, one-third relate to the physical and chemical environments. In particular, data on processes at the sediment-water interface, the Floridan Aquifer System and seafloor morphology in regard to hard-bottom areas are limited. The 28 data gaps identified from the biological environment database relate to the benthos, especially to the distribution of resources and habitat areas. Although some resources, such as seabirds, have received little study, other, better-documented resources may be considered more important to address the potential impacts of marine mining to the resource. Gaps in the socioeconomic database relate to the management of coastal, marine, and cultural resources. In the case of the latter, archeology is perhaps the least-studied field for the entire project area. However, it should be emphasized that given the current regulations for any development on the continental shelf of this nation, site-specific investigations, including cultural resource surveys will have to be performed prior to any marine mining endeavor.

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APPENDIX A

Information Sources

Table A-1. Key Words Used During the Literature Searches

<u>Geographical Terms</u>	Flagellates
* South Carolina	Sarcodina
* Georgia	Foraminifera
* Florida	Radiolaria
* Marine	Porifera
* Southeast Atlantic Embayment	Mollusca
* South Atlantic Bight	Gastropoda
* Georgia Bight	Pelycypoda
* Continental Shelf	Cephalapoda
North Atlantic Ocean	Cnidaria
Southeastern U.S. Coast	Coelenterata
Duval County	Annelida
Nassau County	Oligochaeta
Jacksonville	Polychaeta
Camden County	Ctenophora
Glynn County	Ectoprocta
Brunswick	Endoprocta
Chatham County	Tardigrada
Savannah	Rhynchocoela
Beaufort County	Rotifer
Hilton Head	Gastrotricha
Charleston County	Kinorhynca
	Nematoda
<u>Miscellaneous Terms</u>	Bryozoa
Archeology	Arthropoda
Climate	Crustacea
Weather	Amphipoda
Hurricanes	Isopoda
Beach erosion	Copepoda
Coastal engineering	Decapoda
Coastal zone management	Cirripedia
Names of researchers from area facilities (i.e., Windom)	Ostracoda
	Pycnogonida
Names of each barrier island in study area	Brachiopoda
* Common names for major organisms of each phylum	Loricifera
	Echiura
	Priapulida
<u>Biological Terms</u>	Sipunculida
Bacteria	Brachiopoda
Fungi	Chondrichthyes
Yeasts	Elasmobranchii
Protozoa	Chaetognatha
Amoeba	Osteichthyes
Sarcomastigophora	Urochordata
Ciliates	Cetacea

*Key words used most frequently and in conjunction with the primary key words listed in Table 1 of the main text.

Table A-2. Information Contacts.

Agency Contacted	Person
FEDERAL AGENCIES	
U.S. Environmental Protection Agency	
Headquarters — Washington, DC	Information Office
Region IV	
• Library	John Namath
• Water Resources Division — Atlanta	Drew Kendall
• Environmental Services Division — Athens	Philip Murphy
Department of Interior	
Fish and Wildlife Service	
Southeast Region Office	Public Information Officer
Coastal Georgia Refuges	Pat Metz
Brunswick, GA, Enhancement Office	Phillip Laumeyer
Charleston, SC, Enhancement Office	Roger Banks
Jacksonville, FL, Office	Michael Bentzien
Endangered Species	Lynn Lesebvre
Office of Biological Services	Public Information Officer
Reference Service	Paul Wilson
Minerals Management Service	Dick Wilderman
Office of International Activities and Marine Minerals	Roger Amato, Barry Drucker
National Park Service	
Southeast Region Office	Dominic Dottavio (Chief Scientist)
Cooperative Research Unit — Cumberland Island	Stephen Cofer-Shabica
U.S. Geological Survey	
Savannah, GA, Office	
Georgia Tech Center for Spatial Analysis Office Technology	Jack Alladef
Water Resources Office — Atlanta	Rick Krause
Woods Hole, MA, Office	Frank Manheim, Pete Popenoe
Department of Defense	
United States Navy	
Kings Bay Naval Base	
• Dredging Operations	Jim Moore
• Forestry Operations	Ron Wilkinson
Savannah, GA, Shipbuilding	Cmdr. Richard Johnson (Supervisor)

Table A-2. Information Contacts. *(continued)*

Agency Contacted	Person
Army Corps of Engineers	
Charleston District Library	Marie Dickson
Jacksonville District Library	Oriana West
Savannah District	
• Library	Joe Page
• Public Affairs Office	Jim Parker
• Cultural Resources Office	Judy Woods
Waterways Experiments Station	David Nelson
Department of Transportation	
United States Coast Guard	
Office of Marine Safety	Public Affairs Officer
Seventh District Legal Office	Chief Robert Childs
Charleston, SC, Office	Lt. Cmdr. Dave Alley
Savannah Air Station	Cmdr. Mark Johnson
Department of Commerce	
National Oceanic and Atmospheric Administration	
Central Library — Rockville, MD	Librarian
National Marine Fisheries Service	
• Beaufort Laboratory Library	Ann Rose
• Charleston, SC, Laboratory Library	Lois Winemiller
• Miami, FL, Laboratory Library	Linda Pikula
• Pascagoula, MI, Laboratory	Public Information Officer
St. Petersburg Regional Office	
• Protected Species Management Branch	Jeff Brown
• Fisheries Branch	Peter Eldridge
National Ocean Service	
• Coastal and Geodetic Survey Public Affairs Office	Frank Margiotta
• Geophysical Data Center	Administrative Assistant
National Weather Service	
• Library	Linda Preston (Librarian)
• Jacksonville Port Office	Port Meteorologist
• Savannah Office	Joe Purvis
• National Climatic Data Center Library	Tom Ross, Neil Lott
• National Data Buoy Center	Eric Meindl
Ocean and Coastal Resource Management	
• Estuarine Research Reserves — Sapelo Island	Fred Marland
• Marine Sanctuaries — Gray's Reef	Reed Bohne

Table A-2. Information Contacts. *(continued)*

Agency Contacted	Person
Other Federal Agencies	
National Academy Press	Public Information Officer
National Research Council Marine Board	Public Information Officer
STATE AGENCIES	
State of Florida	
Department of Community Affairs	
• Public Affairs Office	Rosalyn Hozer
Department of Environmental Regulation	
• Public Affairs Office	Janine Rogers
Department of Health and Rehabilitative Services Groundwater Division	Julia Winter
Department of Natural Resources	
• Division of Marine Resources	Jamie Serino
• Florida Geological Survey	Walter Schmidt
• Florida Park Service	Mark Smith
• Public Affairs	Dodie Zeiler
Marine Fisheries Commission	Bob Palmer
Office of Environmental Affairs	Warren May
State of Georgia	
Coastal Georgia Regional Development Commission	David Kyler
Georgia Ports Authority	Patricia Reese
Department of Natural Resources	
• Coastal Resources Division	Duane Harris
○ Coastal Zone Management	Stuart Stevens
○ Fisheries Section	Susan Shipmen
○ Landings Data	Gordon Rogers, Gina Gore
○ Offshore Resources	Henry Ansley
• Environmental Protection Division	
○ Environmental Coordinator's Office	Administrative Assistant
○ Georgia Geologic Survey	Mark Cocker, Earl Shapiro
• Game and Fish Division	
○ Fisheries Management	Greg Crakow
○ Nongame Species	Mike Harris, Charles Maley
• Parks and Historic Sites	Lonice Barrett
○ State Archaeologist	Carl Stein
○ State Preservation Office	Chip Morgan

Table A-2. Information Contacts. *(continued)*

Agency Contacted	Person
State of South Carolina	
Archaeology and Anthropology	Christopher Amer
Coastal Council	Joe Persner
South Carolina Geological Survey	Librarian
Nongame and Heritage Trust	Steve Bennett
Water Resources Commission	Forrest Matthews
Water Resources Division	
• Southeast Regional Climate Center	David Chagnon
Wildlife and Marine Resources	Helen Ivy
• Marine Resources Division	Bob Van Dolah
• Fisheries	Charles Barans
UNIVERSITIES AND COLLEGES	
State of Florida	
Jacksonville University	
• Biology Department	Quentin White
Sea Grant College Program	Public Information Office
• Marine Extension Office	Joe Halusky
University of Miami	
• Rosenstiel School Library	Kay Hale
University of North Florida	
• Coastal Fisheries Laboratory	Carol DeMort
State of Georgia	
Armstrong State College	
• Biology Department	Ken Reylea
Georgia Institute of Technology	
• Earth and Atmospheric Sciences Department	Administrative Assistant
• Atlanta Campus	Deborah Salmond
• Research Institute — Savannah	Larry Eden
Savannah State College	
• School of Marine Biology	Matt Gilligan, Joe Richardson
Skidaway Institute of Oceanography	Tom Turner (Librarian), Clark Alexander, Tom Gross, Rick Jahnke, Dick Lee, Jim Nelson, David Menzel, Peter Verity, Charles Robertson, Jack Blanton

Table A-2. Information Contacts. *(continued)*

Agency Contacted	Person
State of Georgia *(continued)*	
University of Georgia	
• Ecology Institute	Janice Sand, Ron Pulliam, Jim Richardson
• Community and Area Development	Jim Kundell, Hans Neuhauser
• Marine Extension Service	
◦ Athens	Fred Lyda
◦ Brunswick	Dave Harrington
◦ Savannah	Jay Calkins
◦ Shellfish Program	Randy Walker
• Museum of Natural History	Amy Edwards
• Sapelo Marine Institute Library	Lorrene Townsend
• Sea Grant College Program	Mac Rawson
• Zoology Department	Gene Helfman
State of South Carolina	
Columbia College	Martha Griffin
Sea Grant Consortium	Leigh Handal
University of South Carolina — Beaufort	Ed Caine
OTHER CONTACTS	
Atlantic States Marine Fisheries Commission	Diane Stephan
Battelle Memorial Institute	
• Ocean Sciences Department	Heather Trulli
• Daytona Beach Laboratory	Henry Pate
Brunswick Public Library	Reference Librarian
Chatham-Effingham Library	Reference Librarian
Coastal Science and Engineering	Timothy Kana
Georgia Conservancy	Rebecca Shortland
Harbor Branch Foundation	Doreen Keller
National Coalition of Marine Conservation	Carl Paulen
New England Aquarium	
• Edgerton Research Laboratory	Scott Krause
Reef Research Team/Scubanauts	Mark Ullman, Shawn Brayton
South Atlantic Fishery Management Council	Carrie Knight
Independent Consultants	Vernon J. Henry, James Harding

Table A-3. Key Words in the Database

ABARENICOLA PACIFICA
ABSTRACT
ABUNDANCE
ACANTHOCYBINIUM SOLANDERI
ACARTIA TONSA
ACASTA CYATHUS
ACCRETION
ACIPENSER BREVIROSTRUM
ACIPENSER OXYRHYNCHUS
ACOUSTICAL SURVEYS
ADULTS
ADVECTION
AERIAL PHOTOGRAPHY
AERIAL SURVEYS
AGE
AIR POLLUTION
AIR PRESSURE
AIR-SEA BOUNDARY LAYER
AIR TEMPERATURES
ALEWIFE
ALGAE
ALLOGROMIINA
ALOSA AESTIVALIS
ALOSA MEDIOCRIS
ALOSA PSEUDOHARENGUS
ALOSA SAPIDISSIMA
ALTAMAHA RIVER
ALUMINUM
AMELIA ISLAND
AMERICAN EEL
AMERICAN SHAD
AMINO ACIDS
AMMONIA
AMPHIPODS
ANADROMOUS SPECIES
ANGUILLA ROSTRATA
ANNELIDS
ANNUAL REPORT
ANOMIA SIMPLEX
ANTHOSIGMELLA VARIANS
ANTHROPOGENIC CAUSES
APPENDICES
AQUIFERS
ARCHAEOLOGICAL RESOURCES
ARCHOSARGUS PROBATOCEPHALUS
ARGOPECTEN GIBBUS
ARSENIC
ARTIFICIAL REEFS
ASMFC REPORT
ATLANTIC BOTTLENOSE DOLPHIN
ATLANTIC CROAKER
ATLANTIC MACKEREL
ATLANTIC MENHADEN
ATLANTIC SILVERSIDE
ATLANTIC SPADEFISH
ATLANTIC STURGEON
ATLAS
ATMOSPHERE
ATMOSPHERIC FORCING
AUGUST93
AUTUMN CONDITIONS
AXIOTHELLA RUBROCINCTA
AYTHYA AFFINIS
AYTHYA AMERICANA
AYTHYA COLLARIS
AYTHYA VALISINERIA

BACILLARIOPHYCEAE
BACTERIA
BACTERIOPLANKTON
BAIRDIELLA CHRYSOURA
BALAENA GLACIALIS
BANDED DRUM
BARIUM
BAROCLINIC FLOW
BAROTROPIC FLOW
BARRIER ISLANDS
BASELINE STUDY
BASEMENT
BASS
BATHYMETRY
BEACH EROSION
BEACHES
BEACH NOURISHMENT
BEAUFORT COUNTY
BED FORMS
BEHAVIOR
BELTED SANDFISH
BENTHIC
BENTHIC BOUNDARY LAYER

Table A-3. Key Words in the Database *(continued)*

BIBLIOGRAPHY
BILLFISH
BIOACCUMULATION
BIOCHEMISTRY
BIODEGRADATION
BIOLOGICAL ENVIRONMENT
BIOLOGICAL MODELS
BIOLOGICAL RESOURCE AREA
BIOLOGYS
BIOMASS
BIOTRANS
BIOTURBATION
BIRDS
BIVALVES
BLACK GROUPER
BLACK SEA BASS
BLACK SKIMMER
BLAKE PLATEAU
BLM REPORT
BLUEBACK HERRING
BLUEFISH
BLUELINE TILEFISH
BODY SIZE
BOLIVINA LOWMANI
BOLIVINA SUBAENARIENSIS
BORDERLINE
BOREHOLES
BORON
BOTTOM STRESS
BRANCHIOSTOMA
BREVOORTIA TYRANNUS
BRISSOPSIS
BROAD RIVER
BROCHURE
BROMINATED COMPOUNDS
BROWN PELICANS
BROWN SHRIMP
BRUNSWICK
BRYOZOA
BULIMINIDAE
BULL ISLAND
BURROWING ORGANISMS
BUSYCON CANALICULATUM
BUSYCON CARICA
BUTTERFISH
BY CATCH

CABRETTA ISLAND
CADMIUM
CALAMUS
CALAMUS ARCTIFRONS
CALAMUS LEUCOSTEUS
CALAMUS NODOSUS
CALAMUS PRORIDENS
CALANUS FINMARCHICUS
CALCIUM CARBONATES
CALLIANASSA MAJOR
CALLINECTES DANAE
CALLINECTES MARGINATUS
CALLINECTES SAPIDUS
CALLINECTES SP.
CALLIONYMIDAE
CALONECTRIS DIOMEDEA
CAMDEN COUNTY
CARANX CRYSOS
CARBOHYDRATES
CARBON
CARCHARHINUS LIMBATUS
CARCHARHINUS MILBERTI
CARCHARHINUS PLUMBEUS
CARETTA CARETTA
CARISTIUS SPECIES
CASSIDINIDEA OVALIS
CATADROMOUS SPECIES
CATCH AND EFFORT DATA
CAULOLATILUS CYANOPS
CAULOLATILUS MICROPS
CENOLAIMUS SAPELOENSIS
CENOZOIC
CENTROPAGES FURCATUS
CENTROPRISTIS STRIATA
CEPHALOPODS
CERATASPIS
CERATIUM MASSILIENSE
CERATIUM TRICHOCEROS
CERITHIUM ATRATUM
CETACEA
CHAETODIPTERUS FABER

Table A-3. **Key Words in the Database** ***(continued)***

CHARLESTON BUMP
CHARLESTON COUNTY
CHAZ
CHELONIA MYDAS
CHEMICAL ENVIRONMENT
CHIRIDOTEA COECA
CHLORIDES
CHLOROPHYLL
CHLOROPHYTA
CHROMIS ENCHRYSURA
CHTHAMALUS BISINUATUS
CHTHAMALUS FRAGILIS
CHTHAMALUS MONTAGUI
CHTHAMALUS PROTEUS
CILIATES
CIRCULATION
CIROLANA BOREALIS
CIRRIPEDIA
CLADOCERANS
CLADOPHORA
CLASTICS
CLAY
CLIONA CELATA
CLOUDS
CLYDONELLA VIVAX
CNIDARIA
COASTAL ENGINEERING
COASTAL FRONTAL ZONE
COASTAL PROCESSES
COASTAL ZONE COLOR SCANNER
COASTAL ZONE MANAGEMENT
COLLETON COUNTY
COMMERCIAL FISHERIES
COMMUNITIES
CONCENTRATIONS
CONFERENCE
CONFERENCE PAPER
CONFERENCE PROCEEDINGS
CONGER EELS
CONGRID EELS
COORDINATES
COOSAWATCHIE RIVER
COPEPODS
COPPER
CORAL
CORYPHAENA EQUISETIS
CORYPHAENA HIPPURUS
COST GE-1 WELL
CRABS
CRD REPORT
CREPIDULA CONVEXA
CREPIDULA FORNICATA
CREPIDULA PLANA
CRETACEOUS
CRUISE REPORT
CRUSTACEAN FISHERY
CRUSTACEANS
CTENOPHORA
CULTURAL RESOURCES
CUMBERLAND ISLAND
CURRENTS
CYANOPHYTA
CYCLIDIUM
CYNOSCION NEBULOSUS
CYNOSCION REGALIS

DAMSELFISH
DATA ANALYSIS
DATA BUOYS
DATA GAPS
DATA MANAGEMENT
DATA SETS
DEBRIS
DECAPODS
DECAPTERUS PUNCTATUS
DENSITY FRONTS
DEPOSITION
DERMOCHELYS CORIACEA
DETRITUS
DEUTERIUM
DEWEES ISLAND
DIATOMS
DIET
DIMETHYL SULFIDE
DINOFLAGELLATES
DIOPATRA CUPREA
DIPLECTRUM FORMOSUM
DIPLODUS HOLBROOKI

Table A-3. Key Words in the Database *(continued)*

DISEASES
DISSERTATION
DISSOLVED CARBON DIOXIDE
DISSOLVED ORGANIC CARBON
DISSOLVED ORGANIC MATTER
DISSOLVED ORGANIC NITROGEN
DISSOLVED OXYGEN
DISTRIBUTION
DIVERGENCE
DOBOY SOUND
DOE REPORT
DOLIOLETTA GEGENBAURI
DOLIOLIDS
DOLPHIN (FISH)
DREDGE SPOIL
DREDGING
DRILLING
DUDRESNAYA GEORGIANA
DUVAL COUNTY

EARTHQUAKES
EBB-TIDAL DELTA
ECHINODERMATA
ECOLOGICAL AGGREGATIONS
ECOLOGICAL CHARACTERIZATION
ECONOMIC ANALYSIS
ECONOMIC GEOLOGY
ECONOMIC MODEL
ECOSYSTEMS
EDDIES
EDISTO ISLAND
EGGS
EMBRYOLOGY
ENDANGERED/THREATENED SPECIES
ENERGETICS
ENGINEERING GEOLOGY
ENTEROGYRUS SP.
ENTEROMORPHA
ENTOPROCTOA
ENTRAINMENT
ENVIRONMENTAL ASSESSMENT
ENVIRONMENTAL IMPACTS
ENVIRONMENTAL IMPACT STATEMENT
ENVIRONMENTAL STUDIES
ENZYMES
EOCENE
EPA REPORT
EPIFAUNA
EPINEPHELUS
EPINEPHELUS DRUMMONDHAYI
EPINEPHELUS FLAVOLIMBATUS
EPINEPHELUS NIGRITUS
EPINEPHELUS NIVEATUS
ERETMOCHELYS IMBRICATA
EROSION CONTROL
ESTUARY-SHELF EXCHANGE
ETELIS OCULATUS
ETROPUS CROSOSTUS
ETROPUS CYCLOSQUAMOUS
ETROPUS MICROSTOMUS
ETROPUS RIMOSUS
EUBALAENA GLACIALIS
EUCALANUS PILEATUS
EULIMA CAROLII
EULIMA SUBCARINATA
EUPHAUSIACEA
EUTHYNNUS ALLETTERATUS
EVOLUTION
EXCLUSIVE ECONOMIC ZONE
EXECUTIVE SUMMARY
EXPLORATION

FATS
FAULTS
FEASIBILITY STUDIES
FECES
FECUNDITY
FEDERAL PROGRAM
FEEDING
FEEDING AREA
FEMALES
FERESA ATTENUATA
FERNANDINA BEACH
FINAL REPORT
FINFISH FISHERY
FISH
FISH BIOLOGY
FISH DETECTION

Table A-3. **Key Words in the Database** *(continued)*

FISHERY ECONOMICS
FISHERY MANAGEMENT
FISHERY SURVEYS
FISHING
FISHING GEAR
FISHING INDUSTRY
FISHING TECHNIQUES
FISHING TOURNAMENT
FISHING VESSELS
FLAGELLATES
FLEX
FLORIDA
FLORIDA CURRENT
FLORIDAN AQUIFER
FLORISTICS
FLOUNDER
FLUXES
FOLLY BEACH
FOLLY RIVER
FOOD COMPOSITION
FOOD SOURCES
FOOD WEBS
FORAMINIFERA
FRESHWATER RUNOFF
FRIPP INLET
FULVIC ACIDS
FUNGI

GABEX
GAG
GALE
GALEOCERDO CUVIERI
GAMMARIDAE
GASTROPODS
GASTROTRICHS
GEAR RESEARCH
GENERAL COASTAL MANAGEMENT
GENETICS
GEOCHEMISTRY
GEOGRAPHICAL DISTRIBUTION
GEOGRAPHIC VARIATIONS
GEOLOGICAL HISTORY
GEOLOGICAL STRUCTURES
GEOLOGIC HAZARDS
GEOLOGY
GEOMORPHOLOGY
GEOPHYSICAL SURVEYS
GEORGIA
GEOTHERMAL GRADIENT
GERYON FENNERI
GGS REPORT
GLOBICEPHALA MACRORHYNCHUS
GNATHOPHIS BATHYTOPOS
GNATHOPHIS BRACHEATOPOS
GNATHOPHIS TRITOS
GRAVITY SURVEYS
GRAY'S REEF
GREEN SEA TURTLE
GROUNDFISH
GROUNDWATER
GROUPER
GROWTH
GROYNES
GRUNTS
GULF OF MEXICO
GULF STREAM
GULF STREAM INTRUSIONS
GULLS

HABITAT
HABITATS
HAEMATOPUS PALLIATUS
HAEMULIDAE
HAEMULON AUROLINEATUM
HAEMULON PLUMIERI
HALICLONA OCULATA
HALOCERCUS LAGENORHYNCHI
HANZAWAIA
HARBORS
HARD GROUNDS
HATCHLINGS
HAWKSBILL SEA TURTLE
HAWTHORNE FORMATION
HEAD BOATS
HEAT FLUX
HEAVY METALS
HEAVY MINERALS
HELMINTHES

HEMICHORDATE
HETEROTROPHY
HF RADAR
HICKORY SHAD
HILTON HEAD ISLAND
HINDCASTING
HISTORICAL RESOURCES
HISTORICAL REVIEW
HOLOCENE
HORNBLENDE
HUMIC ACIDS
HUMPBACK WHALE
HUNTING ISLAND
HURRICANE HUGO
HURRICANES
HYDRAULICS
HYDROCARBONS
HYDROCHEMISTRY
HYDROGEOLOGY
HYDROGRAPHY
HYDROLOGY
HYELLA PYXIS
HYPSOMETRY

ICTHYOPLANKTON
IDENTIFICATION KEY
ILLEX ILLECEBROSUS
ILLITE
INCIDENTAL CATCH
INCOMPLETE
INCUBATION
INDEX
INDICATORS
INFORMATION SOURCE
INLETS
INNER SHELF
INORGANIC MATTER
INSTRUMENTATION
INTERSPECIFIC RELATIONSHIPS
INTERTIDAL ENVIRONMENT
INVENTORY
INVERTEBRATA
INVERTEBRATES
IODINE
IRCINIA CAMPANA
IRON
IRRADIANCE LEVELS
ISLE OF PALMS
ISONEMA
ISOPACH MAP
ISOPODS
ISOTOPES
ISTIOPHORIDAE

JACKSONVILLE
JACKSONVILLE BEACH
JAMES ISLAND
JASPER COUNTY
JELLYFISH
JETTIES
JURASSIC
JUVENILES

KAOLINITE
KEMPS RIDLEY SEA TURTLE
KIAWAH ISLAND
KINGFISH
KING MACKEREL
KINGS BAY

LABORATORY EXPERIMENT
LAGODON RHOMBOIDES
LANDINGS DATA
LAOPHONTINA REDUCTA
LAOPHONTINA TRIARTICULATA
LAOPHONTINA VARIABILIS
LARIMUS FASCIATUS
LARUS ATRICILLA
LARVAE
LATITUDINAL VARIATIONS
LATREUTES PARVULUS
LEAD
LEASE BLOCKS
LEASING
LEATHERBACK SEA TURTLE
LEGISLATION
LEIOSTOMUS XANTHURUS
LENGTH-WEIGHT RELATIONSHIPS

LEPIDOCHELYS KEMPI
LEPIDOCHELYS OLIVACEA
LEPTOCYLINDRUS DANICUS
LEPTOGORGIA VIRGULATA
LIFE CYCLE
LIFE HISTORY
LIGNIN
LIMITING FACTORS
LIMNORIA TRIPUNCTATA
LITERATURE REVIEW
LITHOLOGY
LITTLE CUMBERLAND ISLAND
LITTLE RIVER INLET
LITTLE ST. SIMONS ISLAND
LITTLE TUNNY
LITTORAL ZONE
LITTORINA IRRORATA
LITTORINA OBTUSATA
LIVE BOTTOMS
LOBSTER
LOCAL MOVEMENTS
LOGGERHEAD SEA TURTLE
LOLIGO PEALEI
LOLIGO PLEI
LOLLIGUNCULA BREVIS
LONGLINING
LONGSHORE CURRENTS
LOPHOGORGIA HEBES
LOPHOLATILUS CHAMAELEONTICEPS
LUCIFER FAXONI
LUNGS
LUTJANIDAE
LUTJANUS BUCCANELLA
LUTJANUS CAMPECHANUS
LUTJANUS VIVANUS
LYASE

MACKEREL
MACROALGAE
MAGNETIC ANOMALIES
MANAGEMENT
MANAGEMENT PLANS
MANATEES
MANGANESE
MAPPING
MAPS
MARINE DEBRIS
MARINE MAMMALS
MARINE MINERALS
MARINERS
MARINE SANCTUARIES
MARMAP REPORT
MATHEMATICAL MODELS
MAYORELLA GEMMIFERA
MCINTOSH COUNTY
MEANDERS
MEGALOPS
MEGAPTERA NOVAEANGLIAE
MELLITA QUINQUIESPERFORATA
MEMBRANE PROCESSES
MEMBRANOBALANUS COSTATUS
MEMBRANOBALANUS DECLIVIS
MENHADEN
MENIDIA MENIDIA
MENIPPE MERCENARIA
MENTICIRRHUS AMERICANUS
MERCURY
MERISTIC COUNTS
MESOPENAEUS TROPICALIS
MESOZOIC
METABOLISM
METACYCLOPINA IMPROVISA
METALS
METAPENAEOPSIS GOODEI
METEOROLOGY
METHANE
METHODOLOGY
MICROBES
MICROFOSSILS
MICROHYDRULA
MICROPHTHALMUS HAMOSUS
MICROPOGONIAS UNDULATUS
MICROWAVES
MIDDLE SHELF
MIGRATION
MIGRATORY SPECIES
MILITARY FACILITY
MINERALIZATION

Table A-3. Key Words in the Database *(continued)*

MINING
MIOCENE
MIXING
MIXING MODEL
MMS REPORT
MODELS
MODERN
MOLLUSCA
MOMENTUM BALANCE
MONACANTHUS HISPIDUS
MONITORING
MORONE SAXATILIS
MORPHOLOGY
MORTALITY
MUGIL CEPHALUS
MUGIL CUREMA
MULLET
MUNITIONS SURVEY
MURRELLS INLET
MYCROCYSTIS AERUGINOSA
MYCTEROERCA MICROLEPIS
MYCTEROPERCA BONACI
MYCTEROPERCA MICROLEPIS
MYCTEROPERCA MICROLEPSIS
MYCTEROPERCA PHENAX
MYCTEROPERCA SPECIES
MYTILUS EDULIS

NANNOPLANKTON
NANNYGOAT BEACH
NASSAU COUNTY
NAVIGATION
NAVIGATION CHANNELS
NAVIGATION CHART
NEMATODES
NEOGENE
NEREIS SUCCINEA
NEREIS VIRENS
NESTING
NETS
NEUSTON
NEW RECORDS
NEW SPECIES
NEWTRANSFER
NICHES
NITROGEN COMPOUNDS
NMFS REPORT
NOAA REPORT
NOABST
NOABSTOK
NOBIBLIO
NOPASTE
NOREJECTS
NORTH CAROLINA
NORTH EDISTO INLET
NPS REPORT
NUTRIENTS
NWS REPORT

OCALA ARCH
OCALA LIMESTONE
OCEAN DISPOSAL
OCEAN DREDGED MATERIAL DISPOSAL SITE
OCEANIC PROVINCE
OCEANODROMA CASTRO
OCEANOGRAPHIC CLIMATOLOGY
OCEANOGRAPHIC DATA
OCS STUDIES
OCTOPUS VULGARIS
OCULINA VARICOSA
OGCOCEPHALUS ROSTELLUM
OGEECHEE RIVER
OIL POLLUTION
OITHONA
OLIGOCHAETES
OLIVE RIDLEY SEA TURTLE
ONCAEA
OOTOLITHS
OPHIODERMA DEVANEYI
OPHIODERMA ENSIFERUM
OPHIOMORPHA NODOSA
OPISTHONEMA OGLINUM
ORGANIC CARBON
ORGANIC MATERIALS
ORGANOCHLORIDE COMPOUNDS
ORGANOMETALLIC COMPOUNDS
ORNITHODOROS CAPENSIS
ORTHOPRISTIS CHRYSOPTERA

OSCILLATORIA
OSMOREGULATION
OSSABAW ISLAND
OSTEOLOGY
OSTRACODS
OSTREOLA EQUESTRIUS
OUTER SHELF
OUTWELLING
OXYGEN

PAGRUS
PAGRUS PAGRUS
PALEOCENE
PALEOECOLOGY
PALEOGENE
PALEOGEOLOGY
PALEONTOLOGY
PANULIRUS ARGUS
PARACALANUS
PARALICHTHYS DENTATUS
PARALICHTHYS LETHOSTIGMA
PARALICTHYS DENTATUS
PARALICTHYS LETHOSTIGMA
PARAMOEBA AESTUARINA
PARAONIS FULGENS
PARASITES
PARTICULATES
PASTE
PASTED
PATH OF POLLUTANTS
PATHOGENS
PB-210
PCB
PEAT
PELAGIC
PELECANUS OCCIDENTALIS
PENAEIDAE
PENAEUS AZTECUS
PENAEUS DUARARUM
PENAEUS DUORARUM
PENAEUS SETIFERUS
PENILIA AVIROSTRIS
PERMEABILITY
PERMITS
PETRELS
PETROGRAPHY
PETROLEUM
PETROLOGY
PETROMYZON MARINUS
PETROMYZONTIDAE
PH
PHAEOCYSTIS POUCHETII
PHAEOPHYTA
PHAETHON LEPTURUS
PHAGOTROPHY
PHALAROPUS FULICARIA
PHALAROPUS LOBATUS
PHENOLS
PHOSPHATE
PHOSPHORITE
PHOSPHORUS
PHOTOSYNTHESIS
PHYSALIA PHYSALIS
PHYSICAL ENVIRONMENT
PHYSICAL MODELS
PHYSICAL OCEANOGRAPHY
PHYSICOOL
PHYSIOLOGY
PHYTOPLANKTON
PIGFISH
PIGMENTS
PILOT WHALES
PINFISH
PINK SHRIMP
PINNIXA LUNZI
PINNIXA RETINENS
PLACOPECTEN MAGELLANCUS
PLANKTON
PLANNING
PLANORBULINA
PLANULINA
PLATYAMOEBA LANGAE
PLEISTOCENE
PLIOCENE
PLUTONIUM
POLICY
POLLUTANTS
POLLUTION

Table A-3. Key Words in the Database *(continued)*

POLYCHAETES
POLYSIPHONIA
POMACANTHUS PARU
POMATOMUS SALTATRIX
POPULATIONS
PORGIES
PORIFERA
PORT ROYAL SOUND
PORTS
PORTUNIDAE
PORTUNUS
POTENTIAL YIELD
POTENTIOMETRIC SURFACE
PRECIPITATION
PREDEVELOPMENT FLOW
PREDICTIVE MODELS
PRICE INLET
PRISTIPOMOIDES AQUILONARIS
PRISTIPOMOIDES MACROPHTHALMUS
PROBOPYRINELLA HEARDI
PROCEEDINGS
PRODUCTIVITY
PROGRESS REPORT
PROPRIETARY
PROTEINS
PROTISTA
PROTOZOA
PROVENANCE
PSEUDODIAPTOMUS CORONATUS
PSEUDOPOLYDORA KEMPI
PUBLICATIONS LIST
PUBLIC EDUCATION
PUBLIST
PUFFINUS LHERMINIERI
PYCNOGONIDS

QUARTZ
QUATERNARY

RADAR ALTIMETRY
RADIOCARBON DATING
RADIOISOTOPES
RADIUM
RAINFALL
RANGE
RATES
RECREATION
RECREATIONAL FISHERIES
RECRUITMENT
RED DRUM
RED PORGY
RED SNAPPER
REEF FISH
REEFS
REGIONAL CHARACTERIZATION
REGULATIONS
REJECTOK
REMOTE SENSING
RENILLA RENIFORMIS
REPRODUCTION
REPRODUCTIVE CYCLE
REPTILES
RESEARCH PROGRAMS
RESOURCE MANAGEMENT AND USE
RESPIRATION
RESUSPENDED SEDIMENTS
REUSSELLA
RHIZOSOLENIA ALATA
RHODOPHYTA
RHOMBOPLITES AURORUBENS
RHYNCOCOELA
RIDLEY SEA TURTLES
RIGHT WHALES
RIVER DISCHARGE
ROUND SCAD
ROYAL TERN
RSMAS REPORT

SACCAMMINA
SACCOGLOSSUS KOWALEVSKII
SAFMC REPORT
ST. ANDREW SOUND
ST. AUGUSTINE
ST. CATHERINES ISLAND
SAINT HELENA SOUND
ST. MARYS RIVER
SALINITY
SALINITY TOLERANCE

Table A-3. Key Words in the Database *(continued)*

SALTWATER ENCROACHMENT
SALT WATER-FRESHWATER INTERFACE
SAMPLING EQUIPMENT
SAND AND GRAVEL
SAND PERCH
SAND WAVES
SANDWICH TERN
SANTEE RIVER DELTA
SAPELO ISLAND
SAPELO SOUND
SAPROTROPHS
SARDINELLA AURITA
SARGASSO SEA
SARGASSUM SPP.
SATELLITE IMAGERY
SATELLITES
SATILLA RIVER
SAVANNAH
SAVANNAH LIGHT TOWER
SAVANNAH RIVER
SCALLOPS
SCAMP
SCHPHOZOA
SCIAENIDAE
SCIAENOPS OCELLATUS
SCLEROBREGMA STENOCERUM
SCOMBER JAPONICUS
SCOMBEROMORUS
SCOMBEROMORUS BRASILIENSIS
SCOMBEROMORUS CAVALLA
SCOMBEROMORUS MACULATUS
SCOMBEROMORUS REGALIS
SCOMBER SCOMBRUS
SCOMBRIDAE
SCOUR
SCSGC REPORT
SCSG REPORT
SCWMRD REPORT
SCWRC REPORT
SEABED MORPHOLOGY
SEABROOK ISLAND
SEAFOOD INDUSTRY
SEA GRANT REPORT
SEA JELLIES
SEA LEVEL
SEA LEVEL CHANGES
SEALS
SEAMAP REPORT
SEAROBINS
SEASONAL DISTRIBUTION
SEASONAL VARIATIONS
SEA SPIDERS
SEA SURFACE
SEA TROUT
SEA TURTLES
SEAWEEDS
SEDIMENTARY PETROLOGY
SEDIMENTARY ROCKS
SEDIMENTARY STRUCTURES
SEDIMENTATION
SEDIMENT COMPOSITION
SEDIMENT CORES
SEDIMENTS
SEDIMENT TEMPERATURE
SEDIMENT TRANSPORT
SEDIMENT-WATER INTERFACE
SEISMIC REFLECTION
SEISMIC SURVEY
SEISMOLOGY
SELENIUM
SERGESTIDAE
SERRANIDAE
SERRANUS SUBLIGARIUS
SESSILE ORGANISMS
SESTON
SEWEE BAY
SEX RATIO
SEXUAL MATURITY
SHALLOW STRUCTURES
SHARKS
SHEARWATERS
SHEEPSHEAD
SHELF DYNAMICS
SHELLFISH
SHELLFISH FISHERY
SHELLS
SHIP COLLISIONS
SHIPS

SHIPWRECKS
SHOALS
SHORELINE CHANGES
SHORTNOSE STURGEON
SHRIMP
SHRIMP BAITING INDUSTRY
SHRIMP BOATS
SHRIMP FISHERY
SICYONIA BREVIROSTRIS
SICYONIA BURKENROADI
SICYONIA LAEVIGATA
SICYONIA STIMPSONI
SICYONIA TYPICA
SIDE SCAN SONAR
SILICA
SILVER PERCH
SINKHOLES
SIO REPORT
SIPUNCULUS NUDUS
SKELETONEMA COSTATUM
SNAPPERS
SOCIOECONOMIC ENVIRONMENT
SOLENOCERA ATLANTIDIS
SOUND PRODUCTION
SOUTH ATLANTIC BENCHMARK PROGRAM
SOUTH CAROLINA
SOUTHEAST GEORGIA EMBAYMENT
SOUTHERN KINGFISH
SOUTHERN PORGY
SPANISH MACKEREL
SPARIDAE
SPATIAL DISTRIBUTION
SPATIAL VARIATIONS
SPAWNING
SPECIES ASSOCIATIONS
SPECIES DIVERSITY
SPECIES LIST
SPECIES LISTS
SPECIES PROFILE
SPECKLED HIND
SPHAEROMA QUADRIDENTATUM
SPHAERONELLA SPINOSA
SPHECIOSPONGIA VESPARIUM
SPHYRNA MOKARRAN
SPINY LOBSTER
SPIOPHANES BOMBYX
SPISULA SOLIDISSIMA
SPONGES
SPOOT
SPOT
SPREX
SPRING
SPRING CONDITIONS
SQUID
STABILIZATION
STAR DRUM
STATE PROGRAM
STELLIFER LANCEOLATUS
STENOTOMUS ACULEATUS
STERNA ALBIFRONS
STERNA ANAETHETUS
STERNA MAXIMA
STERNA SANDVICENSIS
STINGRAYS
STOCK ASSESSMENT
STOMATOPODA
STOMOLOPHUS MELEAGRIS
STOMOLPHUS MELEAGRIS
STONE CRABS
STONO INLET
STORMS
STORM SURGES
STORM TRACKS
STRANDINGS
STRATIFICATION
STRATIGRAPHY
STRIPED BASS
STROMBUS
STROMBUS ALATUS
STROMBUS COSTATUS
STROMBUS GALLUS
STROMBUS GIGAS
STROMBUS GOLIATH
STROMBUS PUGILIS
STROMBUS RANINUS
SUBBOTTOM FEATURES
SUBSTRATES

SULA DACTYLATRA
SULFUR COMPOUNDS
SULLIVANS ISLAND
SUMMER
SURF CLAMS
SURVEY
SURVIVORSHIP
SUSPENDED ORGANIC MATTER
SUSPENDED PARTICULATES
SUSPENDED SEDIMENT
SWIMMING
SYMBIOSIS
SYSTEMATICS
TACTS BORINGS
TAGGING
TAR BALLS
TAXONOMY
TECHNICAL REPORT
TECHNIQUES
TECTONICS
TELEMETRY
TELEVISION
TEMORA STYLIFERA
TEMORA TURBINATA
TEMPERATURE EFFECTS
TEMPORAL VARIATIONS
TERNS
TERTIARY
TESTUDINES
TETRAPTURUS ALBIDUS
THALASSIOSIRA WEISSFLOGII
THALIACEA
THALIA DEMOCRATICA
THALLOPHYTES
THERMAL FRONTS
THESIS
THORIUM
THRAUSTOCHYTRIDS
THRU2226
THRU2327
THRU2469
THUNNUS ALBACARES
TIDAL CURRENTS
TIDES
TILEFISH
TIN
TINTINNIDS
TITANIDEUM FRAUENFELDII
TITANIUM
TOBETABULATED
TOMTATE
TOPOGRAPHIC EFFECTS
TOPOGRAPHIC MAP
TOXICITY
TRACE ELEMENTS
TRACE METALS
TRACERS
TRACER TECHNIQUES
TRACHYPENAEUS CONSTRICTUS
TRANSPORT PROCESSES
TRAP FISHING
TRAWLING
TRAWL NETS
TRAWL SURVEY
TREMATODES
TRIASSIC
TRICHECHUS MANATUS
TRITIUM
TROPHIC RELATIONSHIPS
TROPICAL CYCLONES
TRUNCATEDOK
TUBE DWELLERS
TUNA
TUNICATES
TURBIDITY
TURSIOPS TRUNCATUS
TURTLE EXCLUDER DEVICES
TYBEE ISLAND
TYBEE TROUGH

ULVA CURVATA
UNPUBLISHED
UPPER CRETACEOUS
UPTO1144
UPTO1272
UPTO1574
UPTO1867
UPTO1970

Table A-3. Key Words in the Database *(continued)*

UPTO2020
UPWELLING
UROCHORDATA
USACE REPORT
USFWS REPORT
USGS REPORT
USN REPORT

VANNELLA MIRA
VARIABILITY
VELOCITY
VERMILLION SNAPPER
VERTEBRATA
VERTEBRATES
VIBRACORES
VIBRIO FLUVIALIS
VIBRIO HARVEYI
VIRUSES
VISIBILITY

WAHOO
WANDO RIVER
WARSAW GROUPER
WASSAW ISLAND
WATER COLOR
WATER COLUMN
WATER MASSES
WATER POLLUTION
WATER QUALITY
WATER TEMPERATURE
WAVES
WEAKFISH
WEATHER TOWER
WELL-LOGGING
WHALES
WHELKS
WHITEBONE PORGY
WHITE GRUNT
WHITE MARLIN
WHITE SHRIMP
WILDLIFE CONSERVATION
WINDS
WIND STRESS
WINTER CONDITIONS
WISCONSINAN

XENOLAIMUS PAUROAMPHUS
XREJECTS
XYALA STRIATA

YELLOWFIN TUNA

ZINC
ZONATION
ZOOPLANKTON

Table A-3. Key Words in the Database *(continued)*

APPENDIX B

Database Bibliography

Appendix B
Database Bibliography

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METEOROLOGY

Citation: **Cardone, V. J. 1986. Hindcast of extreme wind, wave, surge and current data offshore Georgia. In: *Oceans '86 Conference Record: Science-Engineering-Adventure. Vol. 1. Systems, Structures and Analysis*, pp. 75-83. Institute of Electrical and Electronic Engineers, New York, NY.**

Resource: Hurricane weather conditions

Type of Research: Hindcasts by predictive models

Geographical Location: Georgia Bight

Summary: A data base of hurricane-generated surface winds, sea state, storm surges and currents is produced through a hindcast of sixteen of the most intense tropical cyclones to affect the South Atlantic Bight since 1900. The hindcasts are made with numerical prediction models (ODGP, SURGE II), which were developed originally for the specification of peak hurricane-generated winds, waves and surge heights in the Gulf of Mexico, but which have since undergone validation in a wide range of storm types in several basins. The extremal analysis of site-specific hindcast peak winds, wave and surge and current data provide new estimates of extremes at eight sites designated for structures.

Key Words: meteorology, hurricanes, hindcasts, waves, winds, storm surges, historical data, database

Citation: **Weber, A. H. and J. O. Blanton. 1980. Monthly mean wind fields for the South Atlantic Bight. *Journal of Physical Oceanography* 10(8): 1256-1263.**

Resource: Monthly wind data

Type of Research: Analysis of field observations

Geographical Location: South Atlantic Bight

Summary: A total of 339,389 marine weather observations are analyzed to produce monthly mean-wind fields for the South Atlantic Bight. The results of plotting wind vectors on a 2 latitude by 2 longitude grid yield four traditional flow regimes (winter, spring, summer and fall) and an additional regime designated as a mariner's fall. These seasonal wind regimes are discussed and related to the monthly mean ocean circulation in the Bight.

Key Words: meteorology, winds, wind stress, atmospheric forcing, circulation, seasonal variations, inner shelf, middle shelf, outer shelf

WATER MASSES

Citation: **Menzel, D. W., ed. 1993.** ***Ocean processes: U.S. Southeast Continental Shelf - A summary of research conducted in the South Atlantic Bight under the auspices of the U.S. Department of Energy from 1977 to 1991.*** **DOE/OSTI - 11674. U.S. Department of Energy, Oak Ridge, TN. 112 pages.**

Resource: Water Masses

Type of Research: Field and laboratory — physical, chemical, biological

Geographical Location: South Atlantic Bight

Summary: This publication summarizes the research conducted between 1977 and 1991, through funds from the Department of Energy, on the processes affecting the water masses of the South Atlantic Bight. The state of the knowledge concerning the processes pertinent to the physical, chemical and biological aspects of the inner and outer shelf regions is presented. The primary areas of research include oceanographic climatology, circulation processes, mixing, primary and secondary production, as well as transport, transformations and fluxes of inorganic and organic materials.

Key Words: physical oceanography, water masses, circulation, wind stress, currents, water column, geochemistry, upwelling, productivity

Citation: **Oey, L-Y., L. P. Atkinson, and J. O. Blanton. 1987. Shoreward intrusion of upper Gulf Stream water onto the US southeastern continental shelf.** ***Journal of Physical Oceanography*** **17(12): 2318-2333.**

Resource: Gulf Stream intrusions

Type of Research: Modeling of data from field observations

Geographical Location: South Atlantic Bight, middle and outer shelves

Summary: In winter, cooling of the South Atlantic Bight continental shelf water results in higher density in the middle-shelf region relative to the shelf-break region where the western flank of the Gulf Stream flows. Shoreward, estuarine-like intrusion of the upper Gulf Stream water in the presence of such a positive onshore density gradient is then possible through advective processes triggered either by the meanders of the Stream or onshore Ekman transports by southward wind stresses. Repeated cross-shelf hydrographic transects from January 10 to January 30, 1986 study this intrusion process more closely. These observations show many features predicted by a previous numerical model study. A semi-empirical model is proposed here in which the state of stratification of water on the outer continental shelf region just inshore of the shelf break is used as an indicator of the intrusion process.

Key Words: physical oceanography, water masses, Gulf Stream intrusions, meanders, advection, wind stress, physical model, circulation, middle shelf, outer shelf

WAVES, TIDES, AND CURRENTS

***Citation:* Pietrafesa, L. J., J. O. Blanton, J. D. Wang, V. Kourafalou, T. N. Lee, and K. A. Bush. 1985. The tidal regime in the South Atlantic Bight. In: *Oceanography of the southeastern U.S. continental shelf.* Coastal and Estuarine Sciences 2. Ed., L. P. Atkinson, D. W. Menzel, and K. A. Bush, pp. 63-76. American Geophysical Union, Washington, DC.**

Resource: Tidal processes and dynamics offshore

Type of Research: Overview of existing knowledge; predictive modeling

Geographical Location: South Atlantic Bight

Summary: Using data collected since 1975, the tidal regime of the South Atlantic Bight is investigated and discussed. Approximately 80% of the total kinetic energy on the inner and middle shelf areas of the South Atlantic Bight is attributed to tidal energies from the M_2 tides. A maximum tidal range of 2.2 m occurs offshore of Savannah, Georgia where the shelf is the widest. The outer shelf waters, which are influenced by the Gulf Stream, are not affected by tides to the same degree as the remainder of the shelf. Seasonal differences appear to exist in tidal currents across the shelf. A simple vertically integrated two-dimensional model is applied to prediction of tidal dynamics on the middle shelf region during winter conditions.

Key Words: physical oceanography, tides, tidal currents, mixing, seasonal variations, physical model, inner shelf, middle shelf, outer shelf

***Citation:* Li, L., M. Wimbush, D. R. Watts, A. J. Brincko, and T. N. Lee. 1985. Gulf Stream and wind-induced current variability on the Georgia continential shelf, Winter 1978. *Journal of Geophysical Research (C Oceans)* 90(C2): 3199-3210.**

Resource: Currents

Type of Research: Analysis of field observations

Geographical Location: Georgia Bight

Summary: Low-frequency longshore current fluctuations on the continental shelf off Georgia and their relationships with local atmospheric forcing and the Gulf Stream displacement are examined for a three-month period from January to April, 1978. On the middle shelf, current variability is dominated by local wind forcing at periods longer than two days, with very little Gulf Stream influence. Longshore wind stresses are the main driving force at periods longer than four days, while cross-shore wind contributed at shorter periods. In contrast, on the outer shelf, current fluctuations in the upper layer are highly coherent with the Gulf Stream displacement at a 12-day period and marginally coherent with a longshore wind at a 6-day period.

Key Words: physical oceanography, currents, atmospheric forcing, wind stress, water masses, circulation, Gulf Stream intrusions, Georgia, inner shelf, middle shelf, outer shelf

BATHYMETRY AND SEABED MORPHOLOGY

Citation: **Pilkey, O. H., B. W. Blackwelder, H. J. Knebel, and M. W. Ayers. 1981. The Georgia Embayment continental shelf: stratigraphy of a submergence. *Geological Society of America Bulletin* 92(1): 52-63.**

Resource: Surface and subsurface sediments of shelf

Type of Research: Field data collection and analysis

Geographical Location: Georgia Bight

Summary: Forty vibracores taken across the continental shelf and in proposed drilling lease areas of the southeast Georgia Embayment are used to document the unconsolidated shelf-sediment cover. The Holocene-Pleistocene sediment veneer is thin, generally less than 4 m thick. Lagoon sediments deposited during the last regression (shelf emergence) occur in patches on the inner and central shelf. Because essentially only late Pleistocene and Holocene mollusk shells are present in the shelf-sediment cover, it is believed that most of the carbonate fraction was removed by subaerial leaching during low sea-level stands aided by mechanical abrasion and biological degradation during the regressive-transgressive cycle. During each transgression or submergence, the surficial sand sheet is recharged with a new biogenic carbonate fraction along with the addition of small amounts of clastic sediments derived from "overrun" estuaries and erosion of underlying Tertiary sediments. The stratigraphy based on the vibracore supports the concept of cross-shelf migration of the shore face-barrier island systems in response to rising sea level. Sedimentologic and paleontologic analyses also indicate that extensive in-place mixing of shelf sediments may have occurred, an important factor to consider in evaluation of the fate of particulate pollutants. The establishment of the time frame of such mixing should be given high priority in future studies.

Key Words: geology, bathymetry, seabed morphology, bioturbation, carbonate fraction, deposition, sediments, stratigraphy, subbottom profiles, vibracores,
Georgia, South Carolina, inner shelf, middle shelf, outer shelf

Citation: **Emmel, F. J. and M. C. Karas. 1978. *Geologic hazard survey - Federal OCS lease block 559, Georgia Embayment, Atlantic coast.* Report (unpublished) prepared for Exxon Company, U.S.A., Houston, Texas. General Oceanographics, Inc., San Diego, CA. 30 pages.**

Resource: Surface and subsurface of shelf - geological structures

Type of Research: Data collection and analysis

Geographical Location: Georgia-Florida border — outer shelf

Summary: This report covers Federal OCS Lease Block 559 in the Georgia Embayment of the Atlantic coast. Conclusions are based upon data obtained in a marine geophysical survey conducted in May, 1978 for Exxon Company, U.S.A., owner of the lease. The survey was designed and executed for the sole purpose of examining seafloor and near-surface geologic conditions and to judge thereby, whether any condition present poses a potential hazard to drilling or construction operations. Block 559 is located about 65 nautical miles southeast of St. Simons Island adjacent to the Georgia-Florida state boundary. (authors abstract)

Key Words: geology, bathymetry, seabed morphology, geologic hazards, lease blocks, isopach map, oil and gas, sediments, unpublished, Georgia, Florida, outer shelf, geophysical survey

SEDIMENTS AND SEDIMENT TRANSPORT

Citation: **Schmitter, R. D. and R. P. Freeman-Lynde. 1988. Hornblende content of Georgia-South Carolina, U.S.A., nearshore sands: Support for shoreward sediment transport in the nearshore zone. *Sedimentary Geology* 57(3-4): 153-169.**

Resource: Heavy mineral tracers

Type of Research: Field and laboratory

Geographical Location: Georgia-South Carolina border - inner shelf

Summary: Core top samples taken off Hilton Head, South Carolina and Tybee, Wassaw and Ossabaw Islands, Georgia, were analyzed for heavy-mineral composition of acid-insoluble sand and gravel fractions and for unacidified samples. High hornblende contents at seaward ends of transects indicate shoreward transport of hornblende-rich sediments from the adjacent inner continental shelf. Low hornblende contents in middle portions of transects indicate dilution of hornblende-rich sands by hornblende-poor coastal plain sediments derived from coastal plain rivers, and exposed by shoreface and tidal inlet erosion. High hornblende contents at nearshore ends of transects reflect contribution of hornblende-rich sediment from Piedmont rivers to the nearshore zone.

Key Words: geology, sediments, sediment transport, heavy minerals, inner shelf, sedimentation, mineral tracers, Hilton Head Island, Tybee Island, Georgia, South Carolina

Citation: **Butman, B., M. Noble, and D. W. Folger. 1980. Bottom currents and bottom sediment mobility in the offshore southeast Georgia Embayment: Part 2, Observations of bottom current and bottom sediment movement in the Southeast Georgia Embayment. In: *Environmental studies: Southeastern United States Atlantic outer continental shelf, 1977 – geology*. U.S. Geological Survey Open File Report 80-146. Ed., P. Popenoe, pp. 4-II-1 to 4-II-29. U.S. Geological Survey, Reston, VA.**

Resource: Bottom sediments

Type of Research: Field

Geographical Location: middle shelf off Brunswick, Georgia

Summary: An instrument system was designed and deployed to measure long-term sediment transport rates on the continental shelf, between latitudes 31°00′ and 32°24′N and longitudes 78°50′ and 80°30′W. Observations of bottom currents and bottom sediments were made from a tripod deployed at a station east of Brunswick, Georgia in water 30 m deep. Current speed, direction and water temperature were averaged every 3.75 minutes, and a camera system photographed the bottom every two hours. Bottom currents are typically 20 cm/sec and were tidal dominated. The surficial bottom sediments are re-worked by benthic organisms and only occasionally by near-bottom currents. Resuspension into the water column is minimal.

Key Words: geology, sediments, sediment transport, currents, tidal currents, Brunswick, Georgia, middle shelf, bottom stress, sediment-water interface

AQUIFERS

Citation: **Johnston, R. H. 1983. Saltwater-Freshwater Interface in the Tertiary Limestone Aquifer, Southeast Atlantic Outer-Continental Shelf of the U.S.A.** ***Journal of Hydrology*** **61(1-3): 239-249.**

Resource: Groundwater

Type of Research: Hydrology tests in well field

Geographical Location: Georgia-Florida border - inner to outer shelf

Summary: The tertiary limestone aquifer of the southeastern USA is a sequence of carbonate rocks from which more than 3 billion gallons (approximately 11,400,000 cu m) of water is pumped daily. This aquifer system is the principal source of municipal, industrial and agricultural water in south Georgia and most of Florida. Hydrologic testing in an offshore oil well determined the position of the saltwater-freshwater interface in Tertiary limestones underlying the Florida-Georgia shelf. At the offshore well, 55 miles east of Fernandina Beach, drill stem tests in the interval 1050-1070 ft (320-326 m) below sea level in the Ocala limestone recovered a sample with a chloride concentration of 7000 mg/1. Formation water probably is slightly fresher. Pressure-head measurements indicated equivalent freshwater heads of 24-29 ft (7.3-8.8m) above sea level. At the coast (Fernandina Beach), a relatively thin transition zone separating freshwater and saltwater occurs at a depth of 2100 ft (640 m) below sea level. Fifty-five miles (88 km) offshore, the base of freshwater is approximately 1100 feet (335 m) below sea level. The difference in depth to the transition at these two locations suggests an interface with a very slight landward slope. Assuming the Hubbert interface equation applies here, the equilibrium depth to the interface is less than the observed 2100 ft. Substituting predevelopment heads in the equation yields depths greater than 2100 ft. Some movement of the interface has occurred during the past 100 years. The implied movement is incompatible with the hypothesis that the freshwater occurring far offshore in this area is trapped water remaining since the Pleistocene Epoch.

Key Words: geology, aquifers, groundwater, saltwater-freshwater interface, Floridan aquifer, salt water intrusion, well sites, Florida, Georgia, outer shelf, middle shelf, inner shelf

Citation: **Paull, C. K. and W. P. Dillon. 1982. The stratigraphy of the Florida-Hatteras shelf and slope and its relationship to the offshore extension of the principal artesian aquifer. In: *Proceedings of the Second Symposium on the Geology of the Southeastern Coastal Plain (Americus, GA, 5-6 March 1979).* Georgia Geologic Survey Information Circular 53. Eds., D. D. Arden, B. F. Beck, and E. Morrow, pp. 178-181. Georgia Department of Natural Resources, Georgia Geologic Survey, Atlanta, GA.**

Resource: Groundwater

Type of Research: Data analysis of field studies

Geographical Location: South Atlantic Bight - outer shelf and slope

Summary: Seismic reflection profiles are used to trace the stratigraphic units of the principal artesian aquifer to the shelf zone. Isopach contour maps were made upon identification and delineation of these units. The data suggest that the offshore extension of the aquifer contains abundant fresh water off northern Florida, but not very far off central Georgia.

Key Words: geology, aquifers, stratigraphy, seismic surveys, isopach maps, groundwater, Georgia, Florida, inner shelf, middle shelf, outer shelf

GEOLOGIC HAZARDS AND ENVIRONMENTAL STUDIES

Citation: **Henry, V. J., C. J. McCreery, F. D. Foley, and D. R. Kendall. 1981. Ocean bottom survey of the Georgia Bight. In: *Environmental geologic studies on the southeastern Atlantic outer continental shelf, 1977-1978.* U.S. Geological Survey Open File Report 81-582-A. Ed., P. Popenoe, pp. 6-1 to 6-85. U.S. Geological Survey, Woods Hole, MA.**

Resource: Bottom and shallow sub-bottom sediments

Type of Research: Field investigation by seismic, side-scan, and CCTV

Geographical Location: Georgia Bight

Summary: Four cruises determined the occurrence and distribution of biologically sensitive areas and shallow geologic hazards through use of a Uniboom, a 3.5KHz seismic sub-bottom profiler, a side-scan sonar and towed underwater television. Strong acoustic reflectors represent outcrops, while weaker reflectors are associated with the thin veneer of sediments associated with the latest rise of sea level. Two shallow sub-surface reflectors appear to represent separate exposures of the continental shelf during lower sea-level stands. Numerous channels and cut-and-fill features reflect fluvial processes active at those times. The larger channels, up to 40 m in depth, are downcut through the deeper reflector, while the smaller of these features are generally established on the surface of the shallower reflector. A tentative correlation of the shallow reflector with the Pleistocene erosion surface and the deeper with the top of the Middle Pliocene is based on stratigraphic details of this investigation and from past studies. The distribution of sessile benthic and pelagic biota appears random, but is related to the presence of reefs and hard bottoms.

Key Words: geology, geologic hazards, environmental studies, geophysical surveys, bedforms, seabed morphology, hard grounds

Citation: **Ball, M. M., P. Popenoe, M. E. Vazzana, E. L. Coward, W. P. Dillon, T. Durden, J. C. Hampson, and C. K. Paull. 1979. South Atlantic outer continental shelf hazards map. In: *South Atlantic Benchmark Program: Volume 5 - South Atlantic Outer Continental Shelf Geological Studies, fiscal year 1976, Geology*. Bureau of Land Management Report No. BLM/YM/ES - 79/11. Ed., P. Popenoe, pp. 484-500. U.S. Geological Survey, Woods Hole, MA.**

*Resource:*Sub-surface geological structures

Type of Research: Field

Geographical Location: South Atlantic Bight

Summary: This report contains a map and narrative description of the map. Four hundred and thirty-seven faults are identified in the mapped area, most of which are normal faults, with relative displacement down to the east and south. No active sand wave fields are noted on the shelf by this report.

Key Words: geology, geologic hazards, faults, cut and fill structures, map

STRATIGRAPHY AND SHALLOW STRUCTURE

Citation: **Henry, V. J. and J. A. Kellam. 1988. *Seismic investigations of the phosphate-bearing, Miocene-age stata of the continental shelf of Georgia.* Georgia Geologic Survey Bulletin No. 109. Georgia Department of Natural Resources, Georgia Geologic Survey, Atlanta, GA. 43 pages.**

Resource: Miocene Strata

Type of Research: Field

Geographical Location: Georgia Bight — inner shelf

Summary: Data from offshore high-resolution seismic survey tracts are correlated with well-defined onshore lithostratigraphy, as well as with widely-separated borings on the continental shelf. Stratigraphic profiles and isopachs, as well as structured contour maps, are constructed depicting Neogene formational contacts as well as buried topographic features. The area of investigation is located along the inner portion of the Georgia coast and on the continental shelf between Port Royal Sound, South Carolina and St. Mary's Inlet on the Georgia-Florida border.

Key Words: geology, stratigraphy, seismic survey, isopach maps, Miocene, Neogene, phosphates, aquifers, Georgia, South Carolina, inner shelf, outer shelf

Citation: **Henry, V. J. and F. M. Idris. 1992. *Offshore minerals assessment studies on the Georgia continental shelf - phase 2: Seismic stratigraphy of the TACTS area and evaluation of selected sites for economic hard minerals potential.* Georgia Geologic Survey Project Report No. 18. Georgia Department of Natural Resources, Georgia Geologic Survey, Atlanta, Georgia. 143 pages.**

Resource: Heavy Minerals

Type of Research: Field investigation

Geographical Location: Georgia — outer continental shelf

Summary: A series of high-resolution seismic profiles between the drill sites and borings from the Department of the Navy's Tactical Aircrew Combat Training System (TACTS) offshore platforms provide a regional stratigraphic framework for the Miocene-age phosphate-bearing deposits, and help to delineate the presence of other hard mineral resources, such as heavy minerals and sand and gravel. A towed gamma mapping system for the detection of naturally-occurring radioactive minerals on or near the seafloor is utilized. Fifteen drill sites are sampled with a vibralift drill capable of 20 feet of penetration.

Key Words: geology, stratigraphy, geophysical surveys, heavy minerals, TACTS, borings, phosphorite, Miocene, Georgia, outer shelf

WATER COLUMN

Citation: **Bush, K. A. 1988. Identification of Savannah River water on the South Atlantic Bight shelf using tritium. *Journal of Geophysical Research (C Oceans)* 93(C8): 9315-9331.**

Resource: Fresh water plumes from river discharges to shelf

Type of Research: Field measurements using tritium and salinity as tracer

Geographical Location: Savannah River and adjacent continental shelf

Summary: Tritium and salinity data are used to investigate the transport and fate of freshwater on the South Atlantic Bight shelf. Tritium and salinity samples were collected at selected locations as part of the April 1985 Spring Removal Experiment (SPREX). A three-source mixing model using tritium and salinity as tracers is used to determine if fresh water from the Savannah River can be distinguished from other sources on the South Atlantic Bight inner shelf. Variations in tritium concentration, integrated freshwater fraction, and model results are related to hydrographic and meteorological conditions. Results suggest that salinity and tritium concentration can be used to identify Savannah River water on the shelf and that Savannah River water maintains a distinct tritium-salinity relationship, at least as far north as Charleston, South Carolina.

Key Words: water column, outwelling, freshwater runoff, river discharge, physical model, circulation, tracers, tritium, salinity, Savannah River, Georgia, SPREX, hydrochemistry

Citation: **Windom, H. L., R. G. Smith Jr., and C. Rawlinson. 1989. Particulate trace metal composition and flux across the southeastern U.S. continental shelf. *Marine Chemistry* 27(3-4): 283-297.**

Resource: Trace metals in suspension in shelf waters

Type of Research: Field sampling of trace metals

Geographical Location: South Atlantic Bight

Summary: The concentration and distribution of particulate trace metals in waters of the South Atlantic Bight are controlled by cross-shelf advection of continentally-derived inorganic detritus from nearshore sources and in situ biogenic particle production. Particulate trace metal flux across the outer continental shelf is mostly in organic particles. With the exception of Fe, the cross-shelf transport of trace metals in terrestrially-derived particles is considerably less than the soluble transport of trace metals delivered to the South Atlantic Bight by rivers.

Key Words: water column, trace metals, flux, transport processes, advection, river discharge, hydrochemistry, hydrogeochemistry

GEOCHEMISTRY

Citation: **Fallon, R. D. 1987. Sedimentary Sulfide in the Nearshore Georgia Bight. *Estuarine, Coastal and Shelf Science* 25(6): 607-619.**

Resource: Sediment chemistry and sediment types

Type of Research: Field sampling and laboratory analysis

Geographical Location: Georgia Bight - inner shelf

Summary: Sedimentary sulfide, iron and organic matter were measured in neritic sediments from the Georgia Bight. Two depth-integrated sulfur pools, FeS + HS super(-1) and FeS sub (2), tend to decrease with increasing distance from shore out to 33 km. Total iron and organic matter are strongly correlated and tend to decrease with increasing distance from shore. Sediment depth profiles of organic matter/reduced sulfur suggest relatively constant rates of sulfate reduction over the top 40 cm of sediment. Within-station variances indicate regions of lower and higher spatial/temporal heterogeneity that may be related to tide-driven circulation patterns. No seasonal cycles are evident in sedimentary sulfides.

Key Words: geochemistry, sediments, sulfides, iron, organic material, Georgia, inner shelf

Citation: **Windom, H. L., S. J. Schropp, F. D. Calder, J. D. Ryan, R. G. Smith Jr., L. C. Burney, F. G. Lewis, and C. H. Rawlinson. 1989. Natural trace metal concentrations in estuarine and coastal marine sediments of the southeastern United States. *Environmental Science and Technology* 23(3): 314-320.**

Resources: Trace metals in sediments

Type of Research: Field and laboratory

Geographical Location: Southeastern U.S. including the Georgia inner shelf

Summary: Over 450 sediment samples from estuarine and coastal marine areas of the southeastern United States, remote from contaminant sources, were analyzed for trace metals. Although these sediments are compositionally diverse, As, Co, Cr, Cu, Fe, Pb, Mn, Ni and Zn concentrations co-vary significantly with aluminum, suggesting that natural aluminosilicate minerals are the dominant natural metal-bearing phases. Cd and Hg do not co-vary with aluminum, apparently due to the importance of the contribution of natural organic phases to their concentration in sediments. It is suggested that the co-variance of metals with aluminum provides a useful basis for identification and comparison of anthropogenic inputs to southeastern U.S. coastal/estuarine sediments. By use of this approach, sediments from the Savannah River, Biscayne Bay and Pensacola Bay are compared.

Key Words: geochemistry, trace metals, sediments, inner shelf, Savannah River

MICROBES

Citation: **Griffith, P. C., D. J. Douglas, and S. C. Wainright. 1990. Metabolic Activity of Size-Fractionated Microbial Plankton in Estuarine, Nearshore, and Continental Shelf Waters of Georgia. *Marine Ecology Progress Series* 59(3): 263-270.**

Resources: Nannoplankton/microbial metabolic activities

Type of Research: Field collection and laboratory analysis

Geographical Location: Georgia - coastal and continental shelf waters

Summary: Estimates of bacterial production and activity, and planktonic community respiration, are made at a series of stations starting in an estuary, passing through the coastal front and across the continental shelf to a distance of 120 km offshore in the Georgia Bight. Measurements are made on unfiltered and on 1.0 mu m (pore-size) filtered water samples to examine the small free-living bacterial size fraction related to the larger plankton. In waters landward of the coastal front, ca 50 to 80% of bacterial and community activity is associated with the large size fraction, indicating the importance of large and particle-associated heterotrophs in the nearshore, highly turbid water. Seaward of the front, 80 to 99%

of activity is in the $< 1.0\ \mu m$ fraction. Thus, the $< 1.0\ \mu m$ size fraction is responsible for most of the respiration in shelf waters.

Key Words: microbes, nannoplankton, bacteria, respiration, metabolic activity, productivity, heterotrophy, Georgia

Citation: **Pomeroy, L. R. 1985. The microbial food web of the southeastern U.S. continental shelf. In: *Oceanography of the southeastern U.S. continental shelf.* Coastal and Estuarine Sciences 2. Eds., L. P. Atkinson, D. W. Menzel, and K. A. Bush, pp. 118-129. American Geophysical Union, Washington, DC.**

Resources: Nannoplankton/microbial trophic activities

Type of Research: Review and synthesis of the literature

Geographical Location: South Atlantic Bight

Summary: This paper provides an overview of the status (ca 1985) of research into the populations and productivity of microbial organisms in marine waters of the South Atlantic Bight. In particular, energy transfers and nutrient cycling within the planktonic food webs are investigated with emphasis upon the microbial trophic interactions between bacteria and protozoan consumers. Populations of microbes are found to fluctuate in size relative to nutrient fluxes associated with intrusions of water masses onto the shelf through river discharge and from upwelling. Bacterial populations, for instance, increase in response to availability of higher phytoplankton concentrations in mixed waters. Aggregates of attached bacteria may also form on each other, or inorganic or on nonliving particulate matter, such as zooplankton fecal particles. Bacterial populations are limited in turn through consumption by protozoans such as flagellates and ciliates. As such, microbial food chains seem to be in parallel, not in series, with phytoplankton-grazing food chains. A significant portion of the energy flux in the marine food web is linked to microbial metabolic activities.

Key Words: microbes, bacterioplankton, population dynamics, food webs, trophic relationships, feeding, nutrients, energy flux

MACROALGAE

Citation: **Searles, R. B. 1987. Phenology and floristics of seaweeds from the offshore waters of Georgia. *Northeast Gulf Science* 9(2): 99-108.**

Resources: Marine flora

Type of Research: Field collection and laboratory analysis

Geographical Location: Georgia - inner shelf (Gray's Reef), outer shelf (Snapper Banks)

Summary: Seaweeds are studied from rock outcrops in two areas on the Georgia continental shelf, Gray's Reef National Marine Sanctuary on the inner shelf and an area known as the "Snapper Banks" on the outer shelf. The seaweeds observed are seasonal; only a few plants persist through the winter. In this study, a gradual increase in number and size of plants and number of species is observed through June; by July-early August, when all 66 species reported are present, the quantity of plants also appears maximal. Of the 66 species, 44 are species not previously reported from Georgia; eight additional taxa are identified only to genus, but are also new to the region. Sixty-five of the species were collected at Gray's Reef and twenty-two at the Snapper Banks; three of the latter did not occur at Gray's Reef. In late August and September, when water temperatures are still near the seasonal high, a rapid decline in number of species and algal cover is reported.

Key Words: macroalgae, species inventory, new records, range, geographical distribution, Gray's Reef, Snapper Banks, hard grounds, live bottoms, Georgia, inner shelf, outer shelf, biological resource areas

***Citation:* Richardson, J. P. 1986. Additions to the macroalgal flora of coastal Georgia. *Georgia Journal of Science* 44: 131-135.**

Resources: Macroalgae

Type of Research: Field collection

Geographical Location: Georgia - coastal and shelf waters

Summary: The macroalgal flora of coastal Georgia have received limited phycological investigation, there being only two published listings of seaweed occurring along the Georgia coast. Forty-three species of Chlorophyceae, Phaeophyceae and Rhodophyceae were reported from inshore Georgia previously. New Georgia records for twenty-six species of eleven Chlorophyceae, four Phaeophyceae and eleven Rhodophyceae are reported based on collections made year-around from a variety of substrata along the coast. This study extends the range for four of these newly recorded species. The recorded marine macroalgal flora of coastal Georgia has now been expanded to sixty-six species, comprised of twenty-nine Chlorophyceae, eight Phaeophyceae and twenty-nine Rhodophyceae.

Key Words: macroalgae, species inventory, new records, range, geographical distribution, Gray's Reef, Snapper Banks, hard grounds, live bottoms, Georgia, estuaries, inner shelf, middle shelf, outer shelf, biological resource areas

PHYTOPLANKTON

***Citation:* Yoder, J. A. 1985. Environmental control of phytoplankton production on the southeastern U.S. continental shelf. In: *Oceanography of the southeastern U.S. continental shelf.* Coastal and Estuarine Sciences 2. Eds., L. P. Atkinson, D. W. Menzel, and K. A. Bush, pp. 93-103. American Geophysical Union, Washington, DC.**

Resources: Phytoplankton

Type of Research: Field and laboratory

Geographical location: South Atlantic Bight

Summary: The processes which affect the primary production, its rate and dynamic nature, differ depending upon the position on the shelf and distance from shore. Within the coastal influence of low-salinity water, the production is relatively constant throughout the year, and is maintained by nutrient input from rivers and marshes. This same coastal area has high turbidity which limits the amount of light available for photosynthesis. At the shelf break, upwelling influenced by Gulf Stream intrusions is the dominant process affecting phytoplankton production. The spread of upwelled water affects the mid-shelf as well as the outer shelf.

Key Words: plankton, phytoplankton, turbidity, nutrients, upwelling, outwelling, upwelling, transport processes, productivity, inner shelf, middle shelf, outer shelf, estuary-shelf exchange

Citation: **Verity, P. G. and J. A. Yoder. 1987. *Biological processes in the water column of the South Atlantic Bight: Phytoplankton response - A three-year progress report.* Report prepared for U.S. Department of Energy. Skidaway Institute of Oceanography, Savannah, GA. 16 pages.**

Resources: Phytoplankton

Type of Research: Field measurements

Geographical Location: South Atlantic Bight

Summary: This project report summarizes three years of interdisciplinary studies on the spring removal period (SPREX), when low salinity waters nearshore move offshore in the South Atlantic Bight, between Cape Fear and Savannah. The objectives of the research were to determine the ultimate fate of the phytoplankton, as well as the affects of wind stress on the biomass nearshore. Shipboard research was augmented with satellite imagery from Coastal Zone Color Scanner (CZCS) data.

Key Words: plankton, phytoplankton, transport processes, wind stress, salinity, SPREX, satellite imagery, South Carolina, Georgia

ZOOPLANKTON

Citation: **Paffenhöfer, G-A. 1988. Feeding rates and behavior of zooplankton. *Bulletin of Marine Science* 43(3): 430-445.**

Resources: Zooplankton

Type of Research: Field measurements

Geographical Location: Northeastern Florida — outer shelf

Summary: The vertical distribution of zooplankton relative to depth, temperature and particulate matter concentrations is measured in the field. High particulate concentrations are noted in near-seafloor low-temperature Gulf Stream water from upwelling. Vertical distribution patterns vary with zooplankton taxa.

Key Words: plankton, zooplankton, spatial distribution, water temperature, suspended particulates, food sources, upwelling, Florida, outer shelf

Citation: **Paffenhöfer, G-A. 1985. The abundance and distribution of zooplankton on the southeastern shelf of the United States. In: *Oceanography of the southeastern U.S. continental shelf.* Coastal and Estuarine Sciences 2. Ed., L. P. Atkinson, D. W. Menzel, and K. A. Bush, pp. 104-117. American Geophysical Union, Washington, DC.**

Resources: Zooplankton

Type of Research: Overview of status of field research/knowledge

Geographical Location: South Atlantic Bight

Summary: The principal conclusion of this document is that the episodic upwelling of nutrient-rich waters from beneath the Gulf Stream, causing increased phytoplankton production, is responsible for the high zooplankton concentrations on the middle and outer continental shelf. The episodic nature of the upwelling causes the food supply to be discontinuous, which, combined with water movements initiated by wind and currents, and predatory feeding by adult copepods and fish, causes high loss of fish larvae.

Key Words: plankton, zooplankton, abundance, upwelling, currents, wind stress, nutrients, ichthyoplankton, Gulf Stream intrusions, middle shelf, outer shelf

UPWELLING AND PRODUCTIVITY

Citation: **Yoder, J. A., L. P. Atkinson, S. S. Bishop, E. E. Hofmann, and T. N. Lee. 1983. Effect of upwelling on phytoplankton productivity of the outer southeastern United States continental shelf. *Continental Shelf Research* 1(4): 385-404.**

Resources: Phytoplankton

Type of Research: Field measurements

Geographical Location: South Atlantic Bight

Summary: Three interdisciplinary studies investigate phytoplankton responses to upwelled water intruded upon the continental shelf by Gulf Stream frontal disturbances. The findings show that when shelf waters are unstratified, the upwelling results in diatom blooms on the outer shelf. When waters are stratified, the new water penetrates well up onto the shelf as a subsurface intrusion.

Key Words: upwelling, productivity, Gulf Stream intrusions, phytoplankton, outer shelf, transport processes, advection, seasonal variations

Citation: **Lee, T. N., J. A. Yoder, and L. P. Atkinson. 1991. Gulf Stream frontal eddy influence on productivity of the southeast U.S. continental shelf. *Journal of Geophysical Research (C Oceans)* 96(C12): 22,191-22,205.**

Resources: Nutrients

Type of Research: Field measurements

Geographical Location: South Atlantic Bight

Summary: The meanders and eddies of Gulf Stream frontal intrusions are found to be persistent features along the southeastern U.S. shelf edge and slope. Data from moored current meters and temperature probes are correlated with satellite imagery to reveal the patterns of growth and decay of those cells across and along the shelf boundary. The onshore movement of the nutrient-rich water is thought to be of paramount importance to the food chain.

Key Words: productivity, Gulf Stream intrusions, meanders, eddies, nutrients, transport processes, satellite imagery, outer shelf, continental slope

OUTWELLING

Citation: **Odum, E. P. 1980. The Status of Three Ecosystem-Level Hypotheses Regarding Salt Marsh Estuaries: Tidal Subsidy, Outwelling, and Detritus-Based Food Chains. In: *Estuarine Perspectives: Proceedings of the Fifth Biennial International Estuarine Research Conference (Jekyll Island, Georgia, October 7-12 1979)*. Ed., V. A. Kennedy, pp. 485-507.**

Resources: Food chain

Type of Research: Review paper

Geographical Location: Georgia Bight - inner shelf

Summary: Three general hypotheses are discussed: (1) that tides provide an energy subsidy; (2) that organic matter is transported from estuaries to the offshore, i.e. outwelling; and (3) detritus dominates the salt marsh ecosystem. Of the three, only the tidal subsidy hypothesis is thought to be verified to the extent that it can be considered a general principle.

Key Words: outwelling, estuary-shelf transport, tides, energy flux, nutrients, trophic relationships, food chains, Georgia, inner shelf

Citation: **Moran, M. A., L. R. Pomeroy, E. S. Sheppard, L. P. Atkinson, and R. E. Hodson. 1991. Distribution of terrestrially derived dissolved organic matter on the southeastern US continental shelf.** ***Limnology and Oceanography*** **36(6): 1134-1149.**

Resources: Organic Matter

Type of Research: Field measurements

Geographical Location: Georgia Bight - inner shelf

Summary: Dissolved lignin concentrations are measured and found to be highest near the shore and in areas receiving discharge from coastal rivers and marshes. Concentrations vary with time on both short-term (weekly) and long-term bases (seasonal). Salinity correlate negatively with lignin concentrations, suggesting mixing in shelf waters.

Key Words: outwelling, estuary-shelf transport, river discharges, dissolved organics, phenols, water column, Georgia, inner shelf

BENTHIC INVERTEBRATES

Citation: **Hopkinson, C. S. and R. L. Wetzel. 1982. In situ measurements of nutrient and oxygen fluxes in a coastal marine benthic community.** ***Marine Ecology Progress Series*** **10(1): 29-35.**

Resources: Benthic Invertebrates

Type of Research: Field sampling

Geographical Location: Georgia Bight - inner shelf

Summary: Fluxes in levels of oxygen and nutrients are measured on the inner shelf nearshore during the summer in the Georgia Bight. Dissolved organic nitrogen is taken up by sediments from the water during this period. Meanwhile, the sediments release phosphate, nitrate, nitrite and ammonium to the water column. The benthos is estimated to account for remineralization of 55% of the net primary production and 25% of the total benthic and pelagic community metabolism. An outside source of carbon is needed in order to balance the carbon budget; the estuaries are the most likely source of this carbon. Approximately 16% of the nitrogen and 53% of the phosphorus that are required by phytoplankton is produced by the benthos. This supports the hypothesis that the availability of both nitrogen and phosphorus for production in the water column is controlled, and limited, by the benthic processes which occur in these nearshore waters.

Key Words: invertebrates, benthic, mineral nutrients, benthic boundary layer, sediment-water interface, productivity, Georgia Bight, inner shelf

Citation: **Hanson, R. B., K. R. Tenore, S. Bishop, C. Chamberlain, M. M. Pamatmat, and J. Tietjen. 1981. Benthic Enrichment in the Georgia Bight Related to Gulf Stream Intrusions and Estuarine Outwelling.** ***Journal of Marine Research*** **39(3): 417-441.**

Resources: Benthic Invertebrates

Type of Research: Field sampling

Geographical Location: Georgia Bight

Summary: Nutrient inputs from intrusions of deep Gulf Stream water are reflected in the distribution patterns of the benthic biomass over the continental shelf of the Georgia Bight. Meiofaunal biomass is highest in the mid-shelf region off Georgia which receives intrusion waters. Throughout the entire shelf, nematode and copepod biomass exhibit an inverse relationship to macrofaunal biomass.

Key Words: invertebrates, benthic, Gulf Stream intrusions, nutrients, biomass, macrofauna, upwelling, outwelling, productivity, Georgia Bight, inner shelf, middle shelf, outer shelf

NEKTONIC INVERTEBRATES

Citation: **Muncy, R. J. 1984.** ***Species profiles: Life histories and environmental requirements of coastal fishes and invertebrates — White shrimp (South Atlantic).*** **FWS/OBS-82/11.27. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. 26 pages.**

Resource: White shrimp

Type of Research: Data collection and description

Geographical Location: South Atlantic Bight

Summary: The white shrimp, *Penaeus setiferus*, is the most important commercial species in the southeastern United States. It serves an important ecological role as food for other large invertebrates and fishes. The major bait industry is in northeast Florida and Georgia. Spawning occurs offshore within the 9 m depth contour where salinities are at least 27 ppt. In spring, postlarval shrimp move with tidal currents into inshore estuarine waters. Juvenile white shrimp prefer shallow organic-rich substrate with low salinities (1-10 ppt). Nearshore soft-sediment areas correlate well with white and brown shrimp distributions. Water temperature influence spawning, growth, habitat selection, emigration and mortality. Low winter temperatures have greatly affected survival, recruitment and harvest in the South Atlantic fishery. Maintaining suitable nursery grounds is a major concern for the future of the fishery.

Key Words: invertebrates, nektonic, Crustacea, shrimp, life history, species profile, life cycle, spawning, commercial crustacean fishery, inner shelf

Citation: **Wenner, E. L. and C. A. Wenner. 1989. Seasonal composition and abundance of decapod and stomatopod crustaceans from coastal habitats, southeastern United States.** ***Fishery Bulletin*** **87(1): 155-176.**

Resources: Crustaceans

Type of Research: Field collection

Geographical Location: South Atlantic Bight

Summary: Sixty species of decapod and three species of stomatopod crustaceans were collected. Fifteen species account for 95% of the total number of individuals and 96% of the total biomass. No consistent changes occur with latitude in regard to totals for numbers of individuals, species or in regard to mean total weight.

Key Words: invertebrates, nektonic, populations, Crustacea, species inventory, geographical distribution, abundance, seasonal variations, inner shelf

FISH

Citation: **Nicholson, N., J. M. Pafford, and A. G. Woodward. 1991.** ***An assessment of the relative abundance of finfish in coastal Georgia, February 1984 - June 1989.*** **Coastal Resources Division Contribution 53. Georgia Department of Natural Resources, Brunswick, GA. 73 pages.**

Resources: Finfish

Type or Research: Field data collection

Geographical Location: Georgia - coastal and inner shelf waters

Summary: This study provides information on feeding habits, age and growth, movement and migration, seasonality of occurrence and reproductive biology of 11 recreationally important species of finfish. Unlike previous studies, which were based in large part on commercial landings data or surveys of fish caught with trawls, personnel from the Georgia Department of Natural Resources investigate these parameters directly in the field. All finfish are measured to the nearest millimeter. Sampling was conducted in daylight hours only, and physiochemical data collected at each site, including salinity, surface water temperature, moon phase, and wind direction and velocity. Trammel nets were used exclusively.

Key Words: fish, vertebrates, life history, fish biology, reproduction, recreational fishery, length-frequency, Georgia, coastal waters

Citation: **Wenner, C. A. and G. R. Sedberry. 1989. *Species composition, distribution, and relative abundance of fishes in the coastal habitat off the southeastern United States.* NOAA Technical Report NOAA-TR-NMFS-79. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Rockville, MD. 58 pages.**

Resources: Fish populations

Type of Research: Collection and analysis of trawl data

Geographical Location: South Atlantic Bight — coastal and inner shelf waters

Summary: Ichthyofauna of the coastal (10 m depth) habitat in the South Atlantic Bight are investigated between Cape Fear, NC and the St. John's River, Florida. Trawl collections from four nonconsecutive seasons in the periods July 1980 to December 1982 indicate that the fish community is dominated by the family Sciaenidae, particularly juvenile forms. Total fish abundance is greatest in winter and lowest in summer and is influenced by the seasonality of Atlantic menhaden and Atlantic croaker in the catches. Biomass is highest in spring and lowest in summer, and is influenced by biomass of spot. Species assemblages are dominated by ubiquitous year-round residents of the coastal waters of the bight. Diversity is highest in summer and appears to be influenced by the evenness of distribution of individuals among species.

Key Words: fin, vertebrates, species inventory, diversity, biomass, populations, abundance, geographical distribution, seasonal variations, South Atlantic Bight, inner shelf

BIRDS

Citation: **Clapp, R. B., R. C. Banks, D. Morgan-Jacobs, and W. A. Hoffman. 1982. *Marine Birds of the Southeastern United States and Gulf of Mexico: Part I, Gaviiformes through Pelecaniformes.* FWS/OBS - 82/01. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, DC. 637 pages.**

Resources: Marine birds

Type of Research: Data compilation, synthesis, and analysis

Geographical Location: Southeastern U.S. Atlantic and Gulf coasts

Summary: This report is a compilation of information on the seasonal distribution and abundance of 39 species of marine birds that occur off the southeast U.S. coast, based on thousands of literature citations. Information on distribution, habitat, food, and various other aspects of life history is summarized. The information is intended to assess the possible effects of offshore oil development on populations of marine birds. This is the first document in a set of three volumes produced during this assessment.

Key Words: birds, vertebrates, life history, geographical distribution, food sources, abundance, habitat, literature review, seasonal variations, inner shelf, middle shelf, outer shelf

Citation: **Haney, J. C. 1987. Pelagic seabird ecology and its relationship to environmental heterogeneity in the South Atlantic Bight. Ph.D. Dissertation, University of Georgia (Athens).**

Resources: Marine birds

Type of Research: Field census

Geographical Location: South Atlantic Bight

Summary: The habitat selection by the seabirds in the South Atlantic Bight appears to be a consequence of processes acting within the water mass, including predator-prey relationships. This study is based on the comparison of three years of shipboard census-taking combined with oceanographic parameters derived with remote-sensing techniques.

Key Words: birds, habitats, food sources, remote sensing, Ph.D. dissertation

SEA TURTLES

Citation: **Shoop, C.R., Ruckdeschel, C.A., and Thompson, N.B. 1985. Sea Turtles in the Southeast United State: Nesting Activities as Derived from Aerial and Ground Surveys, 1982. Herpetologica, Vol. 41, No. 3, pp. 252-259.**

Resources: Sea turtles

Type of Research: Field surveys (aerial and ground-truth)

Geographical Location: Southeastern U.S. Atlantic and Gulf coasts

Summary: Aerial surveys over the entire United States from Cape Hatteras, NC to the Texas-Mexico border by a single-observer team during the spring and summer of 1982 indicate that the greatest sea turtle nesting is in Florida (accounting for more than 85%) followed by South Carolina, Georgia, North Carolina and Alabama, respectively. Almost all nesting activity is by loggerheads *(Caretta caretta).* Possible reasons for present nesting distributions include egg predation by native and feral domestic animals, habitat destruction by introduced animals, natural and human-induced changes in beach areas, and temperature regimes of past decades and centuries. Nesting sea turtles may shift to other beaches if natal beaches are no longer available; consequently, beaches presently supporting small nesting populations may become more important to the species in the future.

Key Words: endangered/threatened species, sea turtles, vertebrates, nesting activity, mortality, populations, aerial surveys, loggerhead sea turtle

Citation: **Nelson, D. A. 1988. *Life history and environmental requirements of loggerhead turtles (revised).* Biological Report 88(23). U.S. Fish and Wildlife Service, Washington, DC. 45 pages.**

Resources: Loggerhead sea turtles

Type of Research: Synopsis of existing data

Geographical Location: Southeastern U.S. Atlantic Coast

Summary: Nesting of loggerheads occurs on the coastal islands of the Carolinas and Georgia. The greatest portion of a loggerhead's life is spent in the estuary and the ocean where it breeds in shallow waters next to nesting beaches. It feeds on a variety of fish and shellfish, and migrates generally north in the spring and summer and south in the fall and winter.

Key Words: endangered/threatened species, sea turtles, *Caretta caretta*, loggerheads, vertebrates, geographical distribution, life history, nesting activity, life history, species profile, life cycle

WHALES AND OTHER MARINE MAMMALS

Citation: **Winn, H. E., C. A. Price, and P. W. Sorensen. 1986. Distributional biology of the right whale (Eubalaena glacialis) in the North Atlantic. In:** ***Report of the International Whaling Commission: Special Issue 10*****, pp. 129-138.**

Resources: Right Whales

Type of Research: Field surveys

Geographical Location: Western North Atlantic/U.S. Atlantic coast

Summary: Right whales (*Eubalaena glacialis*) sighting data from Florida to Nova Scotia are analyzed for patterns of distribution, movements and relationships to certain environmental variables. The distribution of calves, surface feeding and social activities on the northern feeding grounds are also examined. A general pattern of distribution exists with calving activities during the winter off Georgia and Florida. The winter distribution of social units other than cow-calf pairs is poorly known. In the spring, large numbers of right whales arrive in the Great South Channel (between Cape Cod and Georges Bank), where they feed for up to several months and in the Cape-Cod-Massachusetts-Bay area. In June, they migrate across the Gulf of Maine to the Bay of Fundy and the southeastern Scotian shelf, where they also feed for several months. In late October-November, they leave these areas, presumably migrating rapidly southward.

Key Words: marine mammals, right whales, vertebrates, *Eubalaena glacialis*, migration, geographical distribution, calving, endangered/threatened species

Citation: **Kraus, S. D., R. D. Kenney, A. R. Knowlton, and J. N. Ciano. 1993.** ***Endangered Right Whales of the Southwestern North Atlantic*****. Minerals Management Service OCS Study MMS 93-0024. Edgerton Research Laboratory, New England Aquarium, Boston, MA. 69 pages.**

Resource: Right Whales

Type of Research: Field surveys

Geographical Location: South Atlantic Bight — Florida/Georgia border

Summary: Migratory populations of the northern right whale in the South Atlantic Bight were surveyed from 1989 to 1992 through aerial surveys. These studies focus upon calving activities, movements on the shelf, distribution and abundance. The study concludes that these waters offshore the southeastern U.S. coast are probably the only calving grounds for the right whales of the western North Atlantic. A total of 319 right whales are identified for an estimated population of less than 350 in the North Atlantic. Approximately 48% of these individuals have been sighted since 1980 in the study area. During the summer months, the whales range from the Bay of Fundy to Greenland, however, southward migrations extend to north Florida. Areas in the vicinity of the Florida/Georgia border and Jacksonville, Florida are the primary areas of concentration. The return journey to the north begins in mid-February. Calving in the right whale occurs from late November to early March. During the period of the study, 76% of the newborn right whale calves were sighted in the South Atlantic Bight. Pairs of cows and calves were limited to the area between latitudes 27°30' N and 32°00' N. These animals remain in the region longer than other individuals and tend to stay closer to shore also.

Key words: marine mammals, right whale, *Eubalaena glacialis*, calving, populations, migration, endangered/threatened species, Georgia, Florida

HARD GROUNDS

Citation: **Van Dolah, R. F., P. H. Wendt, and N. Nicholson. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. *Fish. Res.* 5(1): 39-54.**

Resources: Hard bottom communities

Type of Research: Trawling and species identification

Geographical Location: Georgia - inner shelf

Summary: The effects of a research trawl on several sponge and coral species in a shallow-water, hard-bottom area southeast of Savannah, Georgia are determined through a census of the numerically-dominant species in quadrats along five transects across a trawling alley. The density of undamaged corals and sponges is assessed in trawled and non-trawled (control) portions of each transect before, immediately after and 12 months after a 40/54 roller-rigged trawl was dragged through the alley once. Some damage to individuals of all target species occurs immediately after trawling, but only the density of the barrel sponges (*Cliona* sp.) is significantly reduced. Damage to the other sponges *(Ircinia campana, Haliclona oculata)*; octocorals *(Leptogorgia virgulata, Lophogorgia hebes, Titanideum frauenfeldii)* and hard corals *(Oculina varicosa)*, vary with the species, but changes in density are not statistically significant. Twelve months after trawling, the abundance of specimens counted in the trawled quadrats increased to pre-trawl densities or greater, and damage healed. Trawl damage in this study is less severe than in a previous study. Differences are attributed to differences in the roller-rig design of the trawls and the number of times the bottom is trawled.

Key Words: benthic habitats, hard grounds, bottom trawls, invertebrates, communities, sponges, coral, populations, gear research, inner shelf, Georgia

Citation: **Hopkinson, C. S., R. D. Fallon, B.-O. Jansson, and J. P. Schubauer. 1991. Community metabolism and nutrient cycling at Gray's Reef, a hard bottom habitat in the Georgia Bight.** ***Marine Ecology Progress Series*** **73(2-3): 105-120.**

Resources: Hard bottom communities

Type of Research: Field and laboratory measurements

Geographical Location: Georgia - Gray's Reef National Marine Sanctuary

Summary: Benthic and pelagic metabolism and nutrient fluxes are measured during the summer on a hard bottom on the continental shelf of the Georgia Bight, USA. Internal pools of organic matter and nutrients in the sediments and the water column are also measured and compared with physical transport associated with ocean currents. Gray's Reef is a heterogenous system consisting of a mosaic of bare sand regions, hard bottom regions, thinly-veneered with shifting sands, and exposed rock outcrops. Sediment organic carbon content increases from less than 0.2% of dry weight in sandy regions to an epifaunal biomass greater than 77 g C m supr (-2) on rock outcrops. Sponges and corals account for a large percentage of macrofaunal biomass when sands were shallow. Benthic metabolism and nutrient regeneration are positively-related to the spatial distribution of epifaunal biomass.

Key Words: benthic habitats, hard grounds, Gray's Reef, biomass, communities, benthos, nutrients, metabolic activity, Georgia, inner/middle shelf

ARTIFICIAL REEFS

Citation: **Georgia Department of Natural Resources. 1991.** ***Georgia Offshore Fishing Guide.*** **Georgia Department of Natural Resources, Coastal Resources Division, Brunswick, GA.**

Resource: Sportsfish habitat

Type of Research: Descriptive

Geographical Location: Georgia

Summary: The fish habitat areas in offshore waters of Georgia are illustrated and described in this large fold-out map with information panels that discuss gamefish, fishing techniques, gear, safety guidelines and regulations. The map indicates the positions of Coast Guard buoys, artificial reefs, shipwrecks, live bottoms, offshore towers and trolling areas. Loran C coordinates for each structure are included.

Key Words: benthic habitats, artificial reefs, sports fish, fishing map, fishing regulations, Georgia

Citation: **Wendt, P. H., D. M. Knott, and R. F. Van Dolah. 1989. Community structure of the sessile biota on five artificial reefs of different ages. *Bulletin of Marine Science* 44(3): 1106-1122.**

Resources: Sessile Biota / Sportsfish Habitat

Type of Research: Field

Geographical Location: Georgia Bight

Summary: Sessile epibenthic communities are examined on five sunken vessels ranging in age (in place) from 3.5 to 10.0 years. The reefs are located offshore South Carolina and Georgia in 22-31 m depths. Results indicate no appreciable trend in biomass, species count or percent cover with age, except that all three of these variables are greater on vertical rather than on horizontal surfaces, perhaps due to predation differences.

Key Words: benthic habitats, artificial reefs, invertebrates, sessile species, communities, biomass, epifauna, shipwrecks, recruitment, Georgia, South Carolina, middle shelf

COMMERCIAL SHELLFISH AND CRUSTACEAN FISHERIES

Citation: **Renaud, M., G. Gitschlag, E. Klima, A. Shah, and J. Nance. 1990. *Evaluation of the impacts of turtle excluder devices (TEDs) on shrimp catch rates in the Gulf of Mexico and South Atlantic, March 1988 through July 1989.* NOAA Technical Memorandum NMFS-SEFC-254. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Rockville, MD. 176 pages.**

Resources: Shrimp

Type of Research: Synthesis of field data and observations

Geographical Location: Southeastern U.S. Atlantic Coast and Gulf of Mexico

Summary: Data are presented from observers for the National Marine Fisheries Service who collected data on catch rates of shrimp from commercial shrimp vessels that voluntarily participated in the study. Catch data is compared between TED-equipped nets and standard shrimp nets.

Key Words: commercial crustacean fisheries, shrimp fishery, landings data, Turtle Excluder Devices, fishing gear, trawl nets

Citation: **Whitaker, J. D. 1984. Effect of severe winter weather on white shrimp stocks in the Atlantic Ocean off the southeastern United States.** ***Journal of Shellfish Research*** **4(1): 103-104.**

Resources: White Shrimp

Type or Research: Data collection

Geographical Location: South Atlantic Bight

Summary: The white shrimp, *Penaeus setiferus*, is the most important species in the South Atlantic shrimp fishery. The species is found to increase in abundance with decreasing latitude. Several winters have periodically caused large fluctuations in landings, particularly in the Carolinas and along the northern Georgia coast. In South Carolina, shrimp mortalities apparently begin to occur as water temperatures approach 6°C. The winter's effect on the shrimp population appears to be related to duration of cold temperatures, lowest temperature, and salinity. The lowest landings since 1950 followed the severe winters of 1963 and 1977, while above-average landings followed mild winters. Sub-adult white shrimp, 80-110 mm total length, remain in the estuarine and nearshore waters during mild winters and make-up the bulk of the spring spawning population. When severe winters cause mass mortalities of overwintering shrimp, the Carolinas are dependent on spawning by large shrimp that migrate north from the warmer waters of southern Georgia or northeastern Florida.

Key Words: commercial crustacean fisheries, shrimp fishery, landings data, mortality, stock assessment, historical review, water temperture, South Carolina, Georgia, Florida, inner shelf

COMMERCIAL FINFISH FISHERIES

Citation: **Christian, P. A. and D. L. Harrington. 1985.** ***Finfishing with shrimp boats: A summary of Georgia's cooperative finfish development and fishing demonstration project for 1983.*** **Georgia Marine Science Center Technical Report 85-2. Georgia Marine Science Center, Savannah, GA. 114 pages.**

Resources: Finfish

Type of Research: Field and catch data

Geographical Location: Georgia offshore waters

Summary: Five shrimp boats were involved in a cooperative program to determine the feasibility of shrimp boats diversifying into offshore finfishing in the Georgia Bight. Three vessels were modified for bottom longlining. They produced 32,578 lbs of finfish which had an ex-vessel value of $48,547. This represents a combined effort of 38 fishing days and 155 bottom longline sets which averaged 210 lbs of fish per set. The two vessels that were fish trawling produced a gross stock of 26,413 lbs of fish, which had an ex-vessel value of $28,562. This represents a combined effort of 28 fishing days and 108 tows, averaging 245 lbs of fish per tow. Much of the effort by the two boats that trawled for fish was devoted to development and testing of gear and handling procedures. Three nets and sweep combinations were used: a four-seam high opening fish trawl with a rock hopper sweep, a mongoose fish trawl with a rock hopper sweep and a Burbank fish trawl with standard cookie rollers on the sweep.

Key Words: commercial finfish fisheries, shrimp boats, fishing techniques, longlining, economic analysis, landings data, Georgia Bight

Citation: **Collins, M. R. and G. R. Sedberry. 1991. Status of vermilion snapper and red porgy stocks off South Carolina. *Transactions, American Fisheries Society* 120(1): 116-120.**

Resources: Populations of red porgies and vermilion snappers

Type of Research: Field sampling (hook and line)

Geographical Location: South Carolina offshore waters

Summary: Standardized trap and hook-and-line collections are made annually at four areas of reef habitat off South Carolina during 1983-1987 for red porgy, *Pagrus pagrus*, and vermilion snapper, *Rhomboplites aurorubens*. Mean annual values for catch per unit effort, estimated mean individual weights, and derived percentages of fish are calculated as being smaller than previously recommended yield-per-recruit critical lengths based on data from two gear types. Although the two gear types do not generate identical results, there are indications that stocks of these reef fishes are overfished. The ratio of vermilion snapper to red porgy in hook-and-line samples increased during the study and in comparison to historical data, suggests that the abundance of red porgy declined more rapidly than that of vermilion snapper.

Key Words: commercial finfish fishery, populations, stock assessment, reefs, habitats, fishing techniques, fishing gear, South Carolina

RECREATIONAL FISHERIES

Citation: **Moore, C. J., D. L. Hammond, M. Bell, and E. C. Roland. 1985. *A guide to saltwater recreational fisheries in South Carolina.* South Carolina Wildlife and Marine Resources Center, Charleston, SC. 96 pages.**

Resources: Sportsfish, shellfish and crustacean fisheries

Type of Research: Descriptive

Geographical Location: South Carolina coastal and offshore waters

Summary: This guide contains information about inshore and offshore fishing facilities, including fishing piers, coastal boat rentals, coastal boat landings, coastal marinas, scuba diving shops, artificial reefs and wrecks, head boats and charter boats. A list of all tackle state record saltwater gamefish and information and rules concerning registering new state record fish is included. A section on fish identification features photographs and information on the local distribution and seasonal occurrence of the fifty most common

South Carolina saltwater fish taken by hook and line. Marine fisheries laws which pertain to the taking of saltwater fish and shellfish for personal consumption are included.

Key Words: recreational fisheries, finfish, shellfish, distribution, reefs, fishing, boats, fishing regulations, identification key, South Carolina

Citation: **Music, J. L. and J. M. Pafford. 1984. *Population dynamics and life history aspects of major marine sportfishes in Georgia's coastal waters.* Coastal Resources Division Contribution 38. Coastal Resources Division, Georgia Department of Natural Resources, Brunswick, GA. 382 pages.**

Resources: Sportsfish

Type of Research: Field measurements

Geographical Location: Georgia coastal waters

Summary: The life histories of 11 species of Georgia's marine recreational sportsfishes are investigated in the coastal waters of Glynn County from July 1978 to June 1982 for the purpose of establishing a baseline for future management decisions concerning the state's marine recreational fishery. Movements and migration are determined through tagging studies, age and growth by scale and otoliths, and feeding habits through analysis of stomach contents.

Key Words: recreational fisheries, stock assessment, populations, tagging, life history, mortality, migration, feeding, growth, Georgia

GENERAL COASTAL MANAGEMENT

Citation: **Christie, D. 1992. *Ocean and coastal law and policy: a United States and Florida perspective.* Florida Sea Grant Publication SGR-108. Florida Sea Grant College Program, Gainesville, FL. 580 pages.**

Resources: Coastal and ocean natural resources

Type of Research: Legal aspects of coastal zone management

Geographical Location: Florida

Summary: Revised in 1992, this massive publication covers the legal spectrum including public and private rights in the coastal zone, preserving shore rights and resources, cooperative management of ocean and coastal resources, and offshore resource and conflict management. Cases are cited from not only Florida and the United States, but also include international legal decisions that may have local applications.

Key Words: general coastal management, legislation, regulations, law, policy, coastal zone management, Florida

***Citation:* Cocker, M. D. 1993. *Report on the Georgia coastal geographic information system.* Georgia Geologic Survey Open File Report 93-1. Georgia Department of Natural Resources, Georgia Geologic Survey, Atlanta, GA. 19 pages.**

Resources: Coastal research and data

Type of Research: Compilation and management of data

Geographical Location: Georgia

Summary: Data from geologic studies on structure, stratigraphy, environmental studies, mineral and water resources, etc. can be compiled into geographically-related databases and effectively handled by a PC-based GIS (Geographic Information System). Such a system is installed at the Georgia Geological Survey to help manage the state's coastal geologic resources and information related to coastal geology. PC Arc/Info Ver. 3.4D Plus is the current primary software for the coastal GIS.

Key Words: general coastal management, electronic database, Geographic Information System, historical records, data management, Georgia

BEACHES

***Citation:* Griffin, M. and V. J. Henry. 1984. *Historical changes in the mean high water shoreline of Georgia, 1857-1982.* Georgia Geologic Survey Bulletin 98. Georgia Department of Natural Resources, Environmental Protection Division, Georgia Geologic Survey, Atlanta, GA. 96 pages.**

Resources: Barrier island shoreline changes

Type of Research: Historical data synthesis and analysis

Geographical Location: Georgia

Summary: A study of Georgia mean high water shoreline change from 1857-1982, based on available topographic, hydrographic, and orthophotographic maps and on controlled serial photographs reports the following results:

(1) During the period from 1857 to 1925, in which several major hurricanes occurred in the late 1880's, approximately 80% of the Georgia coast prograded, due primarily to the great dunation of the Georgia Piedmont prior to soil conservation practices and to the damming of rivers for flood control.

(2) Between 1924 and 1974, the Georgia coast was characterized by dynamic stability; erosion on St. Catherines and Tybee/Little Tybee Islands was offset by deposition on Little St. Simons and Cumberland Islands, while each of the other islands maintained equilibrium.

(3) Between 1957 and 1974, which was characterized by accelerating erosion rates and a major hurricane, most of the major barrier islands nevertheless maintained a dynamic stability.
(4) From 1974 to 1984, partial photographic coverage of the Georgia coast indicated a continuation of erosion/accretion trends established prior to 1974, coupled with an apparent loss in linear extent of depositional sites along the shoreline.

Study results also indicate patterns of island rotation, spit cyclicity, island elongation, shifts about persistent nodal points, and southward migration. Such trends indicate that, presently, dynamic stability, marked by extreme local instability, characterizes 80% of the Georgia coast. (Authors Abstract)

Key Words: beaches, shoreline changes, barrier islands, historical records, geomorphology, erosion, accretion, bathymetry, Georgia, littoral zone

***Citation:* Oertel, G. F., J. E. Fowler, and J. Pope. 1985. *History of Erosion and Erosion Control Efforts at Tybee Island, Georgia.* Report No. CERC-85-1. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Vicksburg, MS.**

Resources: Beaches/Beach Management

Type of Research: Overview of historical data

Geographical Location: Tybee Island, Georgia

Summary: Tybee Island, immediately south of the mouth of the Savannah River, has had a long history of beach instability, caused primarily by modifications by man, but also related to natural processes. Efforts to control the erosion have been partly successful with sequential use of groins, seawalls and revetments in addition to periodic beach renourishment activities which continue to occur.

Key Words: beaches, erosion, coastal engineering, beach nourishment, historical records, Tybee Island, Georgia

PORTS AND NAVIGATION

***Citation:* U.S. Army Corps of Engineers. 1991. *Savannah Harbor, Georgia Comprehensive Study: Draft Feasibility Report and Environmental Impact Statement.* U.S. Army Corps of Engineers, Savannah District, Savannah, Georgia. 565 pages.**

Resources: Benthos, sediment and water column; shipping

Type of Research: Data collection/review, synthesis, and assessment

Geographical Location: Savannah River channel to offshore Tybee Island, GA

Summary: This study includes the lower 45 miles of the Savannah River to the Atlantic Ocean as well as adjacent lands in Georgia and South Carolina. Results of environmental, economic and engineering studies are presented regarding plans for the dredging of the navigation channel and harbor area at

Savannah, Georgia. The proposed dredging activity will create a channel 44 feet deep, 600 feet wide, and about 8.7 miles long across the bar channel at the ocean entrance to the end of the jetties, and 42 feet deep, 500-600 feet wide and 22.2 miles long from the jetties to above the Kings Island turning basin. Over 2.3 million cubic yards of dredge material will be removed from the bar channel to the jetties. Potential environmental effects of dredging activities include impacts upon water quality, beach erosion on Tybee Island and cultural resources such as shipwrecks. Project costs are estimated at approximately $24,924,000; the project benefit-to-cost ratio is 1.7 to 1. Other impacts that are assessed include possible effects on salinity and striped bass populations, wildlife habitat and endangered species.

Key Words: ports, navigation, dredging, Ocean Dredge Material Disposal Site (ODMDS), sediments, environmental impact statement, beach erosion, Tybee Island, Savannah River, Georgia, inner shelf

Citation: **U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 1988. *Final Environmental Impact Statement: Brunswick Harbor, Georgia Ocean Dredged Material Disposal Site Designation.* U.S. Environmental Protection Agency, Region IV Office, Atlanta, Georgia. 65 pages.**

Resources: Benthos, sediment, and water column; shipping

Type of Research: Data review and assessment

Geographical Location: Georgia - inner shelf, southeast of Brunswick

Summary: This document considers the potential environmental impacts from the official designation of an ocean site for disposal of materials dredged from the navigation channels and harbor for Brunswick, Georgia. Located in approximately 9 m of water about six miles southeast of Brunswick, the site was used since 1964 for disposal of sediment from the dredging of the harbor and channel. Potential adverse impacts to the area include: (1) mounding and smothering of benthos through sedimentation; (2) disturbances to the water column such as turbidity plumes, release of chemicals, reduction of levels of dissolved oxygen; and (3) habitat alteration. These impacts, although unavoidable, are considered to be insignificant. Monitoring of the site is proposed in order to prevent any detrimental environmental effects from the disposal. Because the site is already used for disposal, alternative sites are not recommended in order to avoid adversely affecting sites that are currently undisturbed.

Key Words: ports, navigation, dredging, Ocean Dredge Material Disposal Site (ODMDS), sediments, benthos, environmental impact statement, Brunswick, Georgia, inner shelf

POLLUTION

Citation: **Overstreet, R. M. 1988. Aquatic pollution problems, southeastern U.S. coasts: Histopathological indicators. *Aquatic Toxicology* 11(3-4): 213-239.**

Resources: Finfish and shellfish

Type of Research: Field sampling and laboratory analysis

Geographical Location: Southeastern U.S. coasts

Summary: Pollution causes lesions and affect parasitic infections in numerous species of finfish and shellfish in the southeastern United States as well as in many other parts of the world. The relatively high-water temperature in this region may augment the effects of contamination from specific domestic, agricultural, and industrial sources. Because of the lack of detailed cause-and-effect studies in the southeast, individual toxicants or combinations of toxicants have not been related to specific histopathological conditions. Nevertheless, a variety and abundance of specific and general pathological indications of pollution occur in marine and estuarine species along the southern U.S. coasts of the Atlantic Ocean and in the Gulf of Mexico. Among those occurring in several polluted regions are striped mullet with mesenchymal neoplasms; sciaenid and other fishes with lymphocystis; fishes with ulcers, red sores, fin erosion, and granulomas, and crustaceans with shell disease.

Key Words: pollution, diseases, toxicants, indicators, finfish, shellfish, toxicology, parasites

***Citation:* Gillespie, D. M., J. L. Harding, R. A. Culp, J. E. Noakes, and A. L. Edwards. 1989. *Macrofauna Distributions and Sediment Analyses from the Brunswick, Georgia Ocean Dredged Material Disposal Site and Environs.* Georgia Marine Science Center Technical Report 89-1. Georgia Marine Science Center, Savannah, GA. 103 pages.**

Resources: Benthic environments

Type of Research: Field sampling and laboratory analysis

Geographical Location: Brunswick, Georgia - inner shelf

Summary: Sediment samples, water samples and trawl tows were obtained on and in close proximity to the dredge spoil disposal site. All data were analyzed for possible treatment effects related to the disposal of dredged material. No consistent patterns were discerned. Although the dumping of dredge spoil material onto the ocean floor undoubtedly disturbs the environment, this study suggests that the effects are transient in this area.

Key Words: pollutants, ocean dredge spoil disposal material site, sediments, benthos, invertebrates, macrofauna, impacts, Georgia, inner shelf

CULTURAL RESOURCES

***Citation:* Spence, E. L. 1984. *Shipwrecks of South Carolina and Georgia: Volumes I and II.* Sea Research Society, Sullivan's Island, SC. 750 pages.**

Resources: Shipwrecks

Type of Research: Compilation and review of historical accounts

Geographical Location: South Carolina and Georgia — inner shelf

Summary: This extensive work documents hundreds of shipwrecks by the name of the vessel, location of the wreck (as near as it is known), reported or surmised, the date of its loss, cause of the loss, (i.e. storm, fire, war, etc.), details on cargo, lives lost, ownership, and other details. References and quotations from newspaper accounts of the day are included where applicable. The list of shipwrecks covers the span of years from 1520 to the end of the Civil War in 1865.

Key Words: cultural resources, shipwrecks, archeology, maritime history, diving, Georgia, South Carolina, inner shelf

> *Citation:* **Science Applications Inc. 1981.** ***A cultural resource survey of the continental shelf from Cape Hatteras to Key West: Volumes I - IV.*** **Final reports prepared for the Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS Publication Nos. PB 82-138215, 82-138223, 82-138231, 82-138249. Science Applications Inc., Raleigh, NC.**

Resource: Cultural resources

Type of Research: Data compilation

Geographical Location: South Atlantic Bight

Summary: This is a four-volume set of reports dealing with the cultural resources and archeology of the outer continental shelf of the South Atlantic Bight. A literature review is conducted of the information on the archeological research and data regarding maritime history and shipwrecks in the study area. Additional research includes review of existing collections of paleontological materials from the shelf as well as investigations and interviews at museums and management agencies. The study provides information in order to assess potential impacts on such resources by proposed oil and gas exploration on the continental shelf off the southeastern U.S. Recommendations are made for the location, protection, and management of cultural resources that may be located on the shelf. Volume I deals with the Introduction and Physical Environment; Volume II reports on Prehistoric Archeology; Volume III contains the Appendices; and Volume IV presents Conclusions and Recommendations. This work serves as a baseline study that characterizes the resources on a regional basis.

Key Words: cultural resources, archeological resources, shipwrecks, literature survey, baseline study, historical review, South Atlantic Bight

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APPENDIX C

Annotated Citations