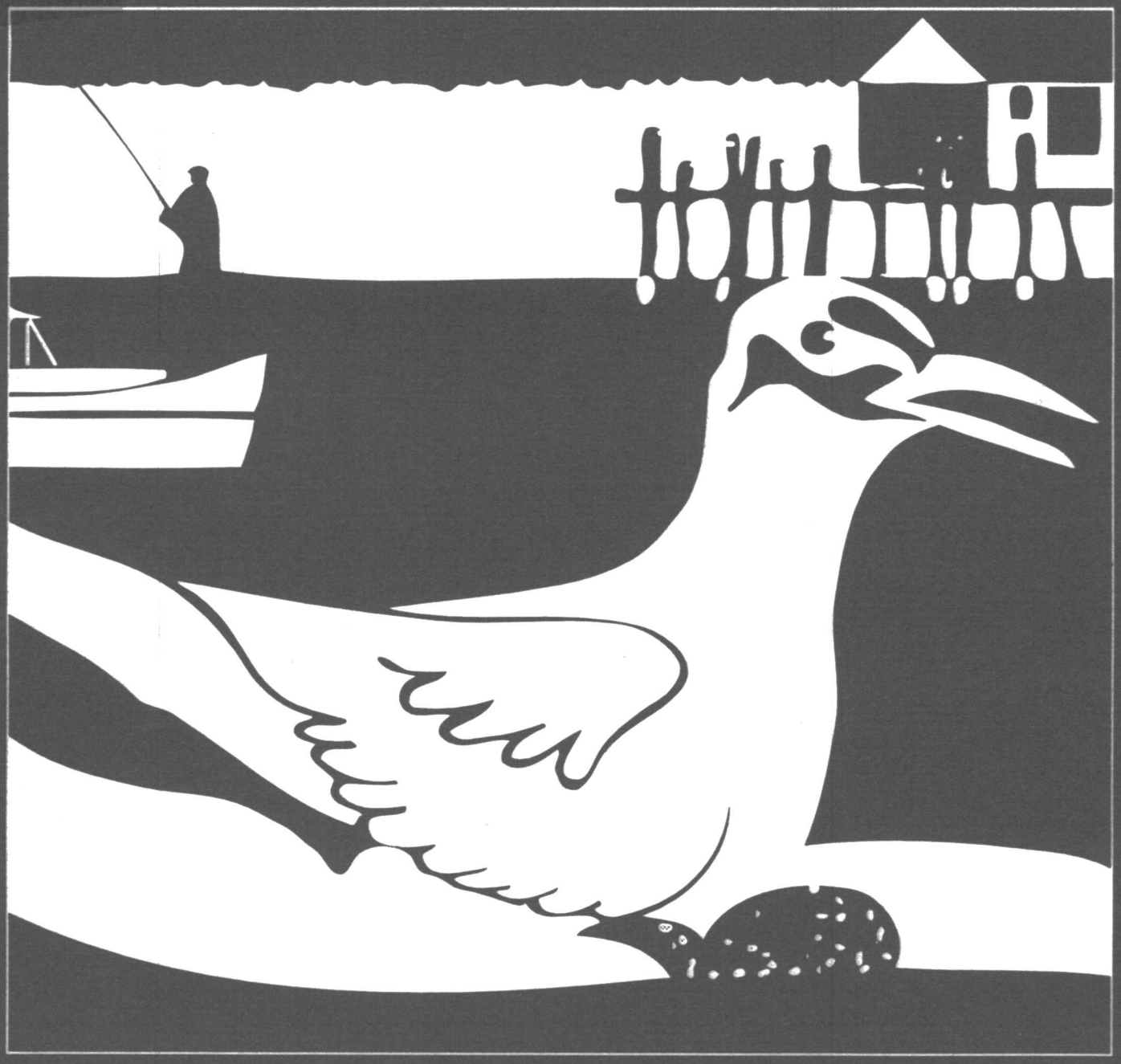
OCS Report
MMS 92-0057

Environmental Studies Results: 1973-1992

Atlantic Outer Continental Shelf



U.S. Department of the Interior
Minerals Management Service
Atlantic OCS Region

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Preface

The Outer Continental Shelf (OCS) Environmental Studies Program was initiated in 1973 under the Bureau of Land Management by the Secretary of the Interior. The purpose of the program was to conduct studies needed to predict, assess, and manage impacts on the human, marine, and coastal environments of the OCS and nearshore areas that may be affected by oil and gas activities (30 CFR 256.82). In May 1982, this program, along with all leasing and resource management functions of the OCS, was consolidated and placed within the Minerals Management Service. Studies in the Atlantic OCS Region have added to the body of knowledge of OCS environments extending from Nova Scotia to the Florida Keys. The Atlantic OCS Region Environmental Studies Program has contributed not only to the characterization of these areas and impacts assessment on OCS resources but also to the advancement of oceanographic technologies and deep-water research. The program is committed to wide dissemination of information available in the form of data bases, reports, maps, models, and peer-reviewed publications. This document focuses on the principle results of studies that may prove valuable to resource managers and scientists investigating OCS processes.

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Introduction

Environmental Studies Program Mission

The objective of the Environmental Studies Program is to "establish information needed for prediction, assessment, and management of impacts on the Outer Continental Shelf (OCS) and the nearshore area which may be affected..." (43 CFR 3001.7). The program accomplishes this objective by conducting environmental studies. The studies are designed to:

1) Provide information on the status of the environment upon which the prediction of impacts of OCS oil and gas development may be based.

2) Provide information on the ways and extent that OCS development can potentially impact the human, marine, biological, and coastal areas.

3) Ensure that information already available or being collected under the program is in a form that can be used in making decisions associated with a specific leasing action or with the longer term Minerals Management Service's (MMS) mission concerning the OCS.

4) Provide a basis for future monitoring of OCS operations, including assessments of short-term and long-term impacts attributable to OCS oil and gas development.

The results are used for both pre- and postlease decisions concerning the development of marine oil and gas resources.

As part of the prelease process, environmental information is a significant factor in the process of selecting lease areas. The area selected is evaluated in an Environmental Impact Statement (EIS). Environmental information about the area, including that gathered by the studies program, is reviewed by a multidisciplinary team of MMS analysts to identify the major environmental issues and leasing alternatives that need to be addressed. The studies also provide the major source of information used to analyze possible effects on the environment covered within the EIS. The analysis of possible environmental effects includes an analysis of the risks of potential oil spills contacting sensitive environmental resources as estimated by the use of the MMS Oil Spill Risk Analysis (OSRA) model. The model provides a measure of the likelihood of an oil spill as well as the probable trajectories of a spill in relation to recreational and biological resources. Biological and physical oceanographic information collected through the MMS Environmental Studies Program constitutes a major source of data input to the model. At the prelease stage, the results obtained by the Environmental Studies Program are also useful in formulating lease sale stipulations.

During the postlease stage, the Environmental Studies Program information is used to evaluate industry exploration, development, and production proposals. The information contributes to the knowledge necessary to understand the environment and properly assess the impact of a particular postlease activity. Study information is also used to review the adequacy of the information submitted in the environmental reports that accompany the exploration and development plans industry submits. As appropriate, the studies information is used in the preparation of National Environmental Protection Act (NEPA) documents before industry plans are approved or rejected and is also used in researching a particular environmental problem. The information is included in reports to the Congress on the cumulative effects of OCS activities.

Report Description

This narrative summary updates the version printed in 1986, which covered studies completed between 1973 and 1985. This report summarizes the impetus behind and principal results of completed studies managed by the MMS in the Atlantic OCS Region between 1973 and 1992. Descriptions of the studies results are divided into the following major categories: Baseline Studies and Environmental Inventories, Biology/Ecology, Drill Site Monitoring, Endangered Species, Geology/Chemistry, Oil Spill Studies, Physical Oceanography/Meteorology, and Social and Economic Studies. Results of each major type of study are subdivided into North Atlantic, Mid-Atlantic, South Atlantic, and Multiregional studies in a chronological sequence in each leasing area.

Trends in the Environmental Studies Program

From 1973 to 1978, the Environmental Studies Program consisted primarily of baseline and monitoring studies. The Bureau of Land Management (BLM) spent approximately $167.8 million on environmental studies through fiscal year 1978. These studies were based upon information assembled through literature syntheses and supplemented by special studies of selected sites or topics of interest. Baseline studies were large-scale, multidisciplinary projects designed to characterize marine animal and plant populations; the physical characteristics of the seafloor and overlying waters; and the concentrations of certain trace metals and hydrocarbons in the water, sediment, and selected organisms before any OCS oil and gas activity occurred in an area. Monitoring studies, were to follow each baseline study to provide information on measurable changes in environmental characteristics relative to the baseline data as OCS oil and gas activities proceeded (CSA, 1990).

In June 1977, as requested by BLM, the National Research Council (NRC) completed the study entitled "OCS Oil and Gas: An Assessment of the Department of Interior Environmental Studies Program." The NRC focused their review on the "needs, concept, and procedures of the Program and the actual or potential use of the results." The general recommendations were to: (1) reallocate funds for greater emphasis

on study of onshore and nearshore impacts; (2) formulate a program based on an adequate problem analysis and relevance to policy decisions; (3) change research management and procurement practices to assure scientifically sound and useful results; and (4) adjust responsibilities for environmental studies within the Department of the Interior to facilitate effective use of program results.

The Department of the Interior anticipated many of the NRC's recommendations and published proposed rule changes in the July 12, 1977 Federal Register.

In 1978, the Government Accounting Office (GAO) submitted a report to the Secretary of Commerce (because of NOAA's management of environmental studies in the Alaska Region) and the Secretary of the Interior entitled "Benefits Derived From the Outer Continental Shelf Environmental Studies Program Are Questionable." GAO recommended that the Secretary of the Interior: reassess the Environmental Studies Program for how the studies could best be used in the OCS decisionmaking process and what information is needed to assess the impact of OCS oil and gas development; develop coordinated plans that identify OCS environmental information needs and focus on those needs; and develop dynamic long-range research planning efforts pursuing interdisciplinary research efforts, using outside expertise when available (GAO, 1978). The Secretary of the Interior, as required by the Legislative Reorganization Act of 1970, submitted to Congress a written statement on actions taken to address GAO's recommendations.

The OCS Lands Act Amendments of 1978 established policy for the management of OCS oil and gas activities and for the protection of marine and coastal environments. They also provided the first legislative mandate for environmental studies in support of offshore mineral development. The OCS Lands Act Amendments of 1978 formally recognized the Environmental Studies Program and required that studies begin at least 6 months before anticipated lease offering dates. At the same time, a major effort was undertaken to restructure the Environmental Studies Program. Information needs of the OCS minerals management decisionmaking process became the thrust of environmental studies planning.

The baseline approach had been criticized by NRC (1977) and GAO (1978) because the program was not providing timely and appropriate information for leasing decisions, as well as by scientists who advised BLM that natural variability in the marine environment was too great to establish a statistically valid baseline within a reasonable length of time. In response, a program management document entitled "Study Design for Resource Management Decisions: OCS Oil and Gas Development and the Environment" was published by the Department of the Interior in October 1978. Program guidance presented in this document required a clear relation between a study and OCS issues and decisions. Criteria were developed to use in the ranking of

environmental studies. Criterion A requires a mandate for conducting a study, specifically that study information is essential for a specific leasing, lease management, or program management decision. Criterion B requires that a study be initiated within the budget period at issue in order to be completed in time for use in a specific leasing, lease management, or program management decision. The "Study Design" document provided for the development of study plans on a 3-year cycle, based on the needs of the 5-year Leasing Program, along with reasonable assumptions of what type of exploration, development, and production activities are likely to occur. This plan was a new approach to develop an integrated long-range management plan for the Environmental Studies Program.

Although MMS revised the Environmental Studies Program, States, public interest groups, and the Environmental Protection Agency expressed concern that the program lacked focus and may not be useful (GAO, 1988). In response, the Chairman of the Environment, Energy, and Natural Resources Subcommittee, House Committee on Government Operations, requested the General Accounting Office (GAO) to determine whether delivery of environmental studies was timely and to identify the level of user satisfaction with the environmental studies.

In June of 1988, GAO reported that users of the environmental studies (MMS and groups outside MMS) were generally satisfied with the usefulness, timeliness, and quality of the program studies. MMS survey results showed that 73 percent of the studies were considered very to extremely useful, 63 percent of the studies were considered timely, and 83 percent of the studies were considered to be above average to excellent quality (GAO, 1988). However, most states and OCS Advisory Board respondents agreed that impacts from trash and debris associated with OCS development and impacts from demolition of offshore platforms had been underemphasized in the Environmental Studies Program. While there was some disagreement among survey groups over which types of studies should receive future emphasis, most groups agreed that coastal habitats and physical oceanography should receive emphasis in future environmental studies (GAO, 1988).

In 1986, MMS requested the NRC to assess the present Environmental Studies Program. The MMS requested the NRC to review the general state of knowledge in physical oceanography, ecology, and socioeconomics. The physical oceanography review was published in 1990. The recommendations briefly summarized are: (1) the MMS should support continuing studies in physical oceanographic/meteorologic processes that are poorly understood or poorly represented on existing models; (2) the MMS should reduce present overreliance on model results until the models can be more fully verified and tested; and (3) the Environmental Studies Program should be modified to ensure that improved scientific input is obtained at all stages of program operation with a better integrated national program, and strengthen the program by publishing

study results more often in peer-reviewed scientific literature (NRC, 1990).

The ecology review was published in 1992. The recommendations briefly summarized are: (1) the MMS should support more ecological process-oriented studies and studies of ecological relationships designed to predict environmental impacts of OCS oil and gas activities; (2) more emphasis is needed on long-term and postlease studies; (3) ecological models should be used in conjunction with field programs, and should be verified and calibrated with field observations; (4) the MMS needs a data management system that allows the integration of information from different disciplines; (5) the MMS should sharpen its focus on hypotheses testing; and (6) the MMS should help in the curatorship of the large collections obtained during its studies (NRC, 1992).

The Environmental Studies Program again anticipated some of the NRC's recommendations and had already begun their implementation. The studies program will continue to evolve and be responsive to the NRC's recommendations. The social, and economics discipline review is expected to be released in early 1993. The program will continue to respond to the environmental concerns expressed by coastal States. Future studies will also address Congressional mandates and Presidential decisions on the OCS Program to assure an environmentally sound, responsive program.

Baseline Studies and Environmental Inventories

Environmental inventories are a compilation of existing information into an original concise format, they contain an identification of data gaps in the published and unpublished literature, and make recommendations for studies designed to fill identified data gaps. Baseline studies include multidisciplinary field studies designed to produce a statistically valid benchmark against which the impacts of the Outer Continental Shelf (OCS) activities could be measured. The emphasis on these studies was discontinued in 1978 following NRC's review of the Environmental Studies Program. The following discussions apply to baseline studies and environmental inventories of the various Atlantic Planning Areas.

North Atlantic

Information on the North Atlantic Planning area was first compiled by The Research Institute of the Gulf of Maine (TRIGOM) in "A Socioeconomic and Environmental Inventory of the North Atlantic Region from Sandy Hook, New Jersey to the Bay of Fundy." The study was conducted to compile existing information for use in preparing impact assessments and defining deficiencies in the information baseline, before new research and field surveys were conducted. The Council on Environmental Quality (CEQ) recommended another set of objectives that required habitat descriptions for the two biogeographical provinces, mapping the aerial extent of those habitats, and life history lists for all key species (TRIGOM, 1974). Data gaps that were identified included every area of the study: geophysics, estuarine dynamics, sediment transport, hydrocarbons, trace metals, nutrients, meteorology, plankton dynamics, bird population studies, marine mammal abundance and distribution, fish zoogeography, and benthic studies (TRIGOM, 1974).

The Georges Bank Workshop was convened by the New England Natural Resources Center in 1975 to identify environmental assessment needs related to petroleum exploration and development on Georges Bank. The stimulus in establishing this workshop was the United States' need for domestic oil and gas resources. The workshop was divided into four working groups (biological, chemical, geological, and physical oceanography) to discuss study needs and the types of studies required to evaluate the environmental impact that oil and gas exploration may have on the Georges Bank environment. As a result of this conference, the BLM recognized the need for baseline environmental assessment information to precede any exploratory oil and gas operations on Georges Bank.

The New England Outer Continental Shelf Benchmark Study conducted by Energy Resources Company, Inc. provided a pre-OCS baseline against which man-induced chemical changes to the environment could be assessed. The contract was terminated before

completion of a final report (due to time and budget constraints) and before the available data could be interpreted. However, the draft report (ERCO, 1978) did include baseline information of the Georges Bank environment (Georges Bank and Basin, Gulf of Maine, Great South Channel, and Nantucket Shoals) on hydrocarbons and trace metals in the sediment, water column, and benthic macrofauna. The report also detailed the seasonal variability of benthic macrofauna. Data showed that regardless of their origin, aromatic hydrocarbons are present in the surface sediments in the Georges Bank area before any exploratory or production drilling occurred. Also, the area cannot be considered pristine. Two basic geochemical regimes exist, due to the distribution of the clay component, one shallow region composed of Nantucket Shoals and Georges Bank, and the other composed of the Gulf of Maine and the southwestern region. Regardless of the parameters considered in the water column, the concentrations of hydrocarbons were less in shelf water than the slope, transition, or intermediate waters.

It should be noted that even though a final report was not completed for the study, several peer-review papers were published as a result of information derived from the study (Boehm et al., 1979; Larsen and Lee, 1978; and Maurer and Leathem, 1980 and 1981).

Mid-Atlantic

The Marine Environmental Implications of Offshore Oil and Gas Development in the Baltimore Canyon workshop was held in 1974. The goal of the workshop was to review the available knowledge about the region, to state the responsibilities of State and Federal agencies, and to recommend the best approach to baseline monitoring studies, if oil and gas development should begin in the Mid-Atlantic OCS. The workshop recommended a comprehensive interdisciplinary study of the region before oil and gas activities were conducted (Cronin and Smith, 1975). This workshop was the first effort by the BLM to publicly address the environmental issues of the Mid-Atlantic associated with oil and gas exploration.

In response to oil and gas industry interest for hydrocarbon exploration in the Mid-Atlantic and an August 1976 lease sale, the BLM funded a joint Virginia Institute of Marine Science (VIMS) and U.S. Geological Survey (USGS) study to conduct a 2-year multidisciplinary environmental survey of the Mid-Atlantic Planning Area (inclusive of New York south to North Carolina). The baseline seasonal geochemistry, biology, and physical oceanography data were collected by VIMS. The USGS was responsible for conducting the geological and hazards studies.

The first year's results indicated that cross-shelf trends in pelagic and benthic processes were more distinct than latitudinal trends (Lynch and Folger, 1977; Lynch et al., 1977; and Harris et al., 1977). As found in the North Atlantic surveys, trace metals and hydrocarbons tend to associate with fine sediments (higher clay content). The results after 2 years of surveys indicated

that spring neuston was important for larval fish recruitment; recovery of benthos from perturbations was a function of sediment distribution; benthos showed no evidence of petroleum contamination; and geologic environmental hazards did not warrant the BLM withdrawing any lease tracts from the sale area (Sale 40) (Burreson and Knebel, 1979).

South Atlantic

The South Atlantic OCS Studies Conference, conducted by Research Triangle Institute in 1975, determined the nature and extent of environmental studies required to monitor the effects of oil and gas exploration and development in the South Atlantic OCS Planning Area. At this time, the South Atlantic Planning Area was under the jurisdiction of the Gulf of Mexico OCS Region Office. The conference was a result of a Department of the Interior (DOI) directive identifying the South Atlantic Planning Area as a geological province that has characteristics warranting oil and gas exploration. The workshop established guidelines for conducting environmental studies that addressed accidents resulting from geologic hazards, permanent destruction of unique environments, and the effects of trace metals and hydrocarbons on organisms. Recommendations of the workshop were ordered into priorities according to baseline studies and predictive studies (Massoglia comp., 1976).

To comply with the requirements of the OCS Lands Act of 1953 and the National Environmental Policy Act (NEPA) of 1953, the BLM initiated the South Atlantic OCS Benchmark Program, which was meant to be a baseline source of information for any further OCS activity related research in the Georgia Bight area. Texas Instruments, Inc. (TI) performed the environmental characterization by determining concentrations of high molecular weight hydrocarbons and trace metals in the water, sediments, zooplankton, and macroepifauna. The natural structure and composition of the benthic and planktonic communities over the continental shelf were characterized as having high species diversity and low biomass. Analysis of the Georgia Bight shelf environment (TI, 1979) showed little evidence of petroleum contamination and identified a persistent upwelling feature within the study area. Testing of microbial hydrocarbon degrading capacity indicated that degradation of any introduced hydrocarbons during the fall and winter would be severely reduced.

In preparation for leasing of South Atlantic OCS frontier tracts (Lease Sale 43) and to complete the inventory of environmental information on the Atlantic OCS, the BLM funded the Center for Natural Areas (CNA) to analyze published and unpublished information on the continental shelf and Blake Plateau from Cape Hatteras to Cape Canaveral (CNA, 1979). The analysis covered the area between the spring high tide mark and the 1,500-meter isobath. This survey complemented the 1974 VIMS socioeconomic environmental literature survey (VIMS, 1974). Compared with most shorelines of the continental United States, this coastal and continental shelf

area is in a relatively undisturbed condition. Hydrocarbon levels were low along the study area. Too many data gaps existed in the trace metal data to draw conclusions.

By 1981, several tracts had been leased off North Carolina, and additional areas were nominated for further lease sales. In response to concerns expressed by the State of North Carolina, the MMS funded Continental Shelf Associates, Inc. (CSA) to update the existing literature on living marine resources and habitats from the shore to the 200-meter isobath. This was the first "South Atlantic" study completed by the Atlantic OCS Region Office. The results (CSA, 1983) were used by the MMS and the State to support management decisions concerning oil and gas activities. Synthesis chapters summarized the geology, oceanography, biological communities, commercial and sport fisheries, endangered and threatened species, and sensitive biological areas and unique habitats. In addition, a computer program was designed to catalog and sort all of the pertinent annotated information sources. The purpose of this computer program was to provide the MMS with a useful and viable method of maintaining, updating, and expanding the database. Data gaps were identified, implications to OCS development were discussed, and suggestions for additional research were provided.

The North Carolina OCS is a transition zone between the South and Middle Atlantic Bight. Sensitive areas included the live-bottom areas and shipwreck sites. Additional information was needed concerning coupling of upwelling events with fisheries and bioproductivity, OCS risk analysis models, and unique habitats of the area.

In 1986, the Straits of Florida Planning Area was established. The MMS funded CSA to perform a "Synthesis of Available Biological, Geological, Chemical, Socioeconomic, and Cultural Resource Information for the South Florida Area" (Phillips and Larson eds., 1990). Published and unpublished literature on South Florida was synthesized as well as the relevant literature on the effects of oil and dispersants. The South Florida Basin is a frontier area for oil and gas exploration. However, its hydrocarbon potential is poorly known because few exploratory wells have been drilled in the geochemically mature offshore portions of the basin, creating perhaps the most significant gap in information. The magnitude of these resources will in turn determine environmental and social consequences. The CSA study concluded that organisms most likely to be affected by routine offshore activities are benthic organisms living within a fixed radius (a few hundred meters) of drill sites and pelagic organisms (fish and possibly sea turtles) that may be attracted to OCS structures. Accidental spills are the foremost public and scientific concern about leasing offshore South Florida. The existing risk of oil spills from tankers traveling through the Straits of Florida probably would be greater than the risk from OCS production. The Loop Current can have a powerful influence on the fate of an oil spill off South Florida. The extent and severity of damage from a large oil spill

in the study area cannot be predicted with confidence. Based on historical data and spill trajectories, the potential exists for damage to mangrove forests, coral reefs, seagrass beds, and associated biota. Current knowledge of ecological relationships will also have to be improved.

Multiregional Studies

In 1976, TRIGOM developed a comprehensive synthesis of published and unpublished information relating to the area south of Nova Scotia and north of Cape Hatteras between the 200-meter and 2,000-meter isobaths. The Center for Natural Areas (CNA, 1977) complemented the TRIGOM study by providing the same comprehensive literature review from Nova Scotia to Cape Hatteras in an area bounded by the spring tide mark and the 200-meter isobath. The review of northeast Atlantic continental shelf information showed that an ability to predict the impacts of hydrocarbons and metals from OCS oil and gas activities, within the study area, was limited by a lack of adequate information. To correct that inability, the BLM was advised to fund studies on general ecosystem models (defining critical species) and toxicology as related to growth, reproductive behavior, and behavioral interrelationships.

In response to a shift of oil and gas industry interest to deeper water sites, the MMS studies shifted towards generic multiregional studies of deep-water environments and processes. Marine Geoscience Applications, Inc. (MGA) completed a survey reviewing the available biological, chemical, geological, meteorological, and oceanographic information related to the Atlantic continental slope and rise (ACSAR) (MGA, 1984). The ACSAR is defined as lying between 28°N. and 42°N. latitude, and between 200 and 4000 m water depth. Air-sea interactions are dominated by the Bermuda High. The ACSAR contains the Gulf Stream and the Western Boundary Current, the strongest low-frequency currents in the world.

Many active commercial fisheries (tilefish, billfish, shark, lobster, and crab) exist for U.S. fishermen on the ACSAR as well as, Deepwater Dumpsite 106 and ten trans telecommunication cables. Major mineral resources of the ACSAR include sand, gravel, manganese nodules, and phosphorites. Oil and gas may also be present. Two habitats which may influence development on the ACSAR are deep-water corals and submarine canyons. There are at least 70 submarine canyons on the continental slope between Georges Bank and Cape Hatteras in contrast to the few canyons that exist on the Florida-Hatteras slope.

The contractor, MGA, advised: better data on the meso- and microscale processes and events of the area are needed; a better understanding of fluxes (water, particles, chemical species, and organisms) in the study area; and more complete utilization and interpretation of existing data sets (MGA, 1984).

Biology/Ecology

Ecological studies are designed to describe the distribution and interactions of benthic and pelagic communities and populations. These studies also describe the biological aspects of birds and nonprotected species (species not protected under the Marine Mammal Protection Act or the Endangered Species Act).

North Atlantic

In 1989, the Submarine Canyons of the North Atlantic Workshop reviewed and assessed the probable impacts that exploratory drilling may have on the biological resources of the "heads" of submarine canyons. The impetus behind this workshop was the 400-meter congressional moratorium imposed on Georges Bank and its relationship to exploration in the canyon "heads." The workshop participants (preeminent specialists in North Atlantic marine sciences) reached a consensus that a 500-meter setback from the canyon "heads" would be adequate to prevent any impacts due to exploratory drilling. As a result of this consensus, the scientific community established its opinion with regard to exploratory drilling on Georges Bank. This is a good example of scientifically sound rationale establishing a boundary for limiting exploratory drilling on Georges Bank. The workshop used a considerable amount of information generated from the MMS sponsored USGS interagency agreements for submarine canyon studies.

Mid-Atlantic

The National Marine Fisheries Service (NMFS) performed a biological baseline survey to support the previously initiated USGS/VIMS environmental baseline survey. Azarovitz et al. (1985) described the distribution and abundance trends of 22 commercial and recreational fish species caught from bottom trawl surveys. Smith et al. (1979) summarized ichthyoplankton data collected by NMFS from the Mid-Atlantic Bight (MAB) between 1965 and 1976. Radosh et al. (1978) analyzed benthic grab samples from the Baltimore Canyon Trough. Murchelano and Rosenfeld (1980) catalogued the significant infectious and noninfectious diseases of North American fish and shellfish, describing the hosts, geographic ranges, etiology, diagnosis, and prognosis. Zoogeographers have been hesitant to recognize the MAB as a separate faunal province; however, several species summarized in this study were found to have their centers of abundance in the MAB. Many of the species were not endemic but seasonal migrants.

One aid in predicting the recovery rate of a population impacted by an oil spill or other impacts from OCS activities is to look at the population's recovery rate after a natural disturbance; such an opportunity occurred in 1984. While crossing the mid-continental shelf, Hurricane Diana stalled in the vicinity of Cape Fear, North Carolina, for 24 hours. Results of pre- and posthurricane biological sampling (Kirby-Smith and Ustach, 1985) suggest that mid-

continental shelf live-bottom communities are not significantly damaged by wave energy and sediment scour associated with the passage of a major storm. Thus, it would appear that temporary disturbance of the in situ sediment is not likely to have a severe or lasting impact on these communities and that these communities are adapted to periodic sand scour and sediment movement.

South Atlantic

South Atlantic hard-bottom areas of the Georgia Bight are considered significant resources because of their potential ecologic and economic importance. However, Lease blocks (James Island Area Blocks 198, 380, and 463 and Brunswick Block 912) of oil and gas industry interest, containing known hard-bottom habitat, were poorly described and mapped. Studies were conducted by CSA to evaluate the adequacy of geophysical techniques in identifying hard-bottom areas and the importance of these hard-bottom habitats as a marine ecosystem.

Geophysical and remote photographic surveys showed that hard-bottom areas (Recent to Subrecent biostromal reef) could be successfully mapped through the conservative interpretation of side-scan sonar records and the identification of areas of apparent outcropping of subbottom reflectors by the subbottom profiler. Visual inspection is necessary to distinguish exposed versus sand covered hard bottoms (CSA, 1979). Many species collected from the 10 distinct biological assemblages (sponges, corals and other invertebrates) were tropical. In general, species abundance appeared to be higher in areas of exposed hard bottom than areas covered by a thin veneer of sand. Commercially important sea bass, porgies, snappers, and groupers were found in this area. A need was indicated for further study to characterize the biota and evaluate the effects of disturbance on the hard-bottom communities.

The South Atlantic OCS Living Marine Resources Study conducted by the South Carolina Wildlife and Marine Resources Department (SCWMRD) examined nine live-bottom areas (3 inner shelf, 3 mid-shelf, and 3 outer shelf) located between 30^{o} N. and 34^{o} N. latitude extending from Florida to North Carolina. North Carolina stations, which proved logistically difficult to sample, were abandoned after one season and replaced with comparable South Carolina stations. The study was conducted in three phases from 1980 to 1984. The first and second phases (1980-1982) provided a comprehensive characterization of benthic invertebrate and demersal fish communities associated with representative hard-bottom areas. These studies also described changes in live-bottom community structure relative to season, depth, and latitude (SCWMRD, 1981 and 1982). The third phase of the study was designed to develop a qualitative trophodynamic model of energy flow through the live-bottom ecosystems. Results of the third phase lead to the conclusions that disruption of the lower trophic levels of the hard-bottom food web from oil and gas operations would affect the feeding ecology of marine reef fish. However, if environmental risks

were minimized, oil and gas structures placed on sand bottom areas would act as artificial reefs, promoting the concentration of fish and invertebrates in areas that previously had none (SCWMRD, 1984).

Multiregional Studies

Results of earlier baseline monitoring programs in the North and Mid-Atlantic Planning Areas indicated that submarine canyons of the continental slope may constitute unique and fragile environments; however, substantiating data were lacking. As deep-water photographic sampling techniques and submersible vessel technology advanced, canyon assessment studies were initiated in areas located near proposed leases. The first of these studied the abundance and distribution of epibenthic and coral fauna in Baltimore, Lydonia, and Oceanographer Canyons using "Cheep Tow" a towed underwater camera sled (Hecker et al., 1980). Baltimore Canyon most closely resembled slope habitats having high sedimentation rate and limited substrate variability. Lydonia and Oceanographer Canyons had much greater exposures of different substrate types (rock outcrops, talus, glacial erratics, and extensive coral debris). Faunal distribution was patchy and usually dominated by three species, the crab *Geryon quinquedens* and two demersal fish *Synaphobranchus kaupiu* and rattails (representing either *Nezumia* or *Coryphenoides*). Both Oceanographer and Lydonia Canyons had high concentrations of a variety of corals dominated by *Eunephthya florida* in Lydonia Canyon and *Paramuricea gandis and Acanthogorgia armata* in Oceanographer Canyon.

Predictions of environmental impacts on canyon and slope fauna by OCS development activities could not be completed because environmental correlates contributing to observed faunal distributions were not adequately known for the study area. However, it was known that the 26 major submarine canyons between Nova Scotia and Cape Hatteras appeared to be sites of enhanced biological activity, with extensive commercial fishing for squid, lobster, and finfish. Submarine canyons are anticipated sites for exploratory drilling and oil production.

Foreseeing a potential conflict between commercial fishing and OCS activities, the BLM initiated the Study of Physical and Biological Processes of Canyons and the Continental Slope in the North and Mid-Atlantic Outer Continental Shelf in 1980. The purpose of the study was to examine the oceanographic processes of the Lydonia and Baltimore Canyons and the slope areas between Linderkohl and Carteret Canyons (Mid-Atlantic), Toms and Meys Canyons (Mid-Atlantic), and Veatch and Hydrographer Canyons (North Atlantic).

Results (LDGO, 1983) indicated that the physical regime of submarine canyons may well concentrate and transport pollutants through areas populated by unique and fragile biological assemblages. The canyon assemblages are often dominated by large populations of sessile filter feeders and by assemblages that represent substantially higher biomass than those at comparable

depths on the slope. In contrast, slope assemblages often consist of sparse, mobile, carnivore/scavenger populations. All canyons investigated demonstrated distinctive faunal communities at the canyon heads. Data lead to the conclusion that recovery of canyon megafaunal assemblages from physical perturbations may be relatively slow and that discharges of toxicants should be avoided in the vicinity of canyon axes (where faunal communities are well developed). Recommendations for further research included a drill site monitoring program for deep-sea communities and a baseline survey to account for patchy distribution of benthic organisms. Both the canyon assessment and processes studies corroborated the use of deferrals and deferral alternatives requested by the National Oceanic and Atmospheric Administration (NOAA) in 1978 and 1982 for tracts containing canyon heads in the North and Mid-Atlantic lease sale areas.

Increased interest for oil and gas exploration in the northeast Atlantic coast focused concern on potential toxic effects of oil on commercially and ecologically important shellfish species, including the American lobster, *Homarus americanus*. The lobster has four larval planktonic stages that could be exposed to oil dispersed in surface waters. Research concerning the physiological effects of chronic exposure to South Louisiana crude oil dispersed in surface waters to planktonic larval stages of lobster was addressed in an investigation by Woods Hole Oceanographic Institution (WHOI). Results of the studies suggested that persistence of petroleum hydrocarbons in sediment may present a chronic contamination problem to the post-larval benthic stages of the American lobster. Juvenile lobsters were unaffected by oil in seawater, but they accumulated hydrocarbons from oiled sediments, and apparently retained these hydrocarbons in their tissues longer than did larval lobsters (Capuzzo, 1982).

To inform Federal and State reviewers and decisionmakers about the potential impacts of oil and gas activities on fisheries, the MMS proposed a study to prepare annotated bibliographies of the recent literature on the life history, distribution, and relative abundance of 67 target fish and shellfish species. An annotated bibliography was also prepared on the potential impacts of OCS oil and gas activities on commercial and recreational fishery resources. Two volumes were produced (TRI, 1989). Volume I contains nearly 2,000 abstracts from distribution and abundance studies and about 30 descriptions of databases related to the target species. Volume II contains over 1,780 abstracts from literature on the potential impacts of OCS activities on fisheries resources.

Drill Site Monitoring

These studies examined short-term (two - three years) effects in the vicinity of exploratory drilling rigs, impacts of exploration on biological populations and communities, and ambient levels of hydrocarbons and trace metals in the environment.

North Atlantic

Concerns about the potential effects of oil and gas exploration activities on the highly productive Georges Bank led to the initiation of the drill site monitoring program in July 1981. The first study, Analysis of Historical Benthic Infaunal Samples from Georges Bank, completed the taxonomic identification of infaunal samples taken during Cruises III and IV of the New England OCS Environmental Benchmark Program and resampled, over a four-season cycle, 11 of the original 42 infaunal stations. In general, the numbers of species and individuals increased with water depth. Lowest numbers of species and lowest mean densities were found on the crest of the Bank, whereas the highest numbers of species and highest densities were found in the deeper sites in the Gulf of Maine (Michael et al., 1983). The high level of sample replicability and the high level similarity and persistence within Georges Bank benthic communities, showed that benthos would function as a good monitoring tool for any potential future impacts of oil and gas activities.

A Biological Task Force was established for Lease Sale 42 (Georges Bank). One of the purposes of the Biological Task Force was to design environmental studies and monitoring programs to detect the possible early warning signs of environmental deterioration on the Bank. The benthic infauna monitoring program addressed whether animal populations in the sediments changed during various stages of oil and gas exploration activity arising from Lease Sale 42. No significant changes in benthic infaunal community structure, attributable to drilling eight dry wells, could be detected either at stations close to the operations or at any regional Georges Bank stations over the 2-year postdrilling period (Blake et al., 1983; Maciolek-Blake et al., 1984; and 1985).

Another study, resulting from the Biological Task Force recommendation, was designed to monitor and analyze hydrocarbons in bottom sediments, and to analyze hydrocarbons and trace metals in the benthic fauna of Georges Bank. The lack of any significant accumulation of aliphatic or aromatic hydrocarbons from exploratory drilling activities in Block 312 was attributed to the scouring and winnowing process of the currents in that area. Those hydrocarbons present were attributable to nondrilling-related activities of man. There was little or no evidence to suggest that any hydrocarbon compounds associated with drilling fluids were accumulating in the tissues of the species analyzed. No evidence of change in the levels of trace metals present within the biota could be found when compared to those collected during the 1977 New England OCS Environmental Benchmark Program (Payne et al., 1982; 1983; and 1985).

In 1982, as part of the Georges Bank Monitoring Program, the MMS funded the USGS to conduct a series of trace metal analyses on bottom sediments of the region. The database included 18 regional stations located across Georges Bank, 29 site-specific stations located around a drillsite in Block 312, and 3 stations around a drilling rig in Block 410. The monitoring program was conducted to provide trace metal data before, during, and after exploratory drilling operations.

Predrilling concentrations of trace metals in unfractionated sediments appeared to be at natural levels based on historical geological data from Georges Bank. Barium (present in barite, a major constituent of drilling mud) increased by a factor of 2 to 5 within 200 meters of the two monitored drill sites. However, even the highest concentrations were equivalent to average predrilling crustal material values in the region (Bothner et al., 1982).

The second and third years of the trace metal monitoring program confirmed that barium was the only trace metal that increased in concentration during exploratory drilling. Most discharged barium is associated with the fine fraction of sediments. In the study area, resuspension of fine sediments can occur 25 meters above the sea floor. The study findings suggest that transport of barium by resuspension was consistent with the prevailing local current regimes (east to west) (Bothner et al., 1983 and 1985).

Multiregional Studies

As oil and gas companies began looking to the continental slope and rise for hydrocarbon resources, deeper water scientific research technology became available. The MMS contracted with Battelle to perform a series of studies to characterize the slope and rise environment as a basis for an evaluation of the impacts of drilling (Biological Processes on the U.S. Atlantic Continental Slope and Rise: Part A - North and Mid-Atlantic and Part B - South Atlantic) (Maciolek et al., 1987; Maciolek-Blake et al., 1985 and Blake et al., 1985 and 1987, respectively). The study design varied for each region according to drilling activity and regional differences. Fourteen stations near the U.S.-Canadian border to south of Rhode Island were established in across shelf transects. This region was characterized by highly diverse, but poorly known epifaunal and infaunal communities (531 new species from 1,019 species collected). Community structure was affected by water depth, sediment texture, currents, and east-west gradients. Recolonization rates were very low, suggesting that perturbations from OCS activities would be long term.

The Mid-Atlantic phase of the study had an array of 14 benthic stations placed at varying distances from two exploratory drilling sites on the continental slope and rise off the coasts of New Jersey (Block 372) and Delaware (Block 93). A total of 862 species were collected, of which 489 were previously undescribed. Community structure was affected by water depth and topographic relief. Temporal variability in species

abundance and diversity was attributed to changes in a few dominant taxa, which were altered by sediment texture differences rather than by drilling-related activities. There was no evidence of drilling-related increases in metals or hydrocarbons within the tissues of the brittle stars or sea urchins analyzed.

The stations in the South Atlantic, located off North and South Carolina, revealed one of the richest and most diverse deep-sea and benthic infaunal communities on the U.S. Atlantic slope and rise discovered to date. Infaunal samples yielded a total of 1,202 species, 40 percent of which were new to science. Communities differed in terms of faunal composition and their associated sediment characteristics. Differences occurred along the bathymetric contours from Cape Hatteras, North Carolina, to Charleston, South Carolina, confirming the presence of a zoogeographic barrier.

Endangered Species

The objectives of protected species studies are to obtain data on the distribution and interrelationships of species listed under the Endangered Species Act or protected under the Marine Mammal Protection Act and to determine the potential effects of OCS activities on those species. (The following discussion applies to multiregional studies.)

Little was known about the abundance and seasonal distribution of marine mammal and sea turtle species early in the OCS leasing program in the North and Mid-Atlantic Planning Areas. Therefore, the Cetacean and Turtle Assessment Program (CETAP) was initiated in 1978 to fill data gaps in the distribution, abundance, migration, and habitat of endangered and nonendangered marine mammal and turtle species. Results from over 250,000 miles of aerial surveys demonstrated seasonal distribution patterns of cetacean and marine turtle populations in continental shelf waters from Cape Hatteras, North Carolina, northward to Cape Sable, Nova Scotia. The CETAP final reports provided information on the distribution of 21 cetacean species, 5 of which are endangered, and 4 turtle species, all of which are endangered (URI, 1981; 1982a, and 1982b). The CETAP results revealed that many cetacean species are common in the study area throughout the year; and many species, particularly the toothed whales (Odontocetes), are sighted regularly over the continental slope and rise. Results also showed that whales were not scarce in northern waters in the winter, as was previously believed, but are present over large areas of the shelf. Observations of cetacean response to the *Regal Sword* oil spill demonstrated no apparent effect on feeding response. The CETAP program revealed that there is a greater abundance of endangered species throughout the year in North and Mid-Atlantic regions than previously anticipated.

Subsequent publication of CETAP program results were funded in 1989, under two different MMS purchase orders. Pelagic Distributions and Abundances of Sea Turtles off the Northeastern U.S. Coast described in detail the patterns of distribution and abundance of loggerhead and leatherback sea turtles in waters of the northeastern U.S. continental shelf and beyond, summarized from several CETAP reports and supplemented by more recent sightings. The patterns of relative abundance (minimal estimates based on observations of turtles at the surface) derived from this analysis could be used as a basis for the designation of critical sea turtle habitat off the northeastern U.S. (Shoop and Kenney, 1992).

The other study, Publication of Scientific Results of the Cetacean and Turtle Assessment Program (CETAP), analyzed perviously unpublished data on marine mammals (Associated Scientists at Woods Hole). Four manuscripts entitled: (1) Multispecies associations in the western North Atlantic; (2) On-shelf distribution of sperm whales; (3) The fin

whale, *Balaenoptera physalus*, in waters of the northeastern United States continental shelf (Hain et al., 1992); and (4) Correlation of cetacean distribution to environmental parameters have been submitted to peer reviewed journals.

In 1978, sea turtles were placed on the Federal List of Endangered and Threatened Species. In Environmental Impact Assessments, the effects of oil and gas activities on marine turtles had frequently been listed as a matter of concern. Marine turtles are particularly vulnerable to oil spills or pelagic tar because they must surface to breathe, increasing the possibility of repeated contact with the oil or tar that floats at the surface. Recognizing the need for additional information, the MMS awarded the study Effects of Oil on Marine Turtles to the Florida Institute of Oceanography/University of South Florida consortium. The objective of the program was to gather existing information and generate new information on the possible effects of oil on hatchling, juvenile, and adult green (*Chelonia mydas*) and loggerhead (*Caretta caretta)* sea turtles. Marine turtles have a limited ability to avoid oil slicks. Experiments to determine avoidance/attraction to floating tar balls were inconclusive. Physiological experiments showed that respiration, skin, blood chemistry, and salt gland function were affected. Based on these results, the study concluded that given the proper circumstances, marine turtles will be at risk in the event of an oil spill, especially if the spill is in the vicinity of a nesting beach (Vargo et al., 1986).

The BLM funded the Naval Oceans Systems Center (NOSC) in 1980 to investigate the effects of sound on marine mammals. The NOSC conducted field studies in areas off Alaska, California, the Gulf of Mexico, and Atlantic coasts. The study objectives were to describe the acoustic environment near oil and gas operations and from vessel traffic observing the associated behavioral responses of marine mammals. Results revealed that oil and gas operations produce significant underwater noise over a wide range of frequencies (below 100 Hz). Marine mammals can detect certain low frequency sounds from considerable distances. Whales apparently ignore or readily avoid platforms without appreciable behavioral alterations. Also platform noise is unlikely to interfere with echolocation or acoustic communication in marine mammals (Gales, 1982). The 1982 report also cautions that at present not enough information is available about the behavior, tolerance, and adaptability of individual species to evaluate conclusively the effect of OCS platforms on marine mammals.

Concern about potential environmental consequences of oil spills lead the BLM to sponsor a study investigating the proximate and ultimate effects of direct contact with petroleum compounds on marine mammals. Final reports for the Study of Effects of Oil on Marine Mammals represent a comprehensive series of behavioral, skin, bioaccumulation, baleen fouling, and percutaneous implant studies (Geraci and St. Aubin 1982; 1985; Geraci et al., 1985). The results of this generic study

are as follows: (1) dolphins, selected as a representative odontocete, can detect and avoid oil slicks but not oil films; (2) dolphin skin forms an effective protective barrier to hydrocarbons; (3) isolated whale baleen (fin, gray, right, humpback, and sei whales) functional ability was not significantly impaired after contact with oil; (4) bioaccumulation studies monitoring naphthalene tissue burdens indicate a pattern consistent with the trophic feeding levels and habitat of stranded animals tested; however, analytical techniques require refinement; and (5) preliminary studies of percutaneous implants of several materials in the dorsal fin of dolphins indicate that all metallic and all but one nonmetallic material were rejected within 3 weeks. Dolphins did successfully retain a surgical plastic implant (HDPE 120) for approximately 3 months. Surgical plastic may be a viable material to be used in the development of a tag for large cetaceans, which is necessary to improve an understanding of migrations and habitat use.

In 1986, the MMS funded Battelle Memorial Institute to complete a synthesis of existing information on the effects of oil, dispersed oil, dispersants, and cleaning agents on marine mammals that migrate through or inhabit OCS planning areas. Among the most vulnerable of marine mammals are the sea otters, because of their thick coat, compulsive grooming behavior, precarious metabolic balance, and inshore distribution. Pelagic cetaceans, with relatively unrestricted movements, are not likely to be at risk to prolonged exposures of spilled oil. There is concern that long-term ingestion of contaminated food organisms could affect the health of marine mammals (Geraci and St. Aubin eds., 1988). The synthesis was then published by Academic Press under the title "Sea Mammals and Oil: Confronting the Risks" (Geraci and St. Aubin eds., 1990)

The North Atlantic right whale (*Eubalaena glacialis*) is now the rarest of the large whales, with perhaps a population of no more than 300-350 along the eastern coast of North America (Crone and Kraus eds., 1990). Major aggregations have been described in the Great South Channel and Cape Cod Bay from late winter to early summer since 1979. *Calanus finmarchicus* is the main species of copepod on which North Atlantic right whales feed. The Great South Channel, an area where water enters from the Gulf of Maine and southern New England, could be impacted by human activities over a wide area of the continental shelf where mineral exploration is proposed. From a management perspective (Marine Mammal Protection Act and Endangered Species Act), the most significant present concern is for habitat protection and the potential problems associated with OCS oil and gas development along the east coast of the United States (URI, 1982a and 1982b).

Over the past decade, studies sponsored by Government agencies, educational institutions and private interest groups have generated information on the effects of noise on marine mammals. In 1987, the MMS funded LGL Ecological Research Associates to synthesize all the existing information, including ongoing

research, concerning the potential and demonstrated effects of noise resulting from OCS oil and gas development on marine mammals. The study will enable decision makers to establish effective mitigation measures and monitoring programs that will coincide with the OCS program. It also identifies data gaps in the existing literature. Marine mammals hear man-made noises from many sources. They possess a number of characteristics that preadapt them to cope with limited exposure to man-made noise. A better understanding is needed of the effects of prolonged or repeated disturbance and of cumulative effects of multiple noise sources (LGL, Ecological Research Associates, 1991).

The MMS and the National Science Foundation cofunded the University of Rhode Island to answer two questions: what are the causal factors relating to whale and plankton distribution; and why do unusually high concentrations of *Calanus* exist? Present information shows that right whale patchy distribution coincides with the densest zooplankton distributions, and whales adjust their dive times to utilize the densest layers of *Calanus*. *Calanus* is fundamental to the survival of the right whale, which has apparently evolved to special conditions and thus is more vulnerable to extinction than other whales (Winn, 1989).

The MMS funded the study Site Specific Monitoring of Marine Mammals the same year as Workshop to Facilitate Efforts to Develop Effective Systems for Tracking Endangered Whales (1987). The purpose of the workshop was to determine what, if any, problems had to be solved to develop a safe and effective system for long-term (12-18 months) tracking and/or relocating large cetaceans. From experience to date, no tagging systems currently being used appear to result in significantly altered behavior or cause injury. However, most radio tagged whales have not been tracked for sufficiently long periods (because of tag loss or malfunctioning) to make conclusions on long-term effects on behavior or survival. The dart-type projectile tag and the barnacle-type tag may be safe and effective for long-term satellite monitoring of large cetacean movements and behavior (Montgomery ed., 1987).

The MMS is continuing to pursue satellite-linked tagging of marine mammals (right whales and bowhead whales) in an effort to learn more about their residence times, migration pathways, timing, speed, and local movements; and to relate locations to known habitat characteristics and other tagged whales to infer behavior, habitat preference and use, and site tenacity.

In 1989, the MMS funded New England Aquarium to study Endangered Right Whales of the South Atlantic. This multi-year study was designed to obtain information on the wintering distribution, relative abundance, behavioral characteristics, and environmental factors possibly affecting the movements and behavior of right whales in coastal waters from North Carolina to Florida. Results to date suggest that the South Atlantic is a critical calving ground for the western North Atlantic right whale population (Kraus et al., 1991).

In 1990, the MMS teamed with the National Science Foundation and the Marine Mammal Commission to support an effort exploring the merits of using blimps, as non-intrusive marine research observation platforms, to collect airborne data on protected marine species. This study complemented the study being conducted by New England Aquarium that used planes and boats. South Atlantic Right Whale Biology and Whale Boat Interactions Using Coordinated Airship Overflights showed that in addition to sighting behavior, blimps have a great potential for improved observations and identification of sea turtles and birds (Hain, 1991).

Geology/Chemistry

Geological and geochemical studies examine the specific features of the OCS, including geohazards, which may present an obstacle to oil and gas operations.

North Atlantic

In 1975, the USGS, funded by the BLM, initiated studies to provide basic geologic and oceanographic environmental data on the Georges Bank region before any scheduled leasing activities. These studies focused on circulation dynamics, sediment mobility, seston dynamics, age of surficial sediments, and shallow structure of the continental shelf and slope off New England (particularly in the area of Lease Sale No. 42). Results of the study showed that circulation dynamics on Georges Bank promote considerable sediment transport and that differential settling may present sediment stability problems for drilling structures placed on the seafloor (Aaron ed., 1980). Further, the "mud patch," an area of the seafloor southwest of Georges Bank, with particularly fine sediments or mud, may act as a "sink" for trace metals and hydrocarbons.

The second year of the North Atlantic geological studies involved both field and laboratory work. Individual studies focused on potential geologic hazards associated with petroleum exploration and were designed to answer questions on sediment mobility over the seabed, sediment transport mechanisms, flux of suspended particulate matter, mass movement features, unstable sediments, and geotechnical properties of near-surface sediments. The "mud patch" region south of Martha's Vineyard, Massachusetts, is considered an area of active deposition and a potential sink for contaminants. This is the only site of present day natural deposition on the continental shelf off the eastern United States, exclusive of the Gulf of Maine. Net currents on the outer half of this continental shelf flow north east to southwest, therefore, the "mud patch" may receive its sediments and possible contaminants from the Nantucket Shoals and the Georges Bank regions. After year 2 of the study, the USGS concluded that no sediment stability problems appear to be related to free gas in the surface sediments on the North Atlantic slope nor was evidence found to relate slope instability directly to gas charged sediments (O'Leary ed., 1982). Slope stability analyses and indirect assessments of consolidation states suggested that the surficial sediments cored are stable with respect to mass movement. The significance of these conclusions are that, in general, the North Atlantic slope sediments are believed to be relatively stable with respect to any recent mass movement.

Mid-Atlantic

The Mid-Atlantic Geological Studies composed the third year continuation of previous BLM/USGS agreements directed towards characterization of the OCS environment. In particular, the study objectives were to measure sediment mobility, the seafloor processes and dynamics causing sediment movement, rates and depths of sediment

mixing in the Sale 40 and 49 lease areas, and to assess the geotechnical properties and potential hazards of the continental slope and nearshore areas. Since completing the 1978-1979 environmental studies of the Mid- and North Atlantic continental shelf, the study authors concluded that cyclic loading resulting in bubble coalescence and increased pore pressures at greater burial depths could present stability problems in slope sediments south of Tom's Canyon, New Jersey (Robb ed., 1982). A sediment slump feature was located on the shelf between Linderkohl and south Tom's Canyon. These studies have shown that the Mid-Atlantic slope sediments may be less stable than the North Atlantic slope environments. However, the North Atlantic shelf "mud patch" region represents a potentially significant site for pollutant deposition in comparison to the Mid-Atlantic shelf, which lacks such a major depositional feature.

South Atlantic

Seven cruises were conducted by the USGS from 1976 to 1977 to generate seismic profiles, collect sediments and seawater, and deploy and recover instruments across the Outer Continental Shelf and Slope between Cape Canaveral, Florida, and Cape Fear, North Carolina. The USGS (1979) concluded from the study results that surficial sediments, bottom currents, and suspended sediments within the water column were related to surface and internal waves, tides, storm-driven currents, and the Gulf Stream. Trace metals levels indicated uncontaminated conditions throughout the surficial sedimentary layer. Hard bottom areas on the South Atlantic OCS were infrequent and found mostly offshore Florida, South Carolina, and North Carolina. One significant finding of this study is that the outer continental slope of the southeast Atlantic coast contains frozen gas hydrates that could produce sediment loading instability that could impede petroleum exploration. With proper precautions, only the strongest currents of the Gulf Stream could present a hazard to exploration or development activities. Proper rig placement and engineering will overcome any geohazards present in the study area, and petroleum exploration and production could proceed on the southeastern U.S. OCS without restrictions imposed by geohazards.

The second year phase of the above study, Geological Oceanography of the South Atlantic covered the period of October 1977 to October 1978. This phase of the study focused on sedimentation rates and processes on the upper slope, geological features supportive of biological communities, transport of bottom sediments, trace metals in particulate matter, geologic hazards, and depth of sediment mixing. The South Atlantic geological studies demonstrated that the slope was an area of deposition relative to the adjacent shelf. Geological hazards causing engineering constraints to rig and pipeline siting, though considered minor, included carbonate features, Florida Current effects, and frozen hydrate layers on the Florida-Hatteras slope. The study conclusions were that productive live bottoms should be avoided, which could be accommodated by offsets and easements during both the

construction and operational phases of offshore oil and gas industry development (Popenoe, 1981a and 1981b).

Marine Habitat Mapping and Pipeline Hazard Assessment of the South Atlantic OCS was performed by the USGS. Having completed the 1979-1982 field studies of the region from Cape Hatteras to Jacksonville, Florida, and seaward to the 50-meter depth contour, the author (Henry, 1983) concluded that sandwaves, scour, and rock outcrops pose hazards. Further, buried channels, clinoform structures, and shallow karst solution features represent potentially unstable foundations. The significance of these conclusions is that rig and pipeline route siting locations should be designed to avoid encountering these features, and that proper site analysis and operating procedures should mitigate both engineering and environmental risks. Results of the fourth (South Atlantic OCS-Blake Plateau Hazards Mapping Study) and fifth (Hazards Mapping Study) years of the South Atlantic Geological Program performed by the USGS were summarized in a final agreement with the USGS entitled Atlantic Geological Studies FY '82/83 (McGregor ed., 1983).

Multiregional Studies

Environmental Geologic Studies on the United States Mid- and North Atlantic Outer Continental Shelf Area (McGregor ed., 1983) included information acquired during the entire geological field study program from 1978 to 1982. The studies were conducted to support management decisions regarding lease sales in the Mid- and North Atlantic. Geological hazards and geotechnical properties of sediments in Lease Sale areas 40, 42, 49, and 52 were assessed. Results of the first year lead to the conclusions that circulation around Georges Bank follows a clockwise pattern with a 6- month cycle time and that sediment transport on the Bank is considerable, being influenced by tidal and storm generated currents. Results also confirmed that the continental slope sediments exhibited high shear strengths but were sensitive and could lose their stability if shocked by sudden and strong earth tremors (O'Leary, 1982 and Robb, 1982).

The second year of these studies focused on bottom current characterization, processes, and seasonal variability of Lydonia and Oceanographer Canyons. The USGS concluded that submarine canyons are important pathways on the continental margin and important features in building and shaping the continental rise. Geotechnical properties indicate that surficial sediments are generally stable; however, several locations could become unstable if subjected to minor earthquake induced ground accelerations (McGregor ed., 1983).

The final year of the program was funded to allow time for finalizing the unfinished portions of the initial study of oceanographic processes and potential geologic hazards on the continental shelf and slope of the Mid- and North Atlantic regions. The study focused on mass sediment movement and mechanisms of instability, particularly in the Lease Sale 59 area. Submarine canyons and gullies

of the continental slope are important transport pathways on the continental margins. Seafloor processes vary among canyons despite their proximity. Findings of the studies document the occurrence of erosion on the continental slope and rise (McGregor ed., 1983). In the North and Mid-Atlantic, sediment slope stability varies depending on location on the slope, sediment loading, shear strengths, state of consolidation, pore pressures, and gradient.

Oil Spill Studies

Oil spill studies examine the fate and effects of oil spills on the surrounding environment and have concentrated on fishery resources.

North Atlantic

On December 15, 1976, the tanker *Argo Merchant* ran aground on Nantucket Shoals off the Massachusetts coast and created one of the largest oil spills in U.S. history. The tanker was carrying 7.7 million gallons of No. 6 fuel oil and spilled 189,000 barrels in one of the most productive fishing grounds of the world. The BLM provided financial support for the NOAA-Coast Guard Spilled Oil Research (SOR) Program in conjunction with 11 other Federal, State, and privately funded organizations.

The preliminary scientific research (Grosse and Mattson eds., 1977) reported most of the oil remained on the surface and moved offshore. Modeling efforts were successful in predicting and hindcasting the offshore movement of oil, primarily because the movement was controlled by predominantly offshore winds whereas the complicated nearshore circulation played only a minor role. Oil caused the apparent mortality of fish eggs and larvae. Zooplankton food of larval and adult fish was also contaminated with oil, indicating an important contaminant pathway from the spill into the food web of Nantucket Shoals. The significance of these conclusions demonstrates the importance of climate, weather conditions, time of year, proximity to fishery resources, and density of the product as critical factors in governing the consequence of an oil spill in the North Atlantic.

The barge *Florida* spilled No. 2 fuel oil into Buzzards Bay, Massachusetts in September, 1969. In 1989, the MMS funded The West Falmouth or "Florida" Oil Spill: Twenty Years Later (Woods Hole Oceanographic Institution). Sediments fron five of the original stations were sampled and analyzed for fuel oil hydrocarbons. Two subtidal and one intertidal marsh station had no evidence of fuel oil. However, on subtidal mud core and one marsh core contained weathered and biodegraded fuel oil hydrocarbons (Farrington et al., 1991).

On July 22, 1972, the Norwegian tanker *Tamano* struck Soldier Ledge in Portland Harbor releasing approximately 340 tons of No. 6 fuel oil into Casco Bay, Maine. Effects of the *Tamano* oil spill on the soft shell clam (*Mya arenaria*) industry at Casco Bay were examined by Mayo, Page, and Gilfillan (1975). The authors found that the clams exposed to oil grew at about 50 percent of the rate characteristic of individuals found at clean sites. Carbon flux measurements (reliable indicators of growth rate) were found to be sensitive measures of stress due to low levels of hydrocarbon contamination. Low molecular weight aromatic hydrocarbons in clam tissues can cause large reductions in carbon flux.

Mid-Atlantic

The impacts of oiled sediments on benthic community structure, benthic

recolonization rates, and microbial biodegradation were investigated in Benthic Recolonization Study Under Simulated Oil Spill Conditions in the Mid-Atlantic OCS Area (Boesch et al., 1981). Hydrocarbon contamination of azoic sediments by macrobenthos or meiobenthos was not significantly altered. But biodegradation of petroleum hydrocarbons in the sediments was minimal, despite persistent populations of petroleum degrading bacteria. Lack of significant changes in community composition between control and oiled populations suggested a response to physically mediated conditions. These study results supported the Mid-Atlantic Benchmark Study hypothesis that less frequently disturbed, finer grained habitats are more susceptible and sensitive to oil contamination.

A study by the University of Rhode Island Applied Science Associates (URI, 1982c) developed and applied an oil-spill fishery model to assess the probable impact of oil spills on key fisheries of Georges Bank and the Gulf of Maine. The model--which simulated shelf hydrodynamics, oil-spill fates, ichthyoplankton transport and fates, and fishery population dynamics--allowed for risk assessment, spill forecasting, and fishery impact assessment. Simulations of tanker spills (20 million gallons released over 5 days) and blow-out spills (68 million gallons released over 30 days) were studied for different times of the year at several locations. Spills occurring during the winter and spring produced the largest impacts. Cod are the most heavily affected species, followed by haddock, herring, and yellowtail flounder. These predictions suggest that exact spill timing is an important factor in evaluating potential spill impacts. The maximum, cumulative long-term loss to the cod fishery from a one-time spill event never exceeded 25 percent of the annual catch. Uncertainty in pre-recruit mortality estimation was the most important factor affecting model estimated impacts.

Physical Oceanography/Meteorology

Physical oceanographic/meteorological studies focus on the circulation patterns of the OCS and the forcing mechanisms creating these patterns. An understanding of the general dynamics allows for the support of diagnostic and predictive modeling efforts such as the MMS Oil Spill Risk Analysis Model (OSRA).

North Atlantic

The prospect of oil and gas development in the Georges Bank area led to several physical oceanographic studies. The largest and most comprehensive of these studies was the New England Outer Continental Shelf Physical Oceanographic (NEOCSPO) Program, funded by the BLM in 1976. The NEOCSPO program had three phases, the first two were field studies to collect current, temperature, and salinity data; the third completed an overall analysis of the field results. Measurements were taken from 1977 to 1979 by EG&G and Raytheon Oceanographic and Environmental Services.

The data from the NEOCSPO program were used in the EG&G study Interpretation of Physical Oceanographic Conditions and Their Applications to Pollutant Transfer in the North Atlantic U.S. Outer Continental Shelf. The objective of this study was to develop a conceptual model of typical circulation patterns on Georges Bank by incorporating a quantitative description of circulation variability and exchange rates that dominate the movement of nutrients and potential pollutants. Major nutrient sources for Georges Bank are considered to be upwelled from the Gulf of Maine Surface and Intermediate Waters. Residence time for water in Georges Bank, based on drogue and current meter measurements, was consistent with the box model flow for the New England OCS and ranged from 40 to 80 days (Flagg et al., 1982).

Ocean circulation patterns and their underlying causes are important to consider when assessing dispersal of pollutants or stability of engineered structures. Data sources derived from files at the National Oceanographic Data Center and the National Climatic Center were analyzed by NOAA's Marine Environmental Assessment Division to provide information concerning environmental processes and data limitations for the study region, and to suggest topics for further research. The prevailing surface winds varied from predominately northwesterly in winter to southwesterly in summer. Three homogeneous water masses (shelf, midshelf, and slope) were identified. Stratification (except for the winter months) should inhibit vertical transport of pollutants to subsurface layers (Godshall et al., 1980). Results suggested that although general meteorologic and oceanographic patterns may be discerned from archived data sources, accurate assessments require finer scale investigations of the individual parameters.

The North Atlantic Slope and Canyon Study (USGS) continued field measurements that were part of the second year of the Environmental Geology of the Middle and North Atlantic OCS study, which focused on bottom current characterization, processes, and seasonal variability of Lydonia Canyon. At water depths below 500 meters, the currents are rarely strong enough to resuspend existing sediments, and particles reaching the seafloor are likely to remain there. The transport of sediment at the outer edge of the shelf is in the downward direction. Sediments from the shelf are transported into the head of Lydonia Canyon and accumulate there. Thus the head of Lydonia Canyon is a sink for fine sediments and a potential sink for pollutants introduced to the shelf (Butman et al., 1983 and Butman ed., 1984). Studies results supported the decision to delete Leasing Blocks at or near canyon heads.

Mid-Atlantic

The Mid-Atlantic Physical Oceanographic and Meteorological Study (NOAA) summarized and analyzed the historical meteorological and oceanographic data for the Mid-Atlantic region. Assessment of the data would provide decisionmakers with a baseline for describing physical characteristics of the marine environment and provide the capability for predicting potential impacts of OCS activities. Seasonal wave climatology from shipboard observations shows the sea state to be maximum in winter and minimum in summer. Vertical mixing is strong in winter with a seasonal thermocline developing in late March to April, at a depth of 15 to 25 meters. The primary oceanographic database was found to be insufficient for reliable analysis of motion and mixing variability at the small time and space scales that are needed for further development of pollutant trajectory prediction models. The study authors recommended an analysis of atmospheric forcing and shelf water response for such modeling as the highest priority, to be followed by a similar analysis of slope water and then of exchanges between shelf and slope water (Williams et al., 1977).

The Mid-Atlantic Slope and Rise Study (MASARS), which began in 1983, showed that exchange processes over the shelf edge, slope, and rise appear to be affected by repeated and drastic changes in the position of the Gulf Stream (GS) off Cape Hatteras. Direct GS entrainment of shelf water can occur as far north as Delaware Bay when the GS is in its northern position. There appears to be a seasonality to the shelf-slope exchange, such that the shelf-slope front is more conducive to cross-frontal transfer in winter than in summer (Science Applications International Corp. [SAIC], 1987 and Brown et al., 1987). The information from this study has been incorporated into the circulation model simulations of current fields that are input to the OSRA model.

In 1985 the scientific review panel, formed as part of the May 1983 Memorandum of Understanding (MOU) between the State of North Carolina and the DOI, recommended that a physical oceanographic field study be conducted to directly measure GS generated eddies and filaments off the North Carolina

coast. The panel's concern was the possible transport of pollutants across the GS front and shelf region. Consequently, the MMS funded Evans-Hamilton Inc. to conduct the Gulf Stream Frontal Dynamics Study Offshore North Carolina (FRED). This study determined that the GS behaves in two distinct meander modes: the large meander mode where the GS front lies offshore of the shelf break and its amplitude is large; and the small meander mode where the GS front lies at the shelf break and its amplitude is small. Cold core eddies, approximately 10 km in diameter, form as a result of both meander modes on a weekly basis. The eddies travel northeast along the GS front. The cyclonically spinning cold core entrains warm GS water and moves it on the shelf shoreward of the GS. These warm GS waters, known as filaments, expand and then dissipate or are re-entrained in the GS as the eddies travel further northeast. All surface drifters used in the study to track the eddies and warm filament waters either stayed with the eddy and traveled northeast or went shoreward with the warm filament water where they remained offshore of the 30-meter isobath and then were ultimately re-entrained into the GS (Ebbesmeyer ed., 1989). No definitive statement that surface pollutants entrained by GS frontal eddies would reach the North Carolina coastline could be made from this study.

South Atlantic

In the late 1970's, national interest increased in offshore mineral exploration and the possible environmental impacts associated with this exploration. The BLM's first efforts in physical oceanographic field work in the South Atlantic Planning Area began with the program South Atlantic OCS Data Buoy, FY '76 - '81. Meteorological data collecting buoys were deployed off Charleston, South Carolina, Jacksonville, Florida, and Savannah, Georgia, from 1976 to 1981. Monthly data reports consisting of hourly measurements of wind direction and magnitude, air temperature, atmospheric pressure, sea surface temperature, and surface wave parameters were delivered to the BLM.

The South Atlantic OCS Physical Oceanographic Literature Synthesis, FY 1977 study was funded to (1) identify the existing physical oceanographic data sets obtained in the South Atlantic OCS from Cape Hatteras to Cape Canaveral, (2) synthesize the data and literature in a coherent dynamic description of the flow, (3) explain the biological consequences of the hydrography and circulation in the study area, (4) identify data gaps, and (5) suggest areas of further research and analysis. The final report (Kirshen, 1979) helped form the basis for the MMS-funded physical oceanographic studies conducted in the study area in the 1980's.

The advent of satellite altimetry raised the possibility of obtaining both long-term and near real-time oceanographic data useful for oil-spill modeling, meteorological and oceanographic research, search and rescue operations, and ship routing. The BLM funded NASA to investigate the degree of accuracy and resolution that NASA's Geodetic Experimental Ocean Satellite

(GEOS-3) could measure sea surface profiles, significant wave heights, and surface wind speeds. Three years of data were collected in the South Atlantic Bight (SAB) in the hope of defining the characteristics of the GS. Results indicate that the level of accuracy and resolution was not sufficient for even monthly simulations of oceanic conditions and was only useful for determining seasonal variations of the GS and its associated eddies (Leitao et al., 1980).

In pursuit of the ability to predict the dispersal, dilution, flushing, and final distribution of pollutants in the SAB, the MMS funded a multiyear physical oceanographic field study entitled South Atlantic Physical Oceanography Study (SAPOS). Before this study, key circulation processes in the SAB and their forcing mechanisms were only briefly hypothesized. Physical oceanographic field data were collected on the OCS from Cape Canaveral to Cape Hatteras from 1977 to 1982. The GS influence on shelf circulation patterns and exchange mechanisms on seasonal and shorter time scales was explained (Waddell et al., 1984). For the first time, the key process, GS boundary eddies, and their associated filament waters were defined in terms of their frequency, lateral extent, associated current patterns, and their contribution to shelf break exchange and flushing. The other key circulation producing mechanisms (wind stress, tides, and water density) were isolated, and characterized, and the oceanic response was defined. This study established the first comprehensive database for ocean circulation model development in the SAB.

The Blake Plateau Bottom and Mid-Water Current Study Years 1 and 2 and Continued Blake Plateau Current Measurement Study, Year 3 were conducted to establish a physical oceanographic database to provide information for initializing and calibrating a prognostic numerical model of SAB-Blake Plateau circulation and a description of the active processes involved in the circulation in the SAB. Year 1 data confirmed the existence of meanders in the GS that produce up to 70 percent of its total variance in current speed and water temperature. Although not known by its name during this study, the Western Boundary Under Current (WBUC) was measured at the two easternmost moorings where anomalous "southward flow events lasting up to 42 days and reaching speeds in excess of 30 cm/sec" occurred (Casagrande and Lee, 1982). Year 2 data enabled the scientists to characterize the mean flow and variability of the WBUC as a function of the semiperiodic lateral shift in the axis of the GS (Casagrande and Watts, 1983).

Year 3 objectives were to determine the three-dimensional current and temperature variability of the GS and to determine the causes of this variability and the effects of the GS on SAB circulation. The authors (Han et al., 1984 and 1986) found that short-period waves (5 and 8 days) propagate to the north at approximately 40 cm/sec, whereas the long-period waves (17 and 40 days) propagate to the north at approximately 20 cm/sec. Also found was that GS flow is influenced by the

Charleston Bump, a topographical feature offshore of Savannah, Georgia, where the GS is steered offshore of its mean downstream axis. This study also developed a further description of GS meander-produced cold core eddies along the coast of North Carolina and the "Charleston Gyre" off Long Bay.

As part of its mandate to predict possible environmental impacts of oil and gas exploration and development activities in the South Atlantic OCS region, the BLM supported an evaluation of existing numerical models and the feasibility of using such models in environmental impact assessments. The 1979 study focused on evaluating 1,100 models for their possible use in simulating the circulation in the South Atlantic OCS from Cape Canaveral to Cape Hatteras. The study determined that there were no numerical models or hierarchy of models that would meet the BLM requirements. If there were such models, there was no existing database that could be used to verify their simulations. It was also found that sediment transport modeling had just recently improved from the use of empirical relationships to the application of hydrodynamic theory with subsequent field verification. It was determined that greater specificity and sophistication of prediction techniques for sediment transport were required before such techniques would be useful to the BLM (Dowe et al., 1979 and 1980). Dynalysis of Princeton is currently perparing a more sophisticated ocean circulation model for the entire Atlantic coast and Straits of Florida under MMS Contract No. 14-35-0001-30318. Results are expected in 1993.

The BLM had a requirement to assess the environmental risks involved with OCS oil and gas exploratory and production activities in the SAB. Consequently, the BLM funded a study designed to adapt a numerical circulation model to the SAB that would supply "reasonably" active predictions of surface current velocities for input into oil-spill trajectory models, mid-water circulation to predict dissolved and suspended matter transport, and near-bottom currents to predict sediment transport (Kantha, 1980a and 1980b; Kantha et al., 1981a and 1981b; Blumberg and Mellor, 1981; and Blumberg et al., 1981). This model was to be tested with existing physical oceanographic data obtained in the SAB.

The Dynalysis General Circulation Model is the three-dimensional numerical model that was used to simulate circulation in the SAB. Open ocean boundaries for this model were calculated using the Dynalysis Characteristic Tracing Model, which uses simplified physics to derive currents from climatological (seasonally averaged) density and sea surface wind stress fields. Circulation simulations were generally realistic, but not enough available synoptic data existed to properly assess the skill of the General Circulation Model.

For the same reasons cited for the adaptation of the General Circulation Model to the SAB, the MMS decided to fund a study to develop a three-dimensional numerical model to simulate the circulation of the entire U.S. Atlantic coast. The study included an extensive update of the climatological database

used to develop the Characteristic Tracing Model and General Circulation Model in the SAB modeling effort. These models were improved through a reformulation of the equations of balance and a modification of open ocean boundaries and grid specifications. The model domains were expanded to include the northern boundary of the Straits of Florida to the Bay of Fundy (Kantha et al., 1983).

The DOI and the State of Florida signed a MOU in May 1983 in response to the State's concern about the possible impacts of OCS oil and gas production activities off its coast. As part of the MOU, the DOI agreed to support a physical oceanography study that would determine the frequency and location of eddies and filament waters formed on the western edge of the GS between 27° N. and 30° N. latitude. The resulting database would also support numerical modeling efforts in the SAB. The study revealed that, as is the case further north off North Carolina, eddies are formed on a weekly basis. The preferred area of eddy formation was the southern boundary of the study area. Satellite imagery indicated filament waters were formed within 24 km of shore (Rinkel et al., 1986).

Multiregional Studies

In response to the scientific community's concern about a valid skill assessment of the OSRA model, the MMS initiated a three-phase study to evaluate, field test, and deploy surface drifters capable of simulating the movement of spilled oil on the surface. These drifters would then be used to assess the accuracy of the OSRA model-generated oil drift tracks.

The first phase of the study identified and evaluated candidate drifters (Reed et al., 1988). The two most highly evaluated surface drifters were the Draper Laboratories Low Cost Drifter (LCD) and Technocean's Argosphere (TA). In phase two of the study, these two drifters were field tested. The movement of 10 of each drifter type was compared to the movement of an actual oil slick in a controlled oil spill experiment off the Norwegian Coast in the North Sea. After the ballast of the 20 drifters was adjusted properly, it was found that both drifter types followed the movement of the oil spill quite well. The performance of the TA was slightly better than that of the LCD in this one experiment. For both drifter types, the weight of the ballast was not as much a factor as its external configuration. When the drifters were externally ballasted, they tended to follow the direction of the subsurface currents. When the drifters were relieved of their external ballast, this "keel" effect was no longer a factor and they responded more to wind forcing, following the leading edge of the oil slick. The study concluded that these drifters required more field evaluation in different marine environments before they could be used as an OSRA skill assessment tool.

The most recent multiregional study is a literature review of all the available physical oceanographic information and processes in the U.S. Exclusive Economic Zone, from Tampa, Florida, to the Gulf of Maine. The final product is a single-volume reference book on the physical

processes related to Atlantic and southeastern Gulf of Mexico OCS oil and gas activities, in a form useful for decisionmakers and the scientific community. Topics include : meteorology and air-sea interactions, circulation on the continental shelf, continental slope and rise circulation, Gulf Stream, Loop Current, deep western boundary current, surface gravity-wave climatology, offshore engineering implications, implications for resource commercialization, and numerical models of pollutant dispersion (Milliman and Imamura eds., 1992).

Social and Economic Studies

Socioeconomic studies characterize complex interactions between processes associated with oil and gas activity and the economic, social, and cultural systems of coastal residents.

North Atlantic

Impacts of oil and gas development and production on fisheries have always been a concern of coastal States. The Georges Bank area is of particular concern because of its highly productive fisheries. The University of Rhode Island (URI) and Applied Science Associates, Inc. (ASA) developed an oil-spill fishery impact assessment model. Impact predictions for the Georges Bank area showed distinct seasonal variations. The largest simulated impacts predicted were for spring and winter oil spills on cod and haddock. Uncertainty in pre-recruit mortality estimation was the most important factor affecting impacts estimated by the model. Comparisons between hindcast model runs and observed data for the Ixtoc I oil spill showed similar results.

Mid-Atlantic

Another study evaluating the onshore impacts of offshore OCS operations used the Strategic Environmental Assessment System and Harris models (Kramer et al., 1975) to determine impacts in four New Jersey coastal counties. Air emissions, other than sulfur oxides, are not likely to increase enough to warrant serious concern. Point source water emissions are not likely to increase significantly, but more information is needed to evaluate the impact of run-off from construction.

A basic understanding of trends in travel and transportation related expenditures is necessary to predict the magnitude and extent of economic impacts associated with offshore development. Trends in discretionary travel (pleasure travel) are the most likely to be altered in response to catastrophic events (such as an oil spill) which adversely affect the attractiveness of a destination. The Travel Economic Impact Model developed by the U.S. Travel Data Center (USTDC) was used to estimate impacts of travel in 12 Mid-Atlantic counties, from New York to Virginia, on State and local economies. This study showed that as economic conditions decline, business travel is reduced. However, pleasure travel does not seem susceptible to the depressed state of the economy. Whether the model or existing data were more accurate at State and local levels was difficult to establish. Further study of the relationships between different types of travel and economic conditions is required before definite forecasts about these effects can be made (USTDC, 1975).

A more recent Mid-Atlantic study addressed the environmental impacts associated with construction and operation of submarine pipelines (Brosius et al., 1983). The identification of suitable areas for pipeline construction involved characterizing and inventorying the geological, biological, cultural, and socioeconomic features of

the Mid-Atlantic OCS where pipelines might be sited.

The characterization was followed by an investigation of potential impacts associated with pipeline construction and operations, based on experience in other areas. Specific environmental features of the Mid-Atlantic Planning Area were given a value of high, moderate, low, or special case reflecting the impact potential associated with the feature. Relatively few high-impact areas were defined in the study area, but a number of mitigating measures and special practices were recommended to minimize impacts that may occur in other areas. Specific areas where pipeline siting activity should be avoided include certain dumpsites; a marine sanctuary; an area inhabited by surf clams off Atlantic City, New Jersey; submarine canyons; and canyon heads. The remaining areas would require adoption of special stipulations involving the design and engineering of pipelines. The study was intended to be a source document in siting pipelines.

South Atlantic

In September 1974, VIMS performed a baseline socioeconomic/environmental summary for the area between Cape Hatteras, North Carolina, and Cape Canaveral, Florida. Economically the study area is generally depressed. The area is also one of the largest portions of relatively unspoiled and undeveloped coasts in the contiguous United States. The possibility of rapid coastal development should be of concern to planners and managers at all levels of government.

Cultural resources are protected and managed under the National Environmental Policy Act of 1969 and the Archaeological and Historic Preservation Act of 1974. The BLM funded Science Applications, Inc. (SAI) to survey the origin, distribution, and recoverability of South Atlantic cultural resources from Cape Hatteras, North Carolina, to Key West, Florida. The shelf off the Georgia and South Carolina coasts had the highest potential for prehistoric habitation. The highest density of shipwrecks occurred off Cape Hatteras and southern Florida (SAI, 1981). These areas were considered in developing management zones (12,000 year and 16,000 year shorelines) and determining the intensity of pre-exploration archaeological surveys.

The Florida Keys is an economically important recreation and tourism region that is supported by favorable climate and natural resources. A well established infrastructure and service industry are also essential to Florida's recreation and tourism needs. Impacts of Oil and Gas Development on the Recreation and Tourism Off the Florida Straits was undertaken in 1989, by A.T. Kearney, Inc. in response to the potential problems of OCS activities having an impact on tourism and recreation in the keys.
The objective of the study was to identify and analyze recreation and tourism activities in those areas that may be affected by proposed OCS development activities and evaluate their significance. The goal was then to develop relationships between recreation and tourism and OCS related economic activity on the south Florida economy.

The study resulted in the Florida Tourism and Recreation Regional Economic Impact Model (A.T. Kearney, Inc., 1991).

Multiregional Studies

Offshore oil and gas development on the OCS may lead to the need for developing processing and support facilities onshore. The operation of such facilities can impact air and water quality through emissions and discharges during normal operations. The Socio-economic Model Run, by International Research and Technology Corp. (IRT), evaluated the onshore environmental impacts of changes in economic activity resulting from offshore oil and gas development on the New England coast (Kramer and Watson, 1976) and in the Mid-Atlantic (Watson and O'Farrell, 1978). Onshore pollution increases from oil and gas development as a result of Lease Sale 49 were determined to be insignificant for all the counties analyzed in the study area. Most major impacts would be associated with the scenario that included development from Lease Sales 40, 42, and 49. Both regions would need stringent air pollution standards for sulfur-removal controls on gas processing plants to mitigate air quality impacts. Water quality would be significantly impacted only in Washington County, Rhode Island, because of increased municipal sewage demands from population growth associated with OCS development.

Cultural resource surveys were conducted by the Institute for Conservation Archaeology (ICA). The purpose of the study was to provide the BLM with information about the existence of known or expected prehistoric sites and historically important sunken ships, as well as methods for locating such cultural resources. The study area included waters from the Bay of Fundy to Cape Hatteras, North Carolina, and seaward to the continental shelf edge (200 meters). A conceptual model was formulated to display the recent evolution of the continental shelf, which was described at 3,000-year intervals. Analyses of the history of shipping, population growth, and published sources of shipwreck locations made it possible to predict the locations of wrecked ships at various time periods. It was recommended that each State implement a program identifying any sites endangered by natural processes or human activity and begin a thorough review of existing State legislation governing land use in the coastal zone so that any deficiencies could be identified and remedied (Moir et al., 1979).

One of the major data gaps identified before 1980 was the degree to which oil and gas activities conflict with commercial and recreational fisheries. Traditionally, OCS resources had primarily been used by commercial and recreational fishing groups. To assess the degree that oil and gas activities on the OCS conflict with fishing activities, the BLM supported a comprehensive survey of ongoing and potential conflicts. Otter trawls, bottom dredges, and purse seines were most likely to conflict with oil structures. Structure-related debris and activities caused more problems to fishermen than the actual oil structures. The most significant projected catch

losses were related to otter trawl fisheries in the North Atlantic, Mid-Atlantic, and eastern Gulf of Mexico. Competition for labor between the two industries was not appreciable, and in some areas there may be a working relationship (Centaur Associates, Inc., 1981).

Because hydrocarbon resource reserves in the Atlantic OCS were estimated to be significant, the MMS funded an investigation of alternative modes of transporting OCS-produced oil and natural gas produced in the Atlantic leasing area. Comparative analyses of existing and expected future transportation technologies concluded that pipelines have the greatest net present value for all base case scenarios. The assumed low discount rates and contingency funds for pipelines compared to other alternatives influenced the results (Carboni et al., 1983).

In 1989, the MMS funded Onshore Impacts of Offshore Oil and Gas Exploration, Development, and Production on the Atlantic Outer Continental Shelf (OCS). A.T. Kearney performed the study and developed a regional econoic impact model that estimates local expenditures of oil and gas operators, and converts them in to estimates of changes in regional employment and personal income (A.T. Kearney, 1991). The study results are designed to be used by MMS analysts in the preparation of Environmental Impact Statements and other socioeconomic analyses required of the agency by the National Environmental Policy Act and the Outer Continental Shelf Lands Act.

Atlantic OCS Region Active Studies

CONTRACT	TITLE	CONTRACTOR
	Biology/Ecology	
PO 14969	Synthesis of Information on Marine and Coastal Birds of the Atlantic Coast	U.S. Fish and Wildlife Service
30672	Seafloor Survey of the Manteo Prospect Offshore North Carolina	Virginia Institute of Marine Science
	Endangered Species	
PO 14669	Site-Specific Monitoring of Marine Mammals	National Science Foundation - University of Rhode Island
PO 16259	Mitigating Human Impacts on Right Whale Calving and Nursing Grounds in Florida	Associated Scientists at Woods Hole
30293	Study of Information on the Effects of Oil on Marine Mammals and Production of a Manuscript	Battelle, Incorporated
30486	Endangered Right Whales of the South Atlantic	Edgerton Research Laboratory New England Aquarium
30590	Abundance and Distribution of Sea Turtles off North Carolina	Virginia Institute of Marine Science
30673	Conversion of Final Report Titled "Effects of Noise on Marine Mammals" into a Book Manuscript	LGL Ecological Research Associates, Inc.
	Physical Oceanography/Meteorology	
30318	Ocean Circulation Model for U.S. Atlantic Coast and Florida Straits	Dynalysis of Princeton

CONTRACT	TITLE	CONTRACTOR
	Physical Oceanography/Meteorology	
30485	Use of Satellite-Tracked Surface Drifting Buoys to Simulate the Movement of Spilled Oil in the Marine Environment	Applied Science Associates, Inc.
30493	Physical Oceanographic Field Study of the Straits of Florida	Science Applications International Corporation
30599	North Carolina Physical Oceanography Literature Study	Science Applications International Corporation
IA 12278	Cable Measurements of Water Transport Between Key West Florida and Havana, Cuba	Pacific Marine Environmental Laboratory
	Social and Economic Studies	
30672	Coastal North Carolina Socioeconomic Study	East Carolina Unversity

Acronyms

ACSAR	Atlantic Continental Slope and Rise
ASA	Applied Science Associates, Incorporated
BLM	Bureau of Land Management
CEQ	Council on Environmental Quality
CETAP	Cetacean and Turtle Assessment Program
CFR	Combined Federal Register
CNA	Center for Natural Areas
CSA	Continental Shelf Associates
DOI	Department of the Interior
EIS	Environmental Impact Statement
ERCO	Energy Resources Company, Incorporated
FRED	Frontal Eddy Dynamics
FY	Fiscal Year
GEOS	Geodetic Experimental Ocean Satellite
GS	Gulf Stream
ICA	Institute for Conservation Archaeology
IRT	International Research and Technology Corporation
LCD	Low Cost Drifter
LDGO	Lamont-Dohtery Geological Observatory
MAB	Mid-Atlantic Bight
MASARS	Mid-Atlantic Slope and Rise Study
MGA	Marine Geoscience Applications, Incorporated
MMS	Minerals Management Service
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NEOCSPO	New England Outer Continental Shelf Physical Oceanographic Program
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPV	Net Present Value
NRC	National Research Council
OCS	Outer Continental Shelf
OSRA	Oil Spill Risk Analysis
SAB	South Atlantic Bight
SAI	Science Applications, Incorporated
SAIC	Science Applications International Corporation
SAPOS	South Atlantic Physical Oceanography Study
SCWMRD	South Carolina Wildlife and Marine Resources Department
SOR	Spilled Oil Research
TA	Technocean's Argosphere
TI	Texas Instruments, Incorporated
TRI	Technical Resources, Incorporated

TRIGOM	The Research Institute of the Gulf of Maine
URI	University of Rhode Island
USGS	United States Geological Survey
USTDC	United States Travel Data Center
VIMS	Virginia Institute of Marine Science
WHOI	Woods Hole Oceanographic Institution
WBUC	Western Boundary Under Current

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