OCS Report
MMS 91-0028

The Offshore Environmental Studies Program (1973 - 1989)

A Summary of Minerals Management Service Research Conducted on the U.S. Outer Continental Shelf

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Minerals Management Service
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1. Introduction

Report Contents

This report provides an overview of the first 15 years of the Environmental Studies Program (ESP), conducted initially by the Bureau of Land Management and now as part of the *Minerals Management Service. From* 1973 *to 1988,* the *ESP spent nearly $500 million on studies directed to better understand the* U.S. *Outer Continental Shelf (OCS) and coastal environment and to use this information to document or predict effects of offshore oil and gas activities. This report organizes the hundreds of completed studies and thousands of resulting documents into 15 study topic chapters. Each chapter (e.g., physical oceanography) cites selected studies and provides a general discussion of program objectives and results. Where appropriate, each topic is discussed by OCS Region (Alaska,* Atlantic, *Gulf of Mexico, and Pacific). A more comprehensive listing of ESP reports and associated publications can be found in OCSEAP (1988) and Johnson et al. (1989).*

The goal of this report is to provide readers with a genera/ account of the ESP's technics/ accomplishments and sources of detailed information. To understand the ESP, however, it is necessary to p/ace this program in perspective with the entire OCS oil and gas program. The rest of this chapter provides background on the history of the ESP, the OCS leasing process, and the planning processes and ongoing objectives of the ES/?

Origins of the Minerals Management Service

The Outer Continental Shelf Lands Act (OCSLA) of 1953 (67 Stat. 462), as amended in 1978 (P.L. 95-372; 92 Stat. 629), established Federal jurisdiction over submerged lands on the Outer Continental Shelf (OCS) seaward of State boundaries (generally 3 geographic miles seaward of the coastline). U rider the OCSLA, the Secretary of the Interior is responsible for administering mineral exploration and development of the OCS. The Act empowers the Secretary to grant leases to the highest qualified responsible bidder(s) on the basis of sealed competitive bids and to formulate such regulations as necessary to perform the provisions of the Act.

The OCSLA, as amended, provides guidelines for implementing an OCS oil and gas exploration and development program. One of the key considerations of this Act is balancing orderly energy resource development with protection of the human, marine, and coastal environments. To take into account this consideration, and to meet information and administrative requirements of the National Environmental Policy Act (NEPA) of 1969, the MMS assesses environmental costs and multiple use conflicts by preparing environmental analyses and Environmental Impact Statements (EIS's) for leasing, exploration, and development activities, as appropriate. Additionally, a nationwide OCS Environmental Studies Program (ESP) was initiated in 1973 to provide environmental information and analysis on marine and coastal ecosystems and to obtain information on environmental conditions in all OCS areas to be used for future impact analysis of OCS activities.

Regulations implementing OCSLA designated the Bureau of Land Management (BLM) as the administrative agency responsible for leasing and the United States Geological Survey (USGS) as responsible for supervising development and production of mineral resources on submerged Federal lands. The offices under BLM and USGS responsible for offshore leasing were reorganized as the Minerals Management Service (MMS) in 1982. Regulations administered by the MMS are contained in 30 CFR 250, 251, and 252, and are supplemented by OCS Operating Orders on an area-specific basis.

Lease Sale Planning Process

Section 18 of the OCSLA directs the Secretary of the Interior to develop and maintain a 5-year program of OCS lease sales to meet the purposes of the Act, as amended. The program document identifies the size, timing, and location of each proposed lease sale. In addition, the 5-year program, must be prepared and maintained in a manner consistent with the principle that the timing and location of exploration and the development and production-of oil and gas bearing physiographic regions of the OCS consider the following:

- Existing information concerning the geographical, geological, and ecological characteristics of such regions;
- An equitable sharing of developmental benefits and environmental risks among the various regions;
- The location of regions with respect to, and the relative needs of, regional and national energy markets;
- The location of regions with respect to other uses of the sea" and seabed, including fisheries, navigation, "existing or proposed sealanes, potential sites of deep-water ports, and other anticipated uses of the resources and space of the OCS;
- The interest of potential 'oil and gas producers in the development of oil and gas resources as indicated by exploration or nomination;
- Laws, goals, and policies of affected States that have specifically been identified by the Governors of such States as relevant matters for the Secretary's consideration;
- The relative environmental sensitivity and marine productivity of different areas of the OCS; and
- Relevant environmental and predictive information for different areas of the OCS.

To help meet the environmentally oriented goals outlined above an EIS on the new 5-year program was issued in January 1987 (MMS, 1987). This document describes the types of environmental impacts that could occur as 'a 'result of the proposed 5-year lease sale schedule. The MMS is currently beginning the process of developing the next 5-year program (1992-1 997), which is envisioned to entail a more comprehensive approach than previous lease sale schedules.

Environmental Studies Program

Leasing of offshore Federal lands for oil and gas exploration and possible production activities is a complex process involving significant cost and potential changes to the marine environment and existing social and economic infrastructure of coastal communities. Adequate environmental information, both on natural and human communities, is needed to make management decisions that balance resource development and protection of the environment as mandated in the OCSLA. The ESP was initiated in 1973 to support the Department of the Interior's (DOI'S) oil and gas leasing program. The objective of the ESP is to *establish information needed for prediction, assessment, and management of impacts on the OCS and the nearshore area which may be affected* (43 CFR 3001 .7).

In the early years of the program, between 1973 and 1978, the ESP involved primarily baseline and monitoring studies that were based on information developed through literature syntheses on the environmental and socioeconomic characteristics of the OCS leasing areas. These were supplemented by special studies of selected sites or topics of interest, The baseline studies were large-scale, multidisciplinary studies designed to characterize the nature, abundance, and diversity of animal and plant populations, the physical characteristics of the seafloor and overlying marine waters, and the concentrations of certain trace metals and hydrocarbons in the water, sediments, and selected biota prior to any OCS oil and gas activity in an area. A series of monitoring studies, in concept, followed each baseline study to provide information on changes in measurable environmental characteristics relative to the baseline data as OCS oil and gas activities proceeded in each study area.

In 1975, an interagency agreement between BLM and the National Oceanic and Atmospheric Administration (NOAA) established the Outer Continental Shelf Environmental Assessment Program (OCSEAP). NOW-OCSEAP provided additional expertise and capabilities to conduct large-scale field studies in Alaska.

In a 1977 review of this baseline approach the General Accounting Office (GAO) concluded that the program was not providing timely and appropriate information for leasing decisions and that the marine environment was too variable for a statistically valid baseline to be determined in a reasonable length of time (GAO, 1978). A major effort was initiated to restructure the environmental studies planning process so that the information needs of the OCS minerals management decisionmaking process would drive the ESP. The National Research Council (NRC) was contracted to study the existing program and to recommend changes. Subsequent to the NRC review, a program management document entitled *Study Design for Resource Management Decisions: OCS Oil and Gas Development and the Environment* was issued. This document restructured the ESP and required a clear relation between a study and OCS issues and decisions (BLM, 1978). This approach is still being used.

ESP Planning Process

Studies conducted by the MMS range from technical meetings/workshops and literature searches to multiyear deep-water oceanographic research. In contrast to agencies such as the Environmental Protection Agency or the National Marine Fisheries Service, MMS does not maintain its own laboratories, research vessels, or other research facilities. Virtually all studies conducted under ESP funding are awarded to external groups. Thus the ESP planning process within MMS is primarily to identify environmental issues relating to OCS oil and gas development that can be addressed through studies and to specify the type of study through a statement of work (SOW). The determination of information needs and ultimate approval and award of specific contracts is a complex process.

The MMS staff directly responsible for technical management of the ESP are organized into a headquarters Branch of Environmental Studies (BES) and four regional Environmental Study Sections (ESS) (see Appendix A). Procurement authority is maintained under the Procurement Operations Branch. Within headquarters, the BES is responsible for the overall management, planning, and budgeting for the program. The four MMS Regional ESS provide local assessment of information needs, propose new studies, prepare SOWS, and manage active environmental studies within their respective areas of jurisdiction (Figure l-l). They also disseminate results of these studies.

Although the daily activities of the ESP center around studies and procurement staff, the planning and definition of these activities involve all of MMS and numerous external groups. The assessment of information needs and the development of environmental studies are conducted annually. The process begins when the MMS establishes and disseminates policy and guidance for the preparation or updating of regional studies plans (RSP's). This guidance may include

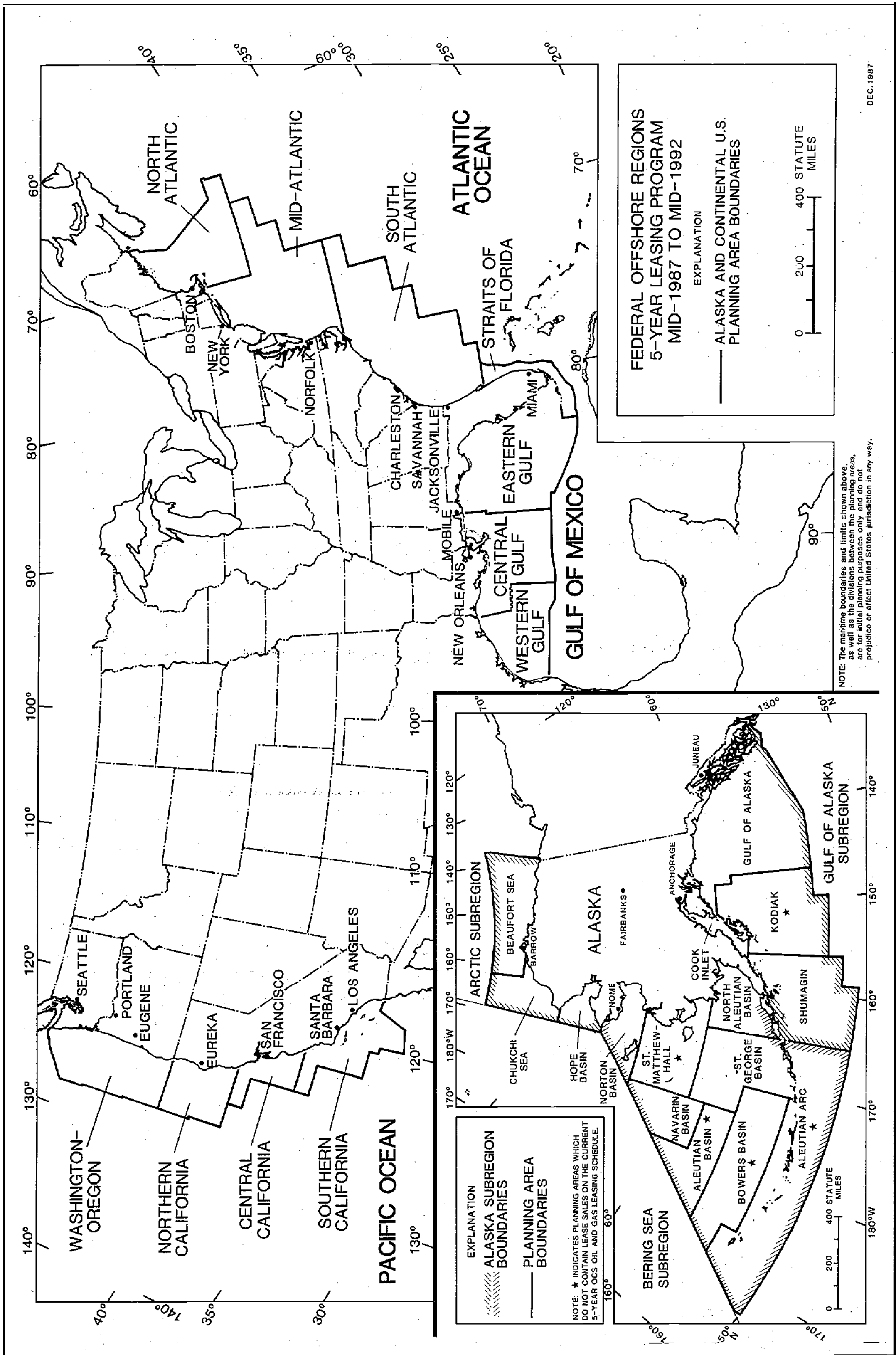

Figure 1-1. The 26 Planning Areas of the OCS Leasing Program (MMS, 1989)

interpretations of DOI policies, input from the OCS Advisory Board's Scientific Committee (see Appendix B), and other matters of national perspective.The RSP's are prepared by the regional offices with the assistance of the OCS Advisory Board's Regional Technical Working Groups (RTWG's) and also input from any groups or individuals submitting information to the regional office. The RSP's include statements of local information needs, the regional perspective on the priorities of these needs, cost estimates (proprietary information is not released in the public version of the RSP), and a brief description of each proposed study. RSP'S were prepared for each fiscal year (FY) through FY 1990. Beginning with FY 1991-92, RSP's will address 2-year intervals.

Because the total cost of all studies nominated for funding during any fiscal year has historically exceeded available funds, ranking criteria were designed to establish the priority of each study on a national studies list (NSL). The current ranking system is a modification of one developed jointly by the MMS and the Office of Management and Budget in 1979. It is based on consideration of the following items:

- Importance of the information to the decisionmaker.
- Date of the resource-management decision for which the study is designed.
- Generic applicability of results and techniques from the study.
- Status of the information.

Studies nominated in the four regional and headquarters studies plans are compiled into the preliminary NSL, which includes all studies proposed for funding for the given fiscal year. According to the ranking criteria, proposed studies are arranged in priority order. The NSL is then reviewed by ESP program managers and returned to the MMS headquarters for any resulting revisions and final approval. Estimated costs for studies are used to determine the funding line at which the annual ESP budget amount is reached. Studies above the line are approved for the fiscal year and are listed in priority order as the final NSL. Each regional office then provides a schedule for procurement of the approved studies. Studies below the line will not be funded but may be resubmitted for possible funding in future fiscal years.

Past Accomplishments

The ESP has represented a large effort to study the OCS, with about $493 million spent on studies through FY 1989 (Figure 1 -2). General scientific knowledge of the OCS has increased significantly as a result of these efforts. As described in this report, ESP results are often the dominant source of recent information for many OCS areas, particularly in Alaska.

In terms of specific oil and gas issues, historically the ESP has been most responsive to prelease sale information requirements and events. The majority of the questions that needed to be answered originated in the preparation of an EIS for a particular sale. Even so, many of the questions focused on impacts that could occur only after development began. The ESP focused on physical oceanography and modeling (necessary for oil-spill trajectory analysis); ecological characterization and key species distribution, including protected species (to define resources at potential risk); and studies to define effects of both oil and waste discharges (e.g., muds and cuttings) on the environment (necessary to define impacts). Lesser amounts of money were spent on other topics of interest, but the focus was on delineating the extent of potential impacts in the many areas of the OCS where little was known about oil and gas impacts. At the same time, MMS initiated studies in producing areas to examine actual impacts.

Overall, what was learned? First, there is a good, and steadily improving, capability to estimate the general risk from oil spills, mostly based on ESP funded research. A great deal more is now known about the resources that might be at risk in OCS areas if development were to occur. Finally, there is reasonable

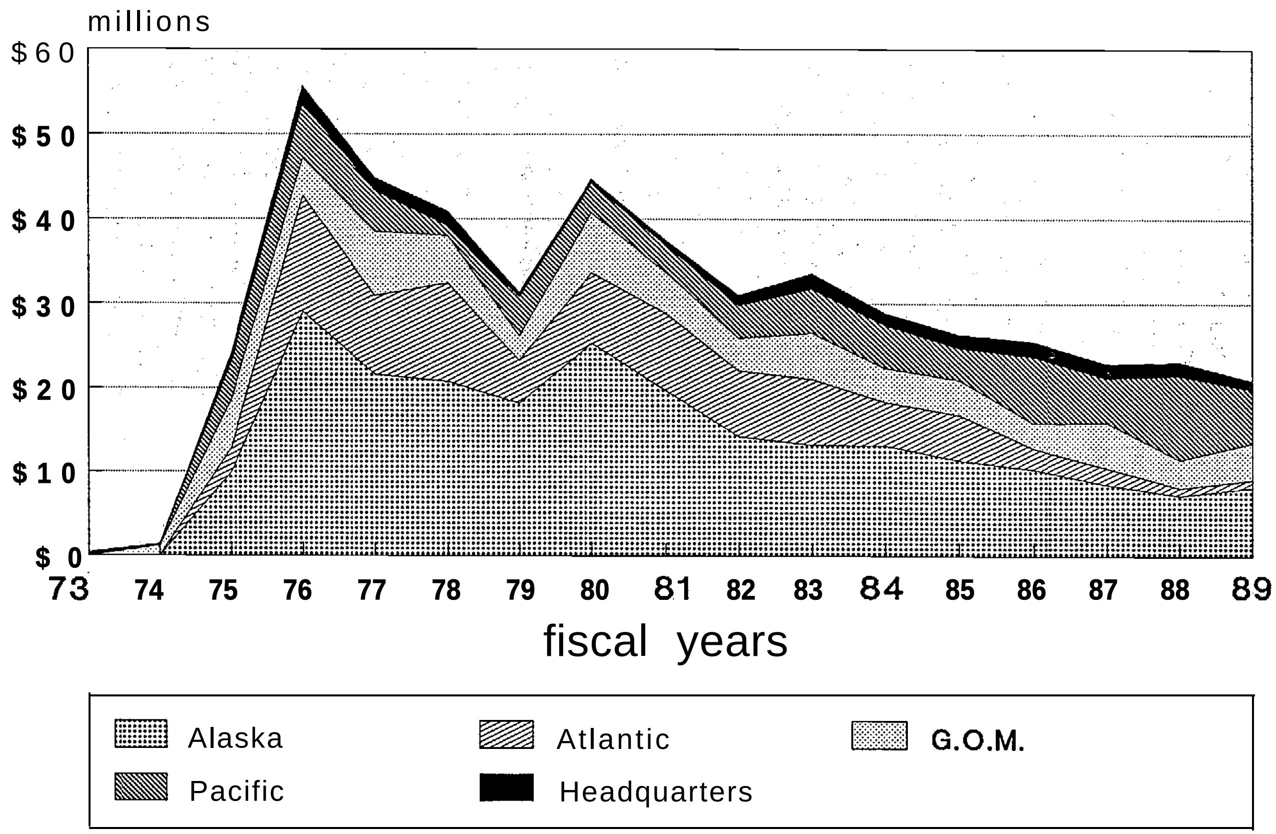

Figure 1-2. Environmental Studies Program, Funding by Fiscal Year and Region

confidence that operational impacts in areas of OCS activities are relatively benign, especially in areas where only limited activity is likely. One oil platform, or even several, is simply not a major ecological factor. The prime environmental issue is evaluation of oil spills, and although ESP data can help define the risk and consequences of oil spills more clearly, such studies can never resolve the issue of what constitutes an acceptable risk.

Current Program Objectives

Based on all of the above these considerations, it is possible to establish general objectives for the ESP (Aurand, 1988):

- The ESP will continue to emphasize the collection of environmental information for postlease decisions, rather than for prelease analyses, except in frontier areas where environmental information is scarce and where the potential for oil and gas production and development exists. In such areas, the MMS will continue the collection of descriptive information specifically for use in the prelease process, and in cases where concerns are high, the MMS may support long-term research for sales 5 to 10 years later. There are lease areas that have an adequate environmental database on which prelease decisions have been made in the past and can be made in the future. In these areas, additional descriptive studies useful only for refining the baseline data for prelease decisions will not be supported.
- As sales are held and exploration begins in various planning areas, the ESP will focus on areas of known oil and gas resources. In areas where the potential for oil and gas development is low or nonexistent, and MMS does not intend to permit activities; no, or only limited, environmental studies will be undertaken.
- In areas of oil and gas development and production, studies will be needed to monitor the possible effects of oil and gas activities on the environment and resources of the area. Studies will concentrate on evaluating the long-term, low-level cumulative impacts of oil and gas development on the environment. A long-term monitoring program is already underway in the Pacific Region, and one is being planned for the Gulf of Mexico. Similar studies will be performed in other areas as appropriate. Emphasis will be placed on process-oriented studies that seek to explain the impacts of the mechanisms at work.
- Studies in all areas will be phased to provide information at the appropriate point in the decisionmaking process. Although committed to providing appropriate environmental studies, the MMS must also operate within a restricted budget. Each phase of the oil and gas program, culminating in production activities, has unique information needs and offers unique study opportunities. For example, it is unreasonable to begin any type of monitoring activity in an area before determining if producible hydrocarbons are present and where they are located. Critics of the ESP have, on occasion, requested that detailed, site-specific information be developed prior to a lease sale. This determination is usually impractical to do on an areawide basis, given the localized nature of the potential impacts. Although it is relatively common for questions related to operational impacts to arise during the prelease evaluation process, all such issues cannot be resolved at that time. In addition, much of the available data from other regions is useful in interpreting potential impacts. Appropriate prelease studies emphasize more generalized characterization, whereas more site-specific studies are appropriate during exploration, development, and production.
- The MMS will try to support studies to evaluate oil-spill impacts whenever the circumstances suggest that a study would be appropriate and that resources are sufficient to cover the costs. Since opportunities for this type of study occur

infrequently, and are not predictable, each situation will be evaluated on its own merits.

- Efforts to improve data accessibility and/or utility– including 'synthesis reports, state-of-the-art summaries and technical position papers–will have a high priority.

Currently, one of the greatest concerns of the MMS is the inability to effectively communicate the results of the ESP (as well as other relevant research) to concerned citizens and non-MMS decisionmakers. Concerns over OCS oil and gas activities are often not considered in the context of other activities on the OCS, and frequently there is no consensus on the, significance of potential impacts. Simply collecting further scientific data cannot resolve disputes involving value judgments. The MMS will improve the process, however, by including information dissemination and management as a priority within the ESP. While having well-designed, focused studies with testable hypotheses is critical for the scientific community, it is equally important that MMS develop mechanisms to ensure that the information is used effective y. In the absence of effective communication, even the best studies are not fulfilling the goals of the ESP.

The goals MMS hopes to achieve through these efforts are four-fold:

- Concentrate the ESP in those areas where there is oil and gas production or with near-term potential for significant OCS development.
- Support additional prelease data requirements where necessary, but only after serious evaluation of information already available.
- Improve the flow, timeliness, and utility of relevant information to the public and to local, State and Federal decisionmakers.
- Increase the efficiency of analytical efforts, including better use of available data.

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2. Geology and Hazards

General Description

Funding geology and environmental hazard investigations in the ESP peaked in FY 1980. The annual expenditures fell rapidly after FY 1980 as a result of a policy decision by the Department of Interior that site-specific geohazards and geology investigations should be the responsibility of the oil and gas industry. Regional characterizations of geohazards within general lease areas and specific topical studies that could be supportive to other studies had been completed by 1980. The broad overview of regional geology and geohazards was complete. It was inappropriate for the ESP to continue with site-specific surveys. These surveys are required of industry when they have decided where to place a particular structure. The more recent ESP investigations in geology have been primarily limited to Alaska. Funding for research on the geologic environment and processes on the Arctic Continental Shelf was terminated in FY 1986. Research was continued until that time because of the unique problems of ice gouging and other environmental constraints that occur in the Arctic region. In the following discussions, geology and hazards will be addressed separately for ease of understanding.

Geology

An understanding of the basic geology of the continental shelf underlies all of the hazard related studies of the ESP. The ESP has not involved itself in basic structural geology investigations, but has, as a secondary mission, collected some geophysical data which has added to the corporate body of knowledge on continental shelf geology. Basic geological investigations for the offshore oil and gas program have been done by the USGS, MMS, or private industry.

Although the ocean severely limits the observations a geologist can make of the seabed, it does provide an excellent laboratory for studying ancient as well as modern marine sedimentary and/or mineral deposits. In addition, observations of active processes of marine deposition and erosion can be directly applicable in understanding our onshore geologic surroundings, as well as in the search for resources. Conversely, studies of former marine settings, which are now on land, together with offshore geophysical data and drill hole or surface samples, can provide an understanding of today's sea floor geology–the setting and makeup of the continental shelves, slopes, and rises, as well as the deep ocean floor. The ESP geologic investigations have supplied geophysical records to improve this understanding. It is the cumulative information of all these studies that has vastly improved the understanding of the processes shaping the Earth and moreover the discovery of significant resources (Rowland et al., 1983).

Hazards

Environmental hazards are natural conditions that place constraints on construction and operations. The constraints often can be mitigated with proper engineering and design. Examples of hazards include active surface faulting, permafrost, and structural icing. Prior to 1980, several types of environmental hazard studies were conducted. Specifically, these studies investigated seismic and volcanic hazards, surface and near-surface faulting, slope and sediment stability, sediment transport, and gas-charged sediments. These studies have resulted in regional descriptions of geologic hazards. The descriptions are used in pre- and post-l easing environmental assessments.

After FY 1980, geologic studies designed to address hazards and other constraints were de-emphasized partly in response to industry's effort in this direction and a general cautious approach by industry to developing offshore oil and gas fields in the presence of hazards.. Sea-ice mechanics, sea-ice forces, and structural icing are currently investigated at a moderate level through the MMS Technology Assessment and Research Program (TARP). Possible constraints imposed by meteorological conditions, such as sea-ice movement, storm surge, wind and wave data, and the acquisition of data to -. improve the predictive capabilities of these conditions, continue to be studied. The engineering studies are often done in cooperation with industry and will improve the MMS capability of assessing mitigating measures to overcome the aforementioned constraints.

Regional Data Availability

Geology

The general geologic structure of all of the U.S. continental shelf regions is understood, at least well enough to address the broad overview of the structure and nature of the underlying rocks. Examples of ESP studies contributing geophysical data to this understanding are; *Geologic Hazards in Santa Monica Basin and Part of Santa Barbara Basin* (Edwards, 1982), and *Geohazards on the Central California Shelf and Slope* (McCulloch, 1982). Continuing acquisition of geophysical data and well logs by both industry and government will sharpen and refine this overview, especially for site-specific areas. The finer-scaled structural interpretation needed for I easing decisions will be continued by industry.

Atlantic Region

The Atlantic region includes a series of basins –Georges Bank Basin, Baltimore Canyon Trough, several southeast Atlantic sedimentary basins, and the Blake Plateau Basin, which are filled with sediments and sedimentary rocks sometimes reaching a thickness of 43,000 feet. In addition, the continental slope and rise are underlain by a great wedge of sediments. The deep basins and the continental rise are all potential targets for petroleum exploration. Another potential resource site is an offshore buried reef extending along most of the continental shelf. Presence of resources depends on the porosity of the reef rock and the thermal history of the nearby slope and shelf. This ancient reef might serve as a hydrocarbon reservoir. Because of the depth of water, these reef-related reservoirs are just beginning to be evaluated for their resource potential.

Gulf of Mexico Region

The early geologic history of the Gulf of Mexico region was characterized by the deposition of a thick low-density salt layer. Later, the Mississippi River flowing into the Gulf deposited a thick accumulation of sediment, eroded from the central United States. This accumulation has built a large delta, the weight of which on top of the salt has resulted in extensive plastic flow of the salt upward into the sediments to form diapirs (salt domes) as well as deforming the sediments and shaping the morphology of the sea floor into ridges, troughs, and hills. This region is bounded on the east and south by the large carbonate platforms of Florida and the Yucatan Peninsula, which were created by marine organisms; in fact, coral reefs can be found growing today on the tops of ridges or hills underlain by salt diapirs in the shallow water. Over millions of years, abundant organic material generated by these marine organisms in the warm, nutrient-rich water and a high rate of sedimentation have served to provide conditions favorable. for the generation of oil and gas, and it is the vertical walls of the diapirs that provide numerous structural traps in which the oil and gas can accumulate.

Pacific Region

The Pacific region constitutes the active margin of the North American continent and is where the continental plate of North America is colliding with the sea-floor plate of the Pacific Ocean. This active margin has a much narrower continental shelf, slope, and rise than that of the passive margin along the Atlantic Coast of North America. Flanking the narrow margin to seaward is a broad continental borderland composed of numerous islands, banks, and basins, some of the basins where sediments transported by ocean currents or eroded from surrounding ridges have accumulated are over 6,000 ft deep. Several basins close to the coast contain old deep-water fan deposits and have proven oil reservoirs, such as those in the Santa Barbara Channel.

Alaska Region

The Alaska region is an enormous area containing diverse geologic elements. Whereas southern Alaska is a complex of small connected plates that extend offshore into the Gulf of Alaska, the Aleutian Islands form a volcanic arc, which is flanked on the south side by a deep basin, or trench. Along this trench, the sea floor of the Pacific Ocean is being pushed down, or subducted, under the continental margin. As this crust is pushed down deep within the Earth, it melts and then rises to form the volcanic rocks of the Aleutian Islands. Minerals originally deposited within the rocks of the sea floor are also subducted beneath and redeposited within the Aleutian arc. Geologists are particularly interested in island-arc regions because they include deep sedimentary basins, which, if conditions are right, may contain oil and gas.

The basins in the Bering Sea area vary widely in geologic origin. Bristol Bay Basin is a single, broad structural depression with a sediment thickness as much as 23,000 ft.; St. George Basin is a 32,800 ft deep, sediment-filled, fault-bounded basin; Navarin Basin is actually three elongate basins with a sediment thickness of as much as 49,200 ft; and Norton Basin is broken by faults into sections with sediment thicknesses as much as 23,000 ft.

The Hope Basin has a sediment thickness of only 9,800 ft, which is barely enough for hydrocarbon generation. The Chukchi Basin is more than twice as thick and has structural features providing potential hydrocarbon traps. By far the most promising basin of the three for hydrocarbon production, is the Beaufort Basin, where the onshore producing oil fields are within 5.4 nautical miles of the coastline; here, petroliferous onshore deposits are thought to extend offshore and sediments at least 19,700 ft thick occur all the way to the edge of the broad shelf.

The northern coast of the Alaska region is a passive-type margin with thick accumulations of sediments, diapirs, and other features similar to the Atlantic margin. The giant onshore oil field at Prudhoe Bay suggests that the continental margin, under the shelf, slope, and rise also may have important hydrocarbon reserves.

Hazards

With basic geology studies of the OCS being a major effort within the USGS, ESP geology studies have been mostly directed to studies on hazards and sediment/chemistry studies in conjunction with basic biological studies. Many of these studies examined slope stability, sediment type, and engineering properties of the bottom, faulting, and earthquake and volcanic risk. Although funded by MMS, many of these studies were conducted by USGS research teams. Each region has focused on its own particular issue or set of issues. The following discussion will focus on the specific studies and findings on a region by region basis.

Atlantic Region

The Georges Bank off the coast of New England has been the center of controversy concerning offshore drilling for oil and gas exploration. In 1975, the USGS initiated studies, funded by the ESP, to provide basic geologic and oceanographic environmental data from the Georges Bank region. The effort focused on circulation dynamics, sediment mobility, seston dynamics, age of surficial sediments, and shallow structure of the continental shelf and slope off New England coast. The results can be found in the report, *Environmental Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Outer Continental Shelf, 1975-1977* (Aaron, 1980). Spatial variability in textural components of shallow buried sediments was significant. Another major finding was that an area of sea floor, covered by mud, lying southwest of Georges Bank might act as a sink for contaminants such as hydrocarbons and trace metals. These types of investigations coupled with physical oceanography studies followed the first Georges Bank investigations into the area southwest of Georges Bank to the shelf off the coast of southern New Jersey. Reports covering this work include, *Environments/ Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Continents/ Margin, 1978-1979* (O'Leary, 1982) and *Environments/ Geologic Studies in the Mid-Atlantic Outer Continental Shelf Area* (Robb, 1982) USGS investigators continued work on sediment chemistry under the Georges Bank Monitoring Program (see Chapter VIII).

In the South Atlantic area, a variety of geological studies were conducted to assess conditions and hazards that might cause or distribute oil spills or pollutants, or constrain petroleum activities in this area (USGS, 1979; Popenoe, 1984. In addition, considerable effort was made to map exposed hard substrate suitable to support "live bottom" areas (Henry, 1983)

Gulf of Mexico Region

With all of this region's development activities and continued exploration for oil and gas, the ESP has funded site-specific geologic hazard studies to answer critical questions of environmental and rig safety. The Mississippi River Delta is known to be an unstable geomorphic feature characterized by mass movements and sediment failures. A study of these hazards to oil and gas structures was conducted in FY 1979 and results can be found in the report, *Subaqueous Sediment Instabilities in the Offshore Mississippi River Delta* (Coleman *et al.,* 1980). Many instabilities were found. Subsurface irregularities found were methane gas, sediment disturbances, faults, folds, shelf-edge separation scars, and diapirs. The final maps allow accurate evaluation of hazards within regional lease blocks. In another Gulf of Mexico investigation, biology and geology were coupled to determine the sensitivity of the biota on or above certain banks on the continental shelf off the coast of Texas. Banks on the Texas OCS can be divided into two groups; a northern group which shows a distribution associated with subsurface salt domes, and a southern group controlled by a Pleistocene shoreline (Bright and Rezak, 1976).

Pacific Region

The geology of the West Coast with its narrow but complex continental shelf has demanded a large commitment of geologic hazards studies. Indeed, it was the lack of understanding of the fault and fracture systems of the underlying rock structures that caused the 1969 blowout in the Santa Barbara Channel. From the start of the ESP, it was recognized that the need for hazard studies, including earthquake risks, was a priority for the West Coast. These types of studies were completed for the areas of: Santa Monica Basin and Santa Barbara Basin (Edwards, 1982); selected areas of the Southern California Continental Borderland (Clarke *eta/.,* 1982); Santa Maria Basin, Gulf of the Farallones, Rockport Shelf (McCulloch, 1982); Northern California Continental Margin in the area of Eel River Basin (Field *et aL, 1980).*

Alaska Region

Alaska hazard studies include coastal erosion, ice scour on the shelf, sediment dynamics, and seismic and volcanic risk activity. Again, these studies were designed to provide MMS with a general regional understanding of hazards. The Alaska region which requires a great deal of planning to even live in, let alone install major structures, includes the Chukchi and Beaufort Seas. Processes involving sea ice and low temperatures are potentially greater hazards to oil and gas development, than are faulting, tectonic activity and sea floor instability. A study, *Geological Processes and Hazards of the Beaufort Sea Shelf and Coastal* Regions, was funded from FY 1975 through FY 1986. This effort investigated ice gouging, reworking and resuspension of bottom materials, coastal erosion, permafrost, and the general sediment character of the inner shelf along the Alaska Arctic Coast (Barnes and Reimnitz, 1980). Subsequent years have furnished additional annual reports.

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3. Physical Oceanography and Pollutant Transport

General Description

From 1973 to 1988, more than $100 million has been spent on physical oceanographic studies. These studies have focused on evaluation of the circulation and surface transport patterns within the various OCS planning areas and the mechanisms creating these patterns in order to estimate the fate of spilled oil or other drilling discharges into the ocean as a result of offshore oil and gas operations. This information is used to estimate potential impacts to various biological or aesthetic resources.

The MMS physical oceanography program consists of two interrelated entities: field programs and circulation modeling programs. The field programs provide physical descriptions of circulation patterns and processes that the MMS uses in lease sale environmental impact statements. The physical descriptions and data collected also aid in the formulation of circulation models procured by the agency and serve as additional data input to the models. Data collected in the field programs normally consist of hydrographic information (temperature, salinity, conductivity, pressure), drifting buoy data (upper water surface particle movement), meteorological data (wind speeds and directions), current meter data (current speed and direction), and satellite imagery for use indetermination of surface water motions. For prelease purposes, particularly in frontier areas, the field programs are most often designed to determine the large-scale circulation patterns active within the planning area. For postlease, in areas where drilling or development and production are more likely to occur, more site-specific studies may be necessary.

The modeling portion of the MMS physical oceanography program consists of procuring numerical circulation models that provide surface current vectors (current speed and direction) for use in the MMS Oil-spill Risk Analysis (OSRA) model. The OSRA model is a tool for environmental assessment that estimates the potential contacts of an oil spill with the various resources within a lease area. The OSRA model is described in detail in Smith et al. (1982); LaBelle and Anderson (1985), and LaBelle (1986).

Regional Data Availability

Atlantic Region

The Atlantic Region has been one of the most extensively researched areas of the OCS in terms of physical oceanography. The Georges Bank area was the site of early oil industry interest in the Atlantic (Figure 3-1), and physical oceanographic studies were funded by the MMS to evaluate oceanographic conditions in the North Atlantic Planning Area and on Georges Bank proper. These efforts have contributed significantly to physical oceanographic research undertaken in the Georges Bank region. Godshall, et al. (1980) summarized historical meteorological and oceanographic data and provided information concerning environmental processes and data limitations for the study area. Flagg et al., (1982) synthesized information from several MMS-sponsored field data collection efforts undertaken by Raytheon and EG&G, in addition to meteorological buoy data, and developed a conceptual model of typical circulation on Georges Bank. The model was developed by incorporating a quantitative description of circulation variability and exchange rates that dominate the movement of potential pollutants and nutrients. The topics studied included the Georges Bank gyre circulation, the cold band, the influences of Gulf Stream frontal events on the shelf-slope front, and factors associated with enhanced biological productivity.

A joint analysis of biological productivity and physical oceanographic data suggested that nutrient replenishment for Georges Bank is

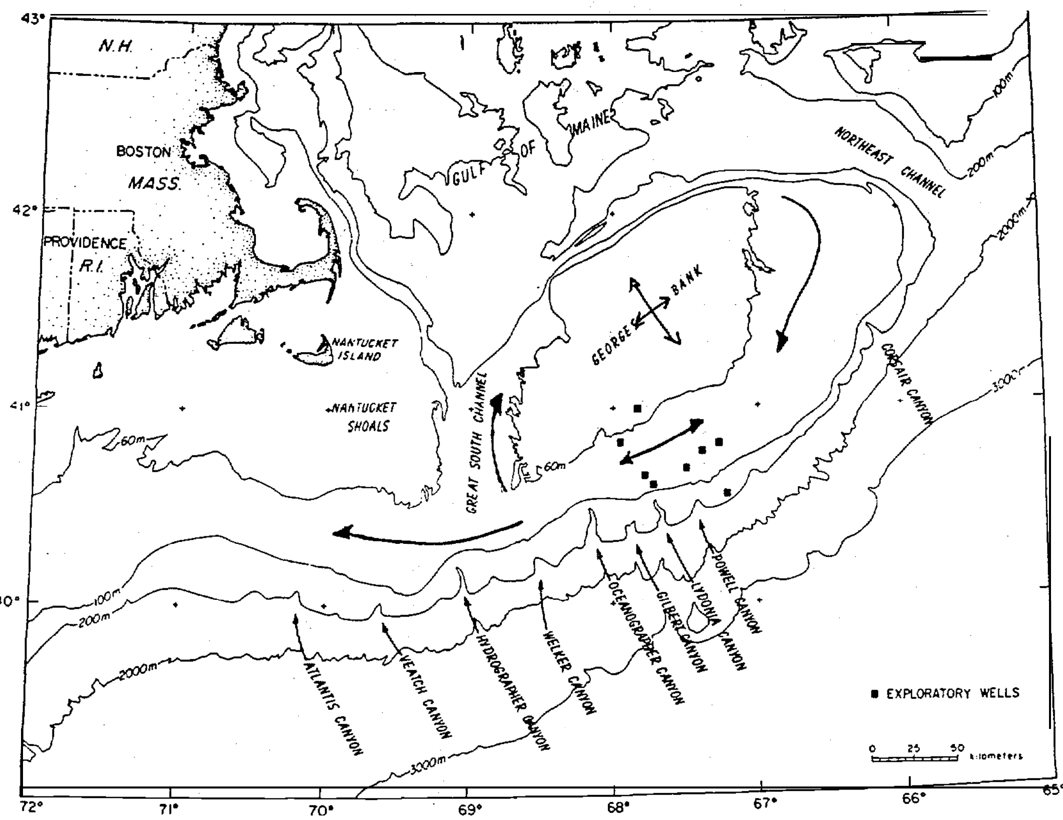

Figure 3-1 Georges Bank, Major Submarine Canyons, and Currents (Butman 1989)

derived from upwelling of nutrient-rich water located at intermediate depths in the Gulf of Maine. In addition, model calculations indicated a shelf water system driven by two major inputs: (1) water from the Scotian Shelf and (2) water from the Northeast Channel. Outflow was primarily along the shelf south of Cape Cod and water displacement offshore by the shelf-slope front eddies. Further analysis of cruise data indicates that the cold band off Georges Bank is totally replenished every 30 to 60 days. The field data indicate four sources for the water in the cold band: (1) the central region of Georges Bank; (2) near surface in the Gulf of Maine; (3) mid-depth along the bank's north flank; and (4) a depth of 100 to 150 m in the Northeast Channel. These waters become mixed at the Northeast Peak to form the cold band.

Studies conducted by the USGS for MMS in the Georges Bank area initially concentrated on understanding the dynamics of the circulation around the bank itself (Butman and Folger, 1979). These studies indicated that Georges Bank circulation is characterized by the presence of a gyre whose currents move in a clockwise direction, Seasonal differences in the current speed and gyre were noted, with the gyre seeming to be more intense and closed in summer than in the winter. The most intense currents of the bank itself are in the crest area, where the influence of strong tidal currents cause nearly continuous sediment movement and, in concert with a westward residual flow, cause a net westward movement of fine-grained sediment along the south flank of Georges Bank toward the Mid-Atlantic Bight (Butman et al., 1982, 1983; O'Leary, 1982). Current speeds in shallower portions of the bank maybe as high as 42-50 cm/see, particularly during the summer months. Current speeds appear to decrease with water depth on the bank, as the influence of the tidal currents decrease.

Additional studies conducted in the planning area shifted towards understanding the physical oceanography of the Georges Bank slope area, particularly within the submarine canyons (Figure 3-1). These studies provided an assessment of water and suspended matter movement on and off of the shelf, characterization of currents within the submarine canyons, and estimated sediment movement in the canyons (McGregor, 1983). A major component of the USGS field studies was the Lydonia Canyon experiment, which mapped surficial geology and measured currents, hydrographic parameters, and suspended sediment in the canyon and on the adjacent shelf and slope areas (Butman et al., 1983).

Studies of the morphology of submarine canyons and the gullies that dissect the slope support the concept that these features form important transport pathways on the continental margins. In the deeper waters of the continental slope, ocean currents facilitate transport of sediments into and through the submarine canyons. Studies of sediment dynamics indicate that resuspension and movement of sediment in the canyons differ significantly from adjacent shelf and slope areas (Butman et al., 1983). Further studies of the submarine canyons by the Lament-Doherty Geological Observatory (1983) indicate that canyon heads are very dynamic regimes and peak bottom currents occur near the canyon head axis. However, synthesis of all the canyon studies to date indicates that some canyon heads may be erosional environments, whereas others may be experiencing deposition.

In terms of circulation modeling, Dynalysis of Princeton(DOF) has provided the MMS with surface current vectors for the entire Atlantic Region using their Characteristic Tracing Model (CTM) (Kantha et al., 1986).

Studies in the Mid-Atlantic Planning Area were similar to those undertaken in the North Atlantic Planning Area. An initial study summarized the historical meteorological and physical oceanographic data for the region (NOAA, 1977). Studies within the shelf region indicated that this area is a storm-dominated shelf, with sediment transport occurring primarily during periods of intense storm activity (Butman et al., 1979). There is, however, a general southwestward shift of sediment on the Mid-Atlantic Shelf.

Focus then shifted towards the slope region, with studies being undertaken by both the USGS (McGregor, 1983) and Lament-Doherty Geological Observatory (1983). Results indicated generally that conditions on the Mid-Atlantic slope are similiar to those on the North Atlantic slope. However, the currents within the canyons of the Mid-Atlantic do not appear to be as energetic as the currents within the North Atlantic canyons.

A 3-year physical oceanographic study of the Mid-Atlantic Slope and Rise (MASAR) was initiated by the MMS in 1983 (Figure 3-2). The goal of the study was to obtain a description of the currents that exist between Cape Hatteras and Long Island in water depths between 120 and 7,000 ft. The study results indicate that the general circulation and exchange processes over the shelf edge, slope, and rise appear to be affected by repeated changes in the location of the Gulf Stream separation lfrom the slope near Cape Hatteras. Northerly shifts of the path of the Gulf Stream occurred during the study period, with the Gulf Stream path differing from the historical mean. The interaction of cold core rings or warm core rings with the Gulf Stream may be the triggering mechanism. Dramatic current and temperature changes appear to be the result of the Gulf Stream position changes, with upper level currents showing substantial reductions in velocity and increases in variability during periods of cold core ring-Gulf Stream interactions (Brown et al., 1986).

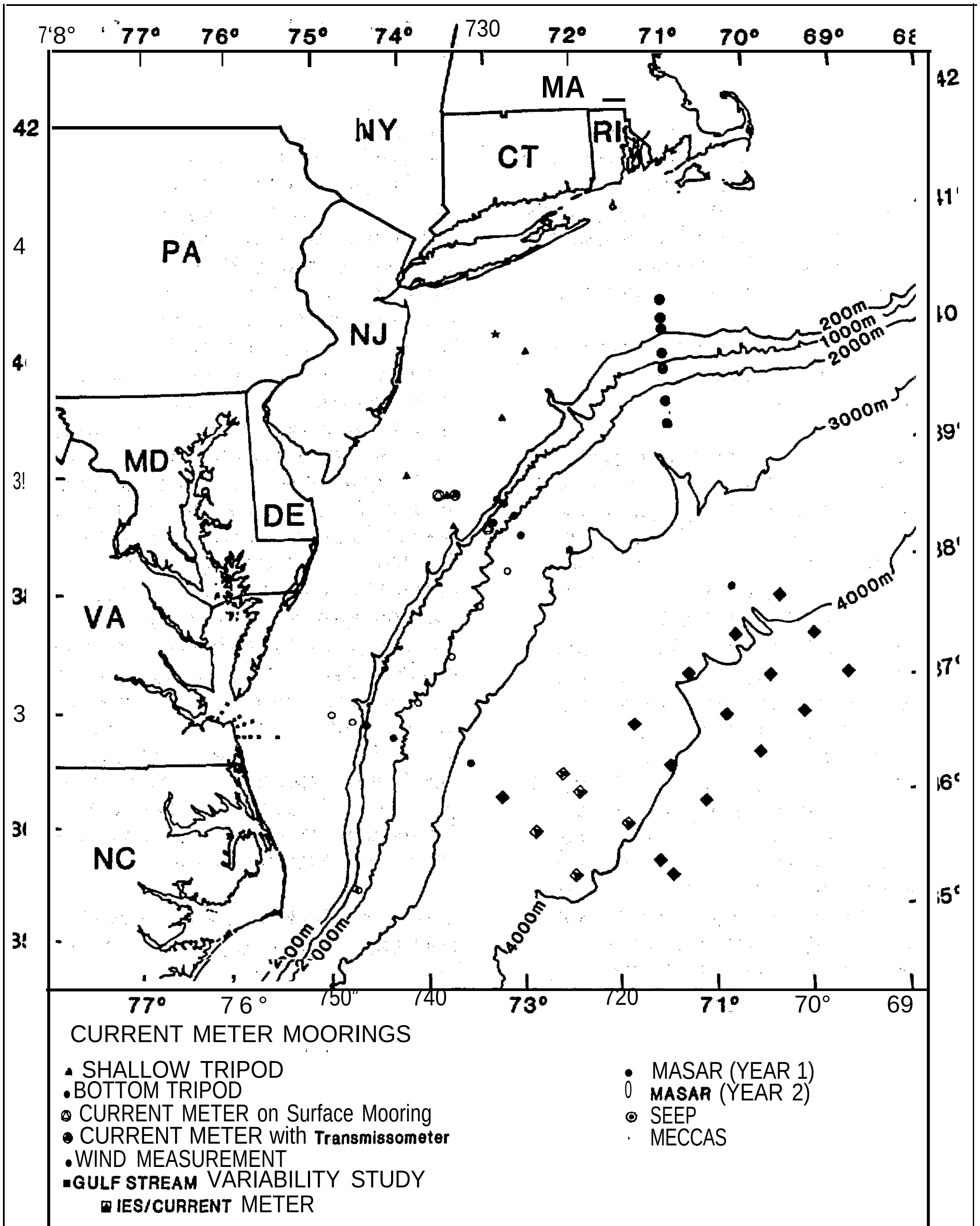

Figure 3-2 Location of MASAR Current Meter Moorings and Relationship to other Mooring Sites in the Mid-Atlantic (Brown et al., 1986).

The MASAR study also indicates the existence of the previously hypothesized Western Slope Sea *Gyre.* This gyre is characterized by an elliptical circulation pattern within the upper 500 m of the slopewater. The gyre's strength appears to be seasonal, having a strong presence during the colder seasons, and then decaying totally by the beginning of summer. The cessation may be related to the Gulf Stream. Near-bottom current measurements in the MASAR area also show a pattern of consistent along-isobath southwestward flow representative of the Western Boundary Undercurrent (Brown et al., 1986).

In the South Atlantic Planning Area between 1977 and 1984, a field measurement and data interpretation and synthesis program was conducted for an area extending along shore from approximately Cape Hatteras to Cape Canaveral and offshore across the shelf and the Blake Plateau (Waddell, 1983; 1984) (Figure 3-3). These studies indicated that, on the inner shelf, in water depths less than 20 m, local surface wind stress, tides, and the density structure are the primary factors influencing circulation. On the mid-shelf, in water depths between 20 and 45 m, tides and local winds combine as the primary forcing mechanisms. On the outer shelf, in water depths between 45 and 90 m, Gulf Stream forcing and winds are the more important mechanisms controlling circulation. The periodic migrating meanders and associated filaments are the primary processes by which the Gulf Stream influences the shelf circulation in the South Atlantic.

The Gulf Stream meanders and filaments in this region have been the target of extensive process studies, both by the MMS and by others. Gulf Stream filaments, or frontal eddies, are mesoscale events that occur at approximately weekly periods throughout the year in the South Atlantic region (Rinkel et al,, 1986). Data from the MMS-sponsored Florida Atlantic Coast Transport Study (FACTS) (Figure 3-4) indicate that the eddies form frequently along the western boundary of the Florida Current and the Gulf Stream between West Palm Beach, Florida, and Cape Canaveral. They then travel rapidly northward and westward, increasing in size and moving shoreward to within 24 km. The eddies continue their northward movement along the Gulf Stream at a rate of between 25 and 85 cm/sec. The meanders may have an amplitude (east-west displacement) of up to 25 km off the coast of Florida and Georgia, but north of the subsea topographic feature known as the *Charleston Bump* (Figure 3-3) located offshore Charleston, South Carolina, the amplitude may increase to approximately 100 km (Han et al., 1986). Several authors have reported that the crest of the meander (shoreward displacement of the western boundary of the Gulf Stream) propagates northward at a rate of between 39 and 46 cm/sec. (Legeckis, 1979; Vukovich and Crissman, 1979; Lee et al., 1981) and that the frontal eddies are associated with the passage of the crests (Waddell, 1984). Legeckis (1979) suggested that the events that initiate the start of a frontal event may occur south (upstream) of the *Charleston Bump* and be enhanced, increasing in amplitude, after the seaward deflection of the Gulf Stream by the *Bump,* Results obtained from the MMS-sponsored Blake Plateau Current Measurement Program (Han et al., 1986) support this conclusion.

Surface instabilities along the western boundary of the Gulf Stream may cause the extrusion of a warm surface filament of Gulf Stream water that usually impinges upon the outer shelf. The filament may be viewed as a tongue of water extending from the Gulf Stream and oriented in a southerly direction. The cul-de-sac formed by this extrusion is filled with a cold core of water that typically is derived from a mix of outer shelf water and nutrient-rich water that is upwelled as a result of the filament/meander passage. Lee et al. (1981) reported that the flow within a filament was approximately 50 cm/sec. in a southerly direction whereas the flow in the Gulf Stream just east of the cold core was northward at greater than 100 cm/sec. The net movement of the entire system was northerly, approximately parallel to the shelf break at a rate of about 46 cm/sec. In some cases the cyclonic frontal eddy maybe sheared from the, Gulf Stream, forming an elliptical lens of warm water that becomes stranded on the outer shelf and subsequently decays. The time period from genesis to decay typically is about 2 to 3 weeks. During this time, the filament may attain the dimensions of 30 m in depth, 30-40 km wide, and 200 km long (Legeckis, 1979; Lee et al., 1981). Lee et al. (1981) reported that the Gulf Stream filaments rarely intrude on the shelf shallower than about the 45-meter isobath. However, Waddell (1984) reported an intrusion of Gulf Stream water in the Raleigh Bay area that was evident to the 20-meter isobath. Generally, it was observed that if the filament did not shear from the Gulf Stream, it would eventually be transported away from the coastline by the

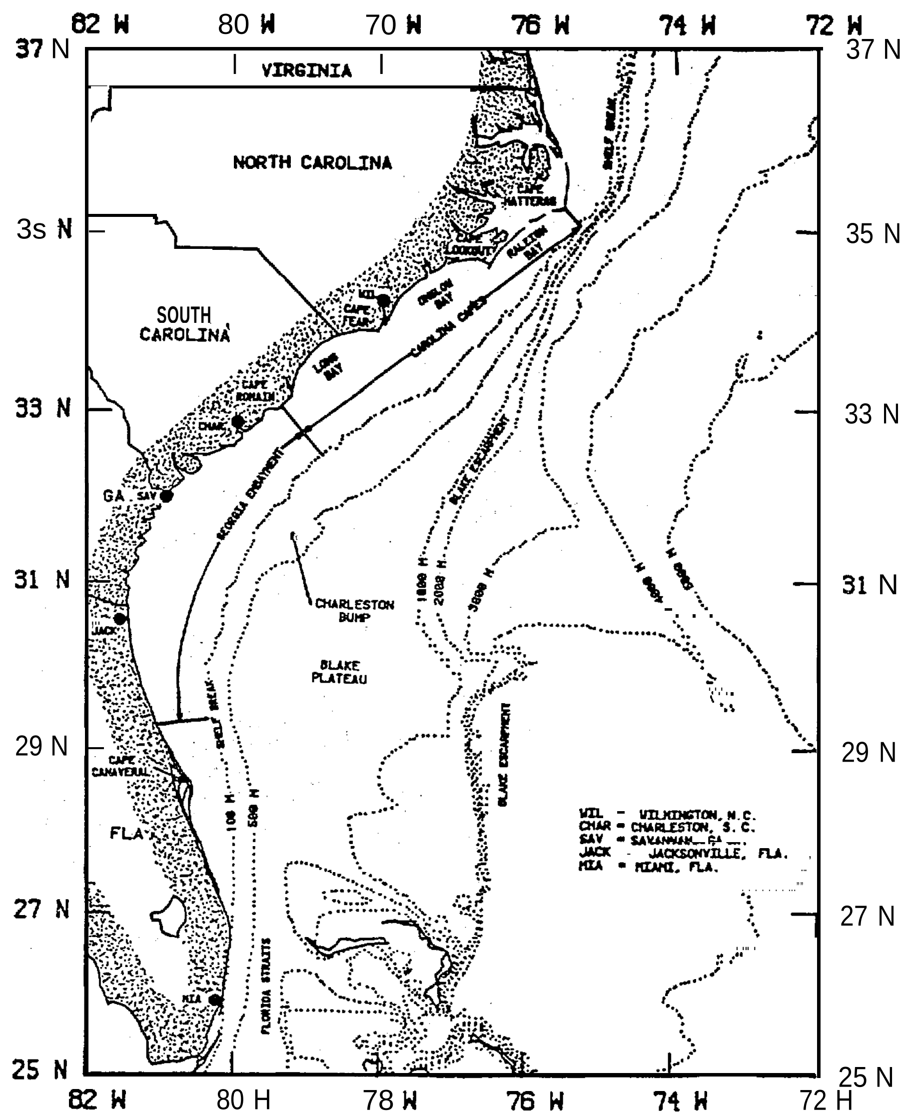

Figure 3-3 Study Area for the South Atlantic Physical Oceanographic Study (Waddell, 1984)

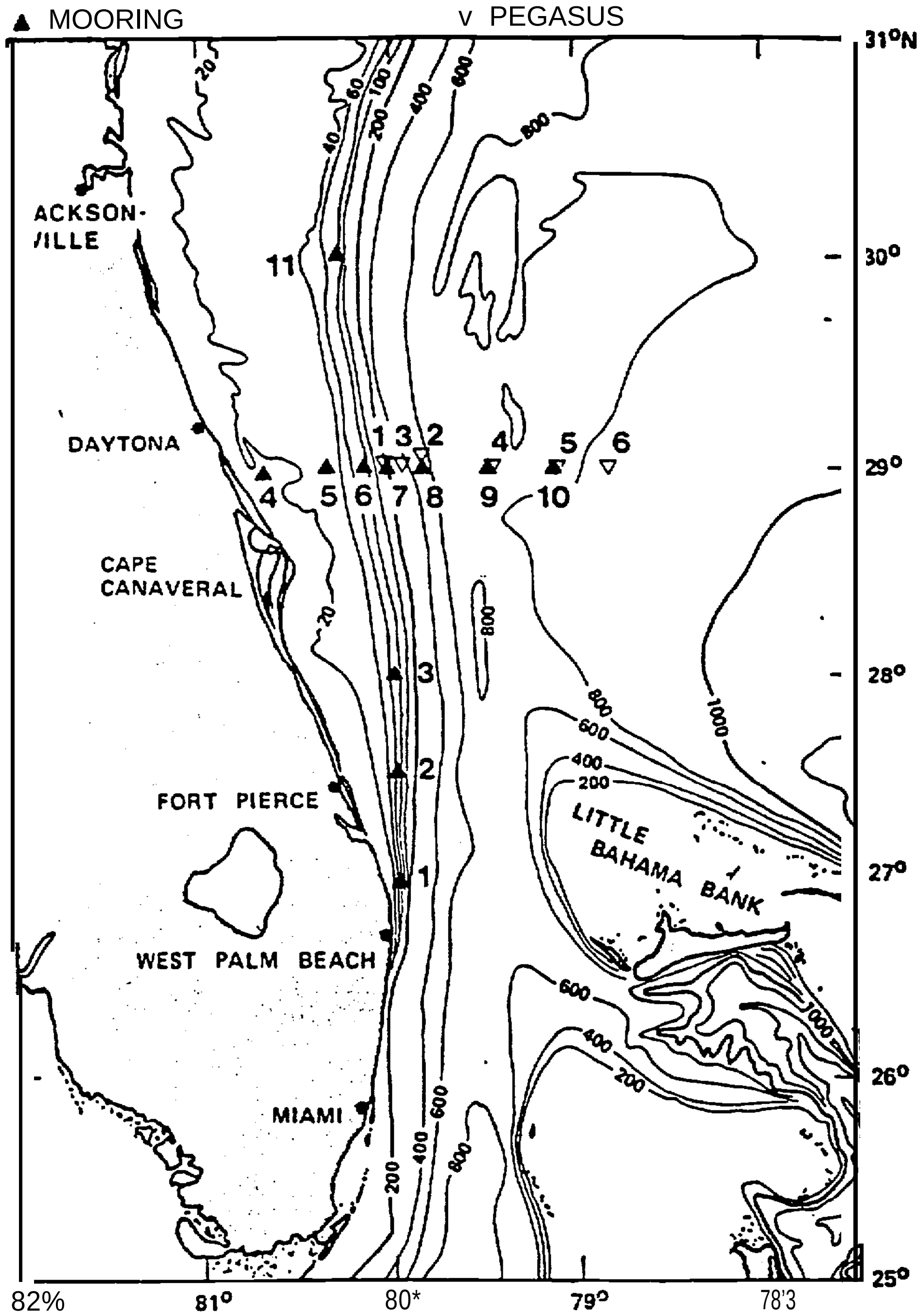

Figure 3-4 Location of FACTS Current Meter Mooring Sites (FIO, l986)

deflection of the Gulf, Stream seaward at Cape Hatteras.

Satellite-tracked buoys have shown that surface material in the Gulf Stream can detrain into the shelf waters. One buoy detrained off Cape Fear, North Carolina where tracking stopped (Vukovich and Maul, 1983). Another buoy, detrained from the Gulf Stream off Cape Lookout, was then, re-entrained and. carried out of the area. The potential for detrained materials to reach the shore has been demonstrated by a card drifter that was found on the North Carolina coast north of Cape Hatteras after being deployed south of Cape Canaveral (Rinkel et al., 1986). This onshore drift comes from the frontal events that begin with an onshore flow. Winds and tidal currents can then carry the material toward land, or the frontal event can carry the' material back to the Gulf Stream where it may be re-entrained and carried out of the area (Rinkel et al., 1986).

To define the mechanics of a Gulf Stream frontal event in more detail, the MMS awarded a contract to study frontal events off the coast of North Carolina. The study involved the placement of current meters at various locations off the North Carolina coast and shipboard hydrographic surveys during a period of intense frontal activity (Figure 3-5). Acoustic doppler profiling, aerial deployed expendable XBTS, and satellite tracked drifters were also used to determine the magnitude and direction of movement of three eddies. The results include a description of two distinct Gulf Stream behavior modes off the North Carolina coast, *large and small meander modes* (FRED Group, 1989).

There is relatively less physical oceanographic information available within the Straits of Florida Planning Area. The best available information within the area comes from the Subtropical Atlantic Climate Study (STAGS) conducted during 1982-1984. This study was designed to monitor and study the variability of the Florida Current transport through the Straits of Florida on a variety of time scales so that a better understanding of the synoptic, seasonal, and interannual variability could be gained (Molinari et al., 1985). This study involved the placement of current meters, Pegasus profiling systems, bottom pressure "gauges, tide gauges, and a submarine cable at approximately.27 degrees N. off Florida. Observations have provided an excellent database on the volume and heat transport of the Florida Current and its low frequency variability, including its interannual variability. The northward transport of the Florida Current is 30 Sverdrups (Sv= 106m3/see) on the average, with lower values around December and higher ones around June. Large fluctuations in transport occur on time scales of 1-3 weeks, apparently in coherence with atmospheric forcing (Lee et al., 1985). The interannual variability in transport appears to be small, of the order of 1 Sverdrup (Schott and Zantopp, 1985).

The MMS awarded a contract in 1987 to review the available physical oceanographic information for the area extending from Key West, Florida, to the Gulf of Maine. This MMS-funded. contract to model the entire Atlantic OCS (see below), stipulates that the Straits of Florida area be included in the circulation model. However, recent proposed studies will address the scarcity of data in the area to allow for the development of the advanced threedimensional model (the General Circulation Model or GCM) for the Straits of Florida area. Presently, the Straits of Florida area is modeled using the less advanced CTM (page 3-3)version, up to the vicinity of 27 degrees N., where the STACS data can be used for development of the GCM.

Dynalysis of Princeton (DOP) is presently working on an MMS-funded contract to develop a prognostic threedimensional circulation model of the entire Atlantic coast, with particular emphasis on specific areas of Gulf Stream frontal activity. The field data described above provide a rich source of data for skill assessment, statistical comparisons, and verification of model output. This study also includes sensitivity anal yses to determine how different oceanographic factors influence the model, and the study will compare the modeled results to field observations with results due in 1991. At present, oil-spill risk analyses for the south Atlantic region use the surface current vectors provided to the MMS under a previous study (Kantha et al. 1986).

Gulf of Mexico Region

Before the early 1980's the Gulf of Mexico had never been the subject of a basin-scale physical oceanography program, other than hydrographic work in the 1960's and 1970's performed by Texas A&M University (TAMU). In fact, not until the 1960's was the dominant physical oceanographic feature of the Gulf of Mexico, the Loop Current, even recognized. Realizing that the data available were not sufficient for environmental impact analysis, the MMS embarked on a comprehensive multiyear study of the physical oceanography of the Gulf of Mexico. The study was originally planned as a 3-year effort; however a Congressional mandate stipulated that an additional 2 years of study be undertaken in the eastern Gulf. Thus, the program evolved into a 5-year study, by far the most extensive

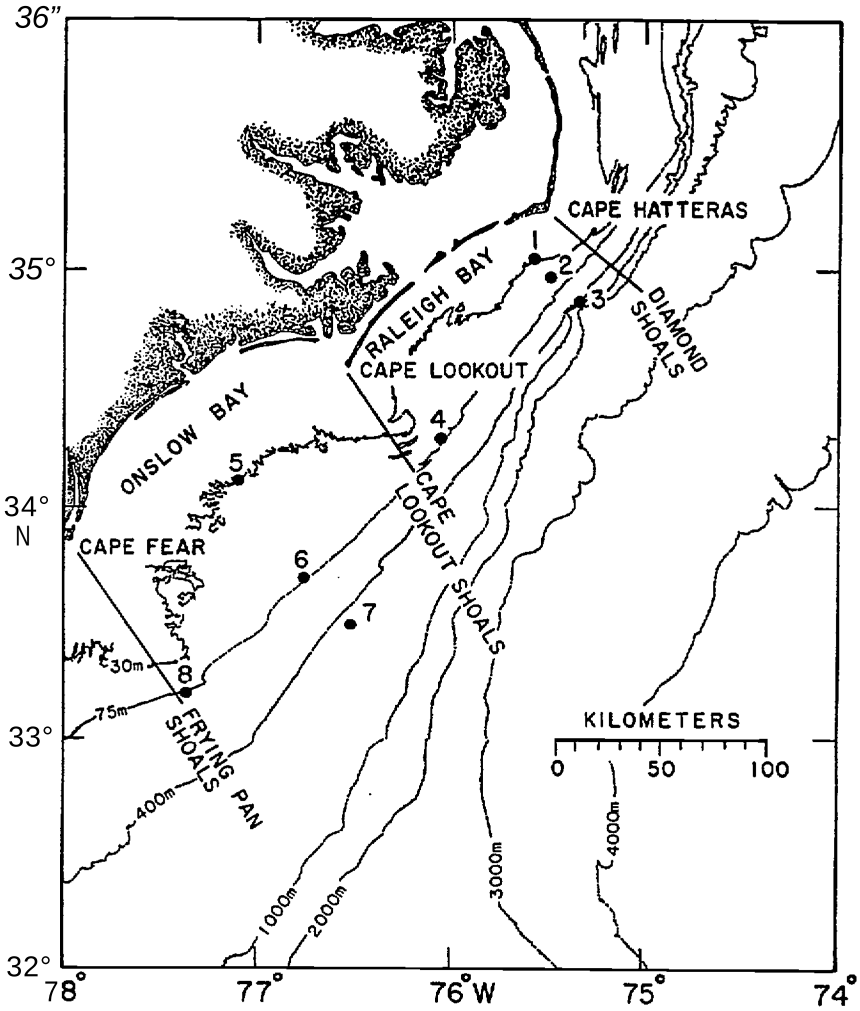

Figure 3-5 Location of Current Meter Mooring Sites for the Frontal Eddy Dynamics Experiment off North Carolina (FRED Group, 1989)

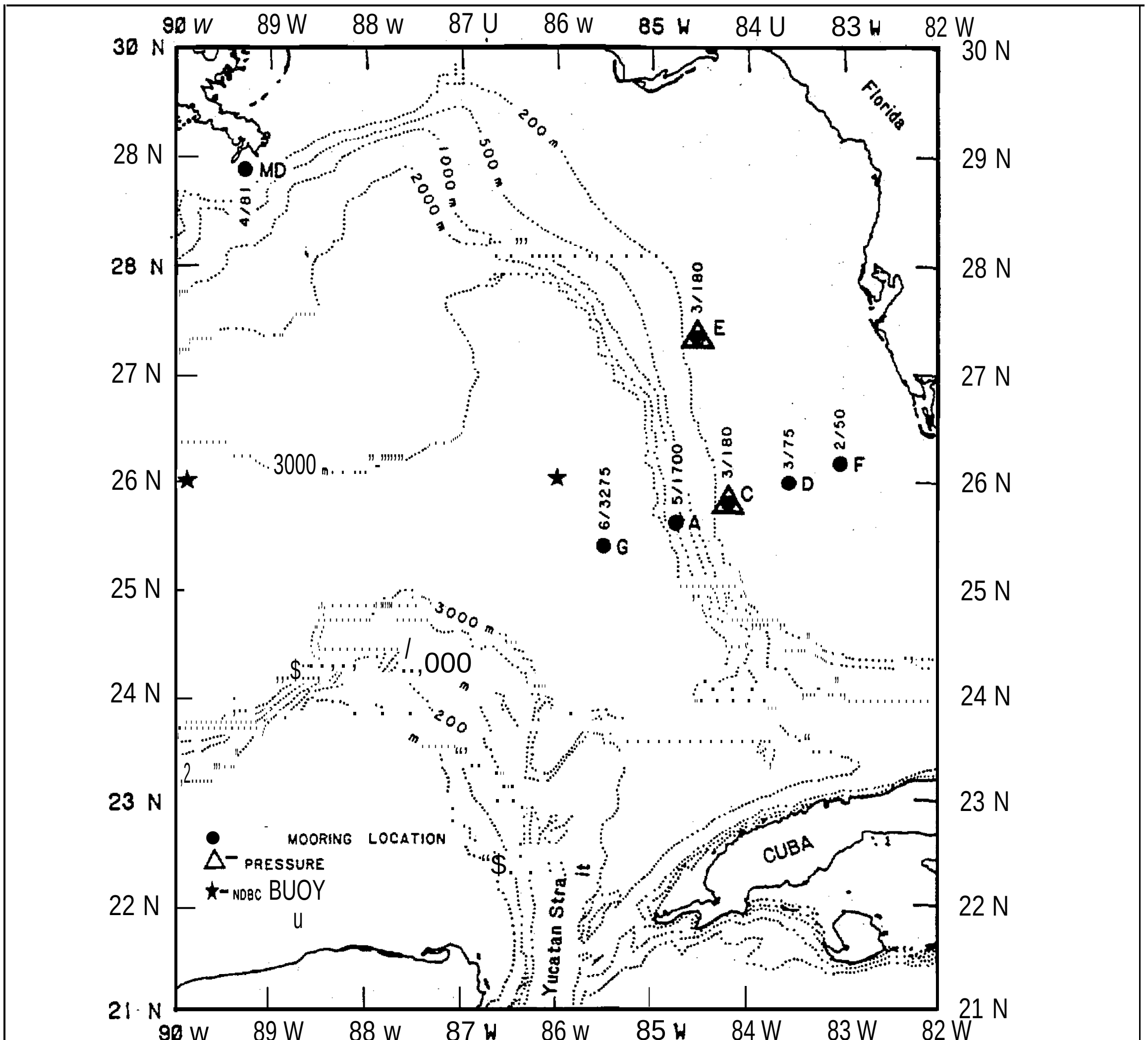

Figure 3-6 Location of Current Meter Mooring Sites in the Eastern Gulf of Mexico (Waddell, 1987)

and detailed physical oceanographic effort undertaken in the Gulf of Mexico. Program years 1,2, and 4 emphasized the eastern Gulf (Figure 3-6), whereas program year 3 emphasized the western Gulf. Program year 5, in progress, involves the analysis of features within the central Gulf (Figure 3-7). All 5 years of the program have or are being undertaken by SAIC. To date, reports have been received for program years 1-3 (Waddell, 1986b), and 4 (Waddell, 1987). Analysis for program year 5 is currently ongoing (Waddell, 1989). The following discussion represents a synthesis of information for the Gulf of Mexico Physical Oceanography Program based on the reports and analyses submitted to the MMS to date by SAIC.

The Loop Current, the dominant physical oceanographic feature in the Gulf, is a highly variable current feature entering the Gulf through the Yucatan Strait and exiting through the Florida Straits after tracing an arc that may intrude as far north as the Mississippi-Alabama shelf. The Loop consists of ascending and descending 30 km wide bands of rapidly moving water enclosing a

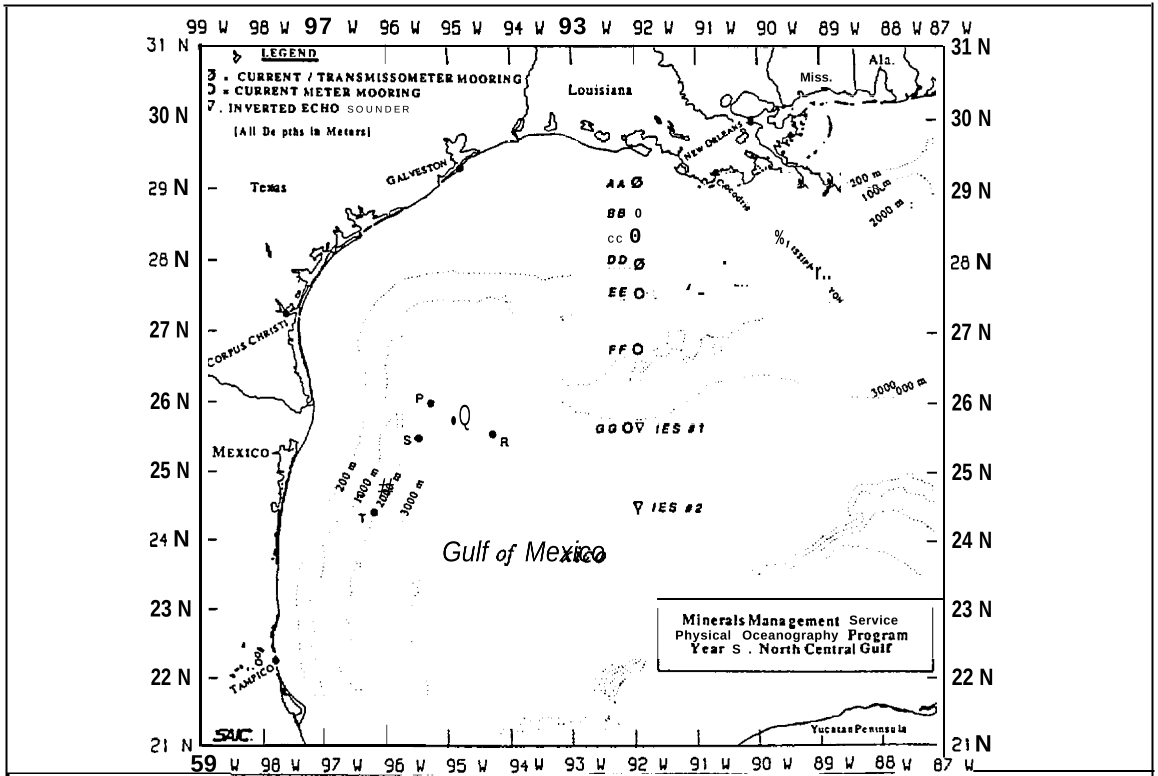

Figure 3-7 Location of Current Meter Mooring Sites in the Central and Western Gulf of Mexico (Waddell, 1989)

relatively quiescent inner region, and the entire feature may clearly be seen in hydrographic sections down to about 1,000 m subsurface water depths. Below that level there is evidence of a counter-current. The volumetric flux of the Loop has been estimated at 30 million cubic meters per second. Velocities up to 300 cm/sec have been measured, but a range of 100-200 cm/sec is probably representative. The location of the Loop Current is definable only in statistical terms, due to its great variability. The eastern Gulf studies indicate that the northern boundary of the Loop Current in that area fluctuates between approximately 25 and 28 degrees N., but the northern boundary was most often located between 27 and 28 degrees N. March has been noted as being the month of greatest apparent intrusion. In addition to the variability observed in the north-south extent of the Loop Current, variability is evident in the east-west extent of the current. During the year 4 observations, it was noted that the manner in which the Loop Current interacted and governed the conditions on the West Florida Shelf depended upon these directional extents of the current.

The process responsible for the first-order variability of the Loop Current is the shedding of anticyclonic eddies, which may occur when the current is greatly extended. The usual eddies are large, necessitating significant dimensional adjustment by the Loop. This eddy shedding cycle has been the subject of much of the field work undertaken by SAIC and the contractor for a Gulf circulation model (Wall craft, 1986). Major Loop Current eddies have diameters of about 300-400 km and may clearly be seen in hydrographic data down to about 1,000 m. Swirl velocities within the eddies have been reported from 50 to 200 cm/sec. The eddies, after spin-off, appear to move into the western

Gulf along various paths to a region between 25-28 degrees N. and 93-96 degrees W. The eddies move at a speed of about 5 km/day, decreasing in size as they mix with resident waters. The life cycle of an individual eddy, to its eventual assimilation by regional circulation patterns in the western G ulf, is about 1 year. The SAIC studies indicate that there is a primary steering mechanism for the eddies that dominates other processes such as different initial mass and velocity fields and different wind forcing. The year 4 results also indicated that during at least part and possibly all of a Loop Current eddy shedding cycle, a recirculating anticyclonic (clockwise) gyre is embedded within the Loop Current.

Processes responsible for smaller, or second-order, variability of the Loop include persistent wind forcing, shelf-edge, interactions along the Yucatan Shelf and West Florida Shelf, and waves along the Loop front associated with the eddy cycle. These waves may grow into large intrusions of warm Loop water onto the adjacent shelf, or intrusion of colder shelf water into the Loop itself. Collectively, these processes set up a zone of Loop Current fluctuation covering the outer shelf, the slope, and abyssal areas off Mississippi, Alabama, and Florida.

The eddy-shedding behavior of the Loop Current is the principal mechanism coupling the circulation patterns of the eastern and western parts of the basin. The heat and salt budgets depend on this importation, balanced by seasonal cooling and river input, and probably also by internal, deeper currents that are poorly understood. They may be evident in intriguing hints of abyssal bottom scour and the reversed currents within the Loop itself. The eddies are frequent] y observed to affect local current patterns along the Louisiana-Texas slope, hydrographic properties, and possibly the biota of fixed platforms. Evidence suggest that these large reservoirs of warm water play some role in strengthening tropical cyclones when their paths coincide.

Smaller anticyclonic eddies have been observed to be generated by the Loop Current, although it is not known if the process is merely a scaled-down version of the above described processes. These features have diameters of about 100 km, but the few data available indicate a shallow hydrographic signature, of about 200 m. Their observed movements indicate a tendency to translate westward along the Louisiana-Texas slope. Similar in size, cyclonic eddies have been observed in the eastern Gulf, associated with the eddy-shedding cycle, and along the Louisiana-Texas slope. Their genesis and role in the overall Gulf circulation patterns have not been well studied. A major cyclonic eddy seems to be resident in the southwestern Gulf, based on older data synthesis, but recent ‘evidence points towards a more complex, less homogeneous structure.

Aside from the winddriven surface layer, current regimes on the outer shelf and slope of the Gulf are the result of balance between the influence of open Gulf circulation features, such as the Loop Current and eddies, and the shelf circulation proper, which is dominated by long-term wind forcing. Offshore northern Mexico and south Texas, a western boundary current occurs, driven by both prevailing winds and the semipermanent anticyclonic eddy. A strong east-northeasterly current along the remaining Texas-Louisiana slope has been explained partly by the effects of the semipermanent cyclonic eddy and a partner cyclonic eddy, and partly by the mass balance requirements of eddy movement. Within the Loop Current fluctuation zone, offshore the States of Mississippi, Alabama, and Florida, the intrusion of the Loop front or the presence of minor detached eddies sets up short-term strong currents. Nearshore currents on the West Florida Shelf have been found to be primarily wind driven, “whereas long period circulation patterns in the area are due to a combination of wind and Loop Current forcing. When the Loop Current impinges onto the Florida shelf and slope, it has been observed that the current structure acts to upwell nutrient-rich water from deeper zones, a mechanism which may also occur as eddies move along the Louisiana-Texas slope. On the Texas shelf a confluence of northeasterly moving water from the south with southeasterly moving water from the Louisiana shelf has been recognized. The convergence zone appears to move seasonally, but the complete cycle has not been studied in detail. On the Mississippi-Alabama shelf the winter circulation is frequently a westward flow. During the summer, this flow is reduced and may reverse. On the West Florida Shelf the currents are predominantly south in all seasons, with the suggestions of a weak cyclonic gyre in the northeastern corner. Analysis of the data gathered from years 3 and 5 of the Gulf physical oceanography program will expand knowledge of Gulf-wide circulation patterns.

A major thrust of the Gulf of Mexico program has been the development of a suitable Gulf-wide circulation model for use in oil-spill risk analyses. In 1982, a circulation model was developed for use on the Southwest Florida Shelf (NECE,1982). In 1983, the MMS awarded a 4-year contract to Jaycor to work on and develop a circulation model encompassing the entire Gulf of Mexico. The aim of the modeling program was to progressively upgrade in modest increments the existing NORDA-Jaycor two layer model of the Gulf to a model with a horizontal resolution of 10 km and vertical resolution approaching 1-10 m in the mixed layer, 10 m at the thermocline, and 100 m in the deep water (Wallcraft, 1984, 1986). Unfortunately, the model, in its present configuration, treats the currents over the shelf as overly deep and energetic, due to the inherent limitations of the layered-model approach. The contractor's final year effort has been changed in order to provide some surface current information for the shelf areas, but at this time it is uncertain whether the final product will be useful as input to the OSRA model runs over the Gulf of Mexico shelf region. The model does, however, agree with field measurements taken over the deep basin and the slope areas.

Pacific Region

Historically, investigators studying the physical oceanography off the California coast have concentrated on examining the large-scale features, such as the California Current. More recent studies have begun to focus on the smaller-scale physical oceanographic features.

General features of the California Current system and synoptic seasonal features have been described by Reid et al. (1958), Jones (1971), Hickey (1979),Chelton(1981), and Huyer (1983). The California Current is a large-scale feature characterized by a broad, shallow, equatorward-flowing current whose maximum speeds are normally found about 200 to 500 km from the coast. This current is the eastern limb of the North Pacific Gyre, an ocean-wide circulation driven by the large-scale wind stress curl. The California Undercurrent, a poleward subsurface current, underlies the California Current over the slope portion of the region. The Undercurrent is believed to be caused by large-scale climatological forces, but does appear to vary seasonally in response to synoptic-scale fluctuations in the wind field (Chelton, 1984).

Off southern California, the California Current generally flows outside of the Santa Rosa-Cortes Ridge and associated islands, largely bypassing the Southern California Bight. Currents within the Southern California Bight itself are complicated by regional bottom topography. There is a northward, near-surface flow known as the Southern California Countercurrent that is composed of water spun off by the California Current and water from the south. Some of this Southern California Countercurrent continues northward past Point Conception to form the Davidson Current, but most of it turns southward and mixes with the California Current and may reenter the Southern California Bight. The result of the flow is a large countercurrent eddy, but near the coast there is often a flow to the southeast (Jackson, 1984). The velocities of the predominant currents within the Southern

California Bight vary markedly between seasons and on shorter scales. Surface drifter studies suggest considerable small-scale structure, including small eddies near some of the offshore islands (Schwartzlose and Reid, 1972). Coastal currents have been measured in the southern portion of the Bight and within Santa Monica Bay (Hendricks, 1977; Winant, 1980, 1983; Winant and Bratkovich, 1981). Currents in the Santa Barbara Channel and near Point Conception were recorded during part of the Organization of Persistent Upwelling Structures (OPUS) (Brink et al., 1984) and MMS-sponsored programs (Brink and Muench, 1986). These programs have also identified the importance of the spatial variability of the wind field off the California coast, particularly in the vicinity of large promontories.

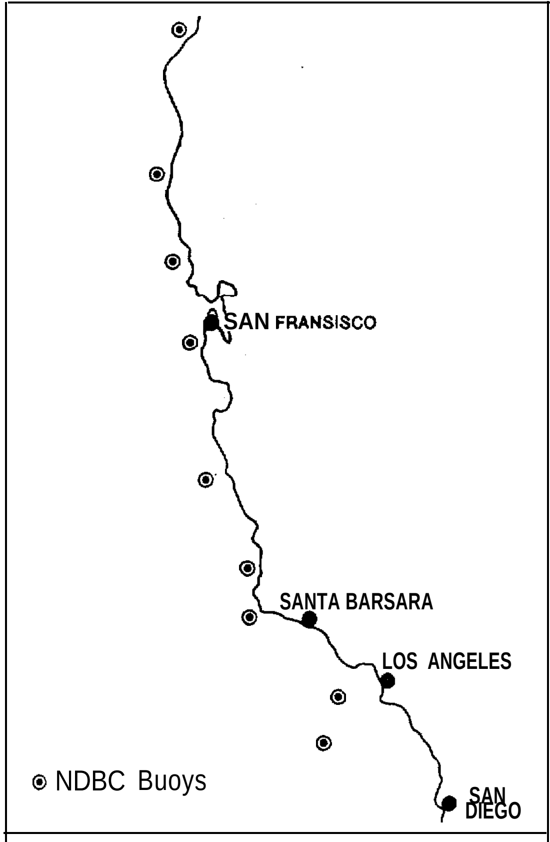

Figure 3-8 NDBC Meteorological Buoy Locations off the California Coast (Raytheon, 1988)

The southern California area is relatively rich in some types of physical oceanographic observations, mainly hydrographic data, as a result of years of research and monitoring by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) and studies funded by the National Science Foundation (NSF), such as OPUS. The CalCOFI program has been valuable because it is a long-term (35 years) data set, but analysis and interpretation are limited to monthly (and in some years, quarterly) measurements spaced 20-miles apart. The OPUS study provided a space intensive sampling regime near Point Conception, but data collection was limited to winter and spring months during 2 years. Most recently, Barth and Brink (1987) reported on the analysis of shipboard acoustic doppler profiler data obtained as a result of the OPUS program during spring 1983 near Points Conception and Arguello in order to characterize the flow fields in this area. They report that persistent westward flow out of the northern half of the Santa Barbara Channel and eastward flow into its southern half were observed regardless of the direction of the local wind stress. Currents continuous with the Santa Barbara Channel outflow were observed flowing to the northwest following the local isobaths before turning offshore west of Point Arguello during periods of weak or downwelling-favorable winds. Also, evidence for wind forcing of current fluctuations nearshore between the points and north of Point Arguello was found.

Early efforts by the MMS to synthesize physical oceanographic data included a summary of southern California offshore information by Maloney and Chan (1974) and later by Williams et al. (1981), who summarized physical data for the entire California shelf region. Since 1980, the MMS has supported a meteorological buoy network that provides continuous records of winds, waves, air and sea temperatures, and barometric pressure (Figure 3-8). Four buoys have been in place in the southern California area, and three are currently operating. In 1986, the MMS awarded a contract to MEC Systems to develop an on-line database of historical wave conditions along the U.S. West coast for in-house use by MMS analysts. This database is derived from the observations from the MMS-supported buoys as well as those collected through other means.

In terms of circulation modeling, a model of the entire California continental shelf region was developed with funding by the MMS to simulate daily-average current, temperature, and salinity fields for the year 1981 (Blumberg et al., 1984). Results of these calculations contain many recognizable features of the California Current system, including the progression of the Davidson Current northward along the coast during the spring transition. The model itself is a three-dimensional, timedependent General Circulation Model (GCM) in orthogonal curvilinear coordinates.

The MMS has supported a major physical oceanographic field and modeling program in the Santa Barbara Channel (Gunn et al., 1987) (Figure 3-9). This study, recently completed, involved the simultaneous development of a numerical circulation model and an observational database for a relatively restricted area south of Point Conception. A fine-resolution model grid was necessary to resolve flow features in the Santa Barbara Channel, and the field measurements were closely coordinated with the model for input and verification. In addition to these modeling efforts, Dynalysis of Princeton (with funding by the MMS) has begun work on a circulation model for the Southern California Bight.

The physical oceanography of central California area has not been studied extensively. In addition to the CalCOFI program, the major research efforts in the area have been funded by the NSF (Coastal Ocean Dynamics Experiment (CODE); SuperCode) and by the MMS (Central California Coastal Circulation Study(CCCCS) (Figure 3-10).

In general, circulation offshore the central California area is dominated by the California Current. Like the southern California area, countercurrents and undercurrents are evident near the coast. The strength and position of the currents vary on a variety of time scales and depend, in part, upon offshore wind patterns (Hickey, 1979; Chelton, 1984). Spring and summer are considered the upwelling season. Upwelling is often locally intense and may be associated with capes or other coastal features. Satellite imagery shows filaments, jets, and eddies, which are of major importance in transport across the shelf (Mooers and Robinson, 1984).

In 1981, 1982, and 1983, the NSF funded a series of field experiments known as CODE. This study, conducted in an area straddling the boundary between the Central and Northern California Planning Areas, was designed to identify and study the dynamic processes that govern the winddriven motion of water over the California continental shelf (Beardsley and Lentz, 1987). The site for the CODE experiments was a region of the continental shelf just north of San Francisco extending from Point Reyes north to Point Arena. The study consisted of two small-scale, densely instrumented field experiments involving moored instrument arrays, shipboard surveying, aircraft observations, surface drifters, and satellite imagery. To help separate the local wind-driven response in the CODE region from water motions generated in distant regions of the California coast, a more sparsely instrumented, long-term, large-scale experiment (SuperCODE), funded by NSF, was conducted between 35 and 48 degrees N. Results generally indicate that the flow over the shelf may be strongly influenced by eddies, distant and local wind forcing, and local topographic features such as Point Arena and Point Reyes. The flow over the slope does not appear to correlate well with the flow over the shelf or with the wind (Halliwell and Allen, 1987).

The MMS funded a large-scale physical oceanographic study off central California (Chelton et al., 1987) (Figure 3-10). The Central California Coastal Circulation Study provided important new information on the

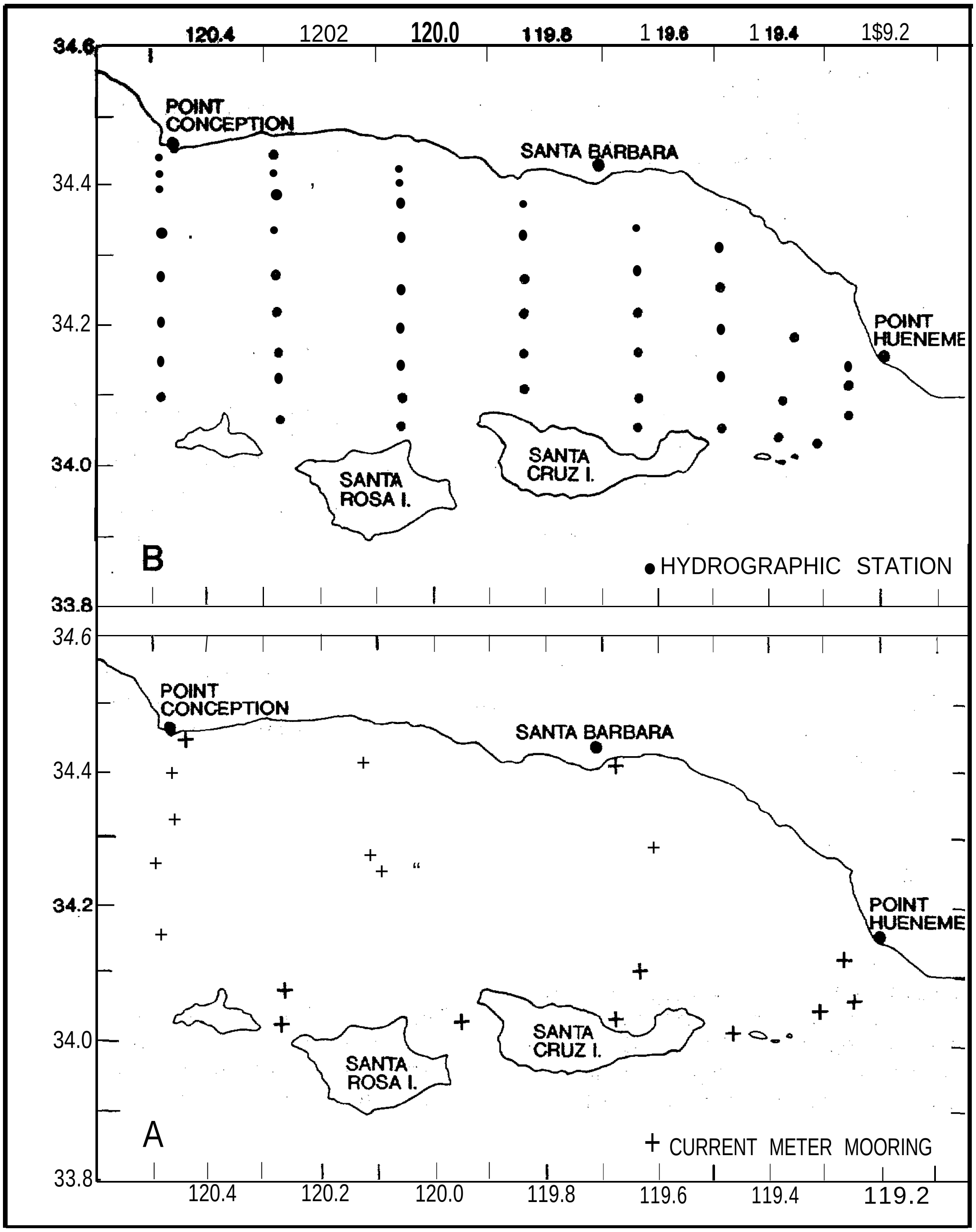

Figure 3-9 Basic Hydrographic Sampling Grid and Current Meter Mooring Station-Locations for the Main Program (Gunn et al., 1987)

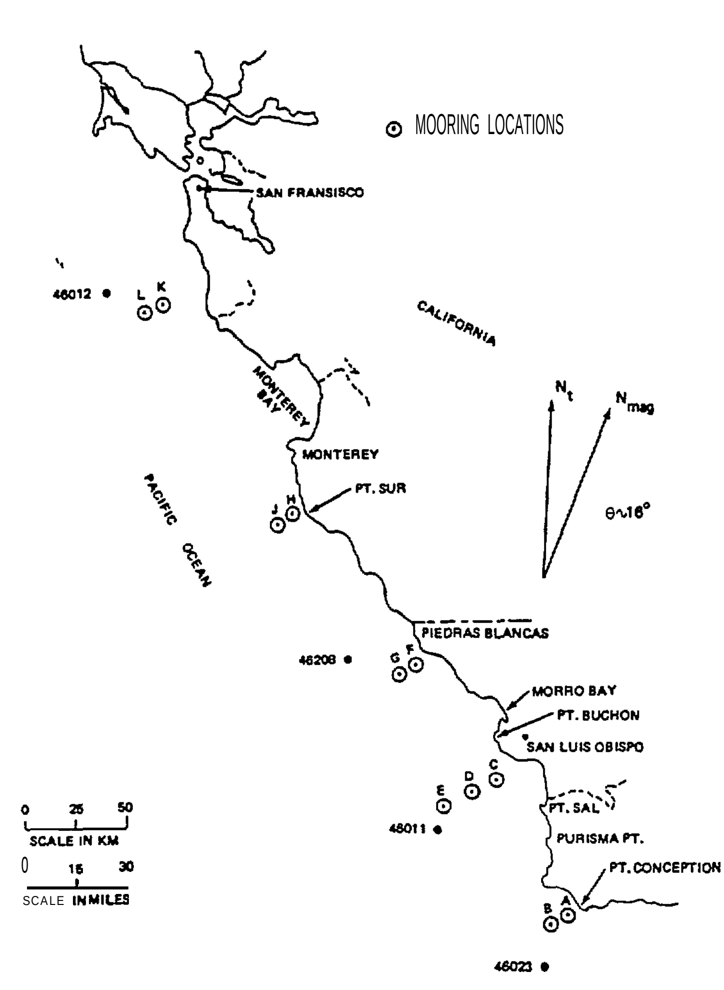

Figure 3-10 Location Map of the CCCCS Study Area (Raytheon, 1988)

modes of variability seen along the California continental shelf. Field data collection ended in July 1985 and a draft report has been submitted (Raytheon, 1988). Satellite imagery has revealed well defined patterns and processes associated with the coastal circulation system and confirmed to varying depths by hydrographic surveys. Most surprising is the predominant year-round poleward flow on the shelf and upper slope (Chelton et al., 1988). Additional results from the study suggest that variability in the alongshore component of current over the shelf is highly correlated with the local wind, everywhere except Point Conception.

Fluctuations of the currents over the slope were somewhat less correlated with local wind.

This program further documented a major mode of variability of currents over the California shelf referred to as the *relaxation event.* These currents are strong pulses of poleward flow on the shelf and slope that occur when the generally strong, upwelling-favorable (equatorward) winds weaken substantially or *relax.* The significance of these events to oil-spill movement was demonstrated in the movement of the spill resulting from the sinking of the tanker *Puerto Rican* in November of 1985.

In addition to these studies and to the circulation modeling study mentioned previously, the MMS, since 1980, has supported a meteorological buoy network off central California (Figure 3-8). MMS funds have also been used to analyze a small set of current meter observations off the Big Sur coast and to investigate coastal circulation in the central planning area north to San Francisco.

The northern California area has been the least studied area of the U.S. west coast in terms of physical oceanography. Little or no current meter data exist for the region north of Point Arena, and the physical oceanographic processes are not fully documented. In addition to some historical CalCOFI data, NSF funded the SuperCODE program, which included a single instrumented mooring off Eureka and the collection of hydrographic sections. Satellite imagery also exists. The CODE program

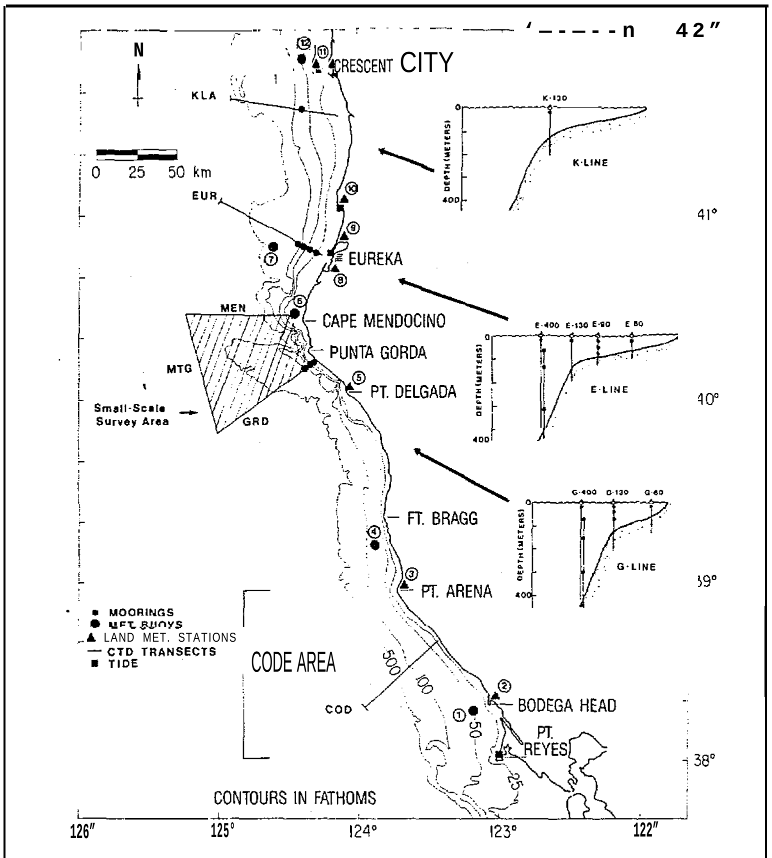

Figure 3-11 Pilot Mooring Locations for Northern California Circulation Study, March-August 1987 (Magnell, 1989)

provides some information for the coastal area off Point Arena.

Stabeno and Smith (1987) recently presented information on the deep-sea currents in the deep-sea basin far from the shelf south of the Mendocino Fracture Zone. Their results indicate that there is a significant southward mean flow only in the deep current meter records. The shallower instruments showed no presence of a mean California Current. In addition, the currents in the upper 500 m nearest the continental margin appear to be influenced by the presence of cold filaments originating near Point Arena. An intensive, 4-year study of the physical oceanography off northern California was recently begun by Magnell et al. (1989) with funding provided by the MMS (Figure 3-1 1). This study, along with the ONR-funded Coastal Transition Zone program (Brink and Hartwig, 1986), which is specifically aimed at illuminating the physical processes responsible for the formation and decay of the upwelling filaments found off the California coast, should significantly enhance information about the physical oceanography and pollutant transport mechanisms occurring on the continental margin off northern California.

The MMS awarded a contract in 1988 to provide the agency with a statistical characterization of the variability of both surface winds and currents along the U.S. west coast. Information will be applied to the problem of accurately specifying boundary conditions in numerical modeling or circulation.

Extensive physical oceanographic data are available for the area off Washington and Oregon. Field studies by the Universities of Washington and Oregon State, the National Marine Fisheries Service, and the Pacific Environmental Marine Laboratory have included current meters, drifters, bottom pressures, and collection of other hydrographic parameters. Hickey (1 979) has provided a comprehensive treatment of California Current characteristics, and Huyer (1983) presented a review of the knowledge about coastal upwelling in the California Current. The Coastal Upwelling Experiment of the early 1970's provided oceanographic data along the Oregon continental shelf; these data were subsequently evaluated and current variability described by Kundu and Allen (1976) and by Huyer et al. (1978). Hickey (1981) and Hsieh (1982) have contributed additional analyses of circulation within the region.

The MMS awarded a contract in 1987 to Envirosphere, Inc. to provide a description of all previous physical oceanographic studies in the area, as well as a comprehensive list of data reports. This study will help determine the adequacy of existing data for describing shelf-slope circulation and for circulation modeling purposes along the coast in the Washington and Oregon Planning Area. In addition, the MMS is currently providing funding for the placement of meteorological buoys off the Oregon and Washington coasts.

Alaska Region

Before the start of the Outer Continental Shelf Environmental Assessment Program (OCSEAP), a portion of the Alaskan ESP administered by NOAA, little was known regarding the circulation patterns within the various Alaska OCS lease sale planning areas. The MMS-funded studies have concentrated largely on investigations of currents, tides, sea-ice motion, and meteorological forcing in order to provide an increased database for use in oil-spill modeling. The studies have described the physical oceanography of the Gulf of Alaska, the Bering Sea, and the Beaufort Sea.

As with the other regions, potential oil spills and their transport have been, a major focus of the environmental assessments for Alaska OCS lease sales. However, unlike the other OCS lease sale regions, the presence of ice in the Alaskan waters plays an important role in how an oil spill would impact biological or other resources. Greenhorn and O'Mara, Inc. are presently under contract to provide the motion fields and a model that will allow MMS to calculate the oil-spill trajectories. This ambitious project will work towards completing a dynamically and thermodynamically coupled ice-ocean-atmosphere model.

As mentioned above, oil-spill analyses for the Alaska OCS Region must consider the presence of sea ice and the extreme weather conditions that play a role in the weathering and transport of oil. A model describing the physical and chemical changes in oil spilled in the presence of sea ice was developed by Payne et al. (1987a). This model was integrated with the open water oil-weathering model. Several studies have been completed or are ongoing that will improve the understanding of oil fate, including (1) a study evaluating the interaction of dispersed oil droplets with suspended particulate matter (Payne et al., 1987b); (2) a study evaluating the mechanisms of oil transported into the surf zone (Reed et al., 1988); (3) a study to develop a predictive oil-sediment-ice interaction model during ice freeze up and break up.

Since the first lease sale for the Alaska OCS was in the Gulf of Alaska, this region was the earliest focus for hydrology and meteorology. The Gulf of Alaska differs from other Alaska areas in that the continental shelf is narrow (10 to 150 km wide), and in that *blue water* oceanography has greater influence on the modeling of oil-spill transport. Many streams and glaciers along the Alaska and Canadian coastline provide fresh water to the nearshore regime; the result is a lower salinity offshore water. Major storms associated with low pressure systems are common in the Gulf of Alaska. Pressure systems in the continental interior give rise to katabatic winds blowing offshore. These winds can reach 150 km/h and extend 30 km offshore. Tidal amplitudes range from 11 m near Anchorage to 1 m along the Gulf of Alaska and Cook Inlet shorelines.

Study elements in the Gulf of Alaska oceanographic program have included literature searches, analysis of hydrographic data, descriptions and analysis of current meter data, drift buoy trajectories, satellite image interpretation, stream flow data, and CTD data. A coastal meteorology study emphasizing winds and the processes acting to modify them was conducted by Macklin (1986) who documents the wind field of the coastal zone of the southeastern Al aska

Peninsula. Earlier, Brewer et al. (1977) completed a climatic atlas for the Gulf of Alaska. Muench et al. (1982) examined the coastal oceanography of the northeastern Gulf of Alaska.

In general, water circulation in the Gulf of . . Alaska is dominated by the Alaska Current, ' which flows counterclockwise adjacent to the continental shelf break (200 m). The Alaska , Current has been described as a boundary between the warm, high-salinity water of the North Pacific and the cooler, low-salinity water of the continental shelf. The current has a surface layer of low salinity and a subsurface temperature maximum. Associated with this current is a permanent halocline at about a 150 m depth and a warm surface water. The Alaska Current is less than 75 km in width, with a mean speed of about 60 cm/s (Muench et al., 1982).

Field data have shown the presence of a coastal jet of water 20 to 30 km wide, with a typical baroclinic speed of 15 to 40 cm/see, along the coast of the Gulf of Alaska. Mean currents over the continental shelf are weak in comparison to the Alaska Current and the coastal jet. The shelf flow is longshore toward the west; however, there is also considerable cross-shelf flow (Muench et al., 1982).

Kayak Island separates the relatively wide continental shelf to the west from the narrower shelf to the east. The island is an important topographical feature that controls local circulation and also forces the coastal jet and the Alaska Current into close proximity. Directly west of Kayak Island is a permanent, clockwise eddy estimated speeds of 15 to 30 cm/sec. Low density water may be supplied to the eddy by the coastal jet.

Greisman (1985) studied the Western Gulf of Alaska tides and circulation. Tides in the Gulf of Alaska are predominantly mixed and semidiurnal. Tidal amplitudes vary considerably, typically, 3 to 5 m. However, tidal amplitudes as high as 10 m are attained at the head of Cook Inlet.

Initial studies in the Bering Sea region were oriented toward atmospheric measurements (mainly pressure, winds, and temperatures), hydrography, and ocean circulation. The MMS-funded studies have been greatly supplemented by the NSF-funded PROBES program, an interdisciplinary study designed to study the mechanisms and transfer rates of energy from primary producers to higher trophic levels in the shelf waters of the southeastern Bering Sea (McRoy et al., 1986).

The Bering Sea is an area of large meteorological variabilities, and atmospheric conditions can be extreme. Seasonal contrasts are also extreme; during winter, over half the sea surface is covered with ice, and during summer, sea surface temperatures may become almost temperate, exceeding 16 degrees C in the isolated eastern sector of Norton Sound.

The strong westward flow of the Gulf of Alaska stream provides most of the Bering Sea's water, which enters through deep passes between the Aleutian Islands. In the eastern part of the Bering Sea, three hydrographic fronts (roughly corresponding with the 50-, 100- and 250-m isobaths) separate the water overlying the shelf into distinguishable domains with distinctive seasonal oceanographic and stratigraphic 'properties. Shelf circulation is generally sluggish and characterized by eddies. Mean circulation is northward toward the Bering Strait. Coachman (1986) has identified the importance of tidal currents in terms of the overall circulation of the southeastern Bering Sea shelf. Tidal currents account for about 80 percent of the flow field on the outer shelf and 95 percent of the flow energy in the coastal domain. These currents undoubtedly account for the strong onshore-offshore flows noted by Coachman (1986).

Generally, the southern limit of the ice edge is from northern Bristol Bay to the vicinity of St. George-Island in "the Pribilofs. In extreme years, ice may extend as far south as the Aleutian Islands. Ice formation usually begins in mid-October in the northern Bering Sea

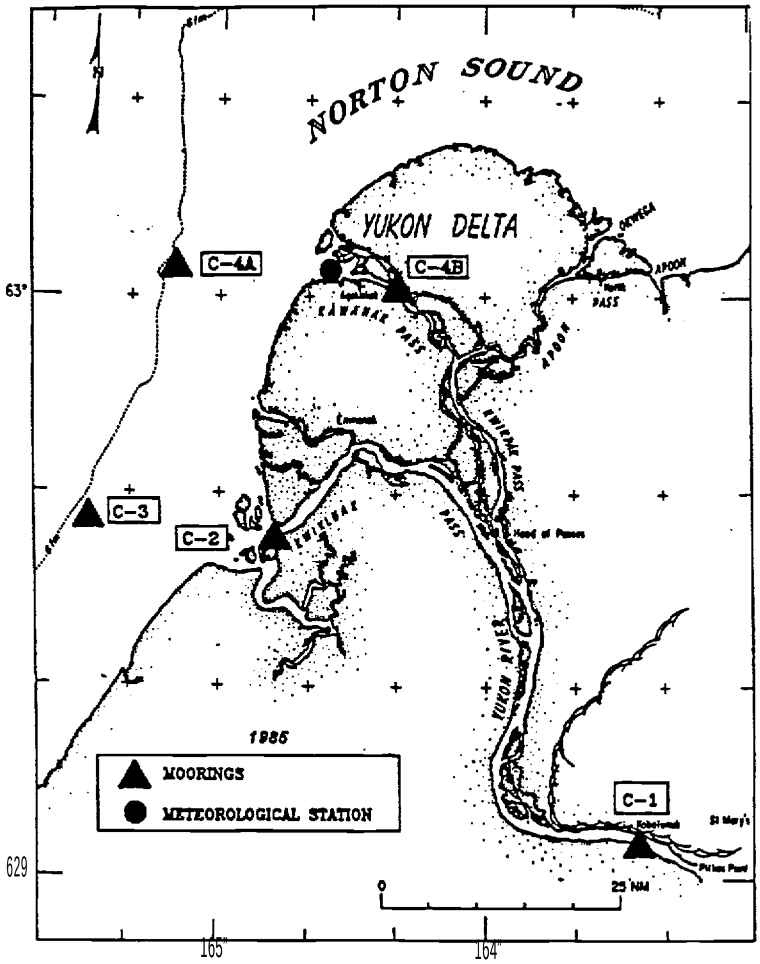

Figure 3-12 Location of Current/Water-Level Moorings and a Meteorological Station Deployed During the 1985 MMS Field Program in the Yukon Delta (EG&G, 1987)

and progresses southward. The retreat of the ice begins in April, and by mid-to late June, the Bering Sea" is generally ice free.

Major features of the Bering Sea such as the three zones or fronts in the Bristol Bay area, the circulation pattern of Norton Sound, and the seasonal trends of sea ice, are generally understood. Recent studies have focused on particular area needs, such as the circulation near the Yukon Delta (EG&G, 1987) (Figure 3-1 2) and wave heights in the central Bering Sea. A climatic atlas (Brewer et al., 1977) is being updated and will include the past 10 years of Bering Sea data.

Most meteorological and physical oceanographic studies conducted in the Arctic region have been in the nearshore zone and lagoons because of sea ice limitations on logistics (Mungall, 1978; Craig et al., 1984; Kozo, 1984; Hachmeister and Vinelli, 1985). Some current and tidal data were gathered farther out on the continental shelf for limited areas and time periods (Aagaard, 1981, 1984). Winds along the Arctic coast have been observed and modeled under the MMS studies program using a mesoscale data network (Kozo, 1984). Several oceanographic studies have been undertaken as part of the OCSEAP within nearshore areas of the Beaufort Sea, (e.g., in Simpson Lagoon, Stefansson Sound, and Beaufort Lagoon). Hachmeister and Vinelli (1985) studied the nearshore and coastal circulation in the northeastern Chukchi Sea.

Remote sensing imagery has been cataloged, and analyses of seasonal and geographic distributions of sea ice features have been performed for the past 10 years (Stringer, 1982; Stringer et al., 1982; Weeks et al., 1984). The MMS continues to aid the funding of the Arctic Ocean Buoy Program, which report daily positions, atmospheric pressure and temperature, and ice movement.

The physical oceanographic processes on the Beaufort Sea Continental Shelf are

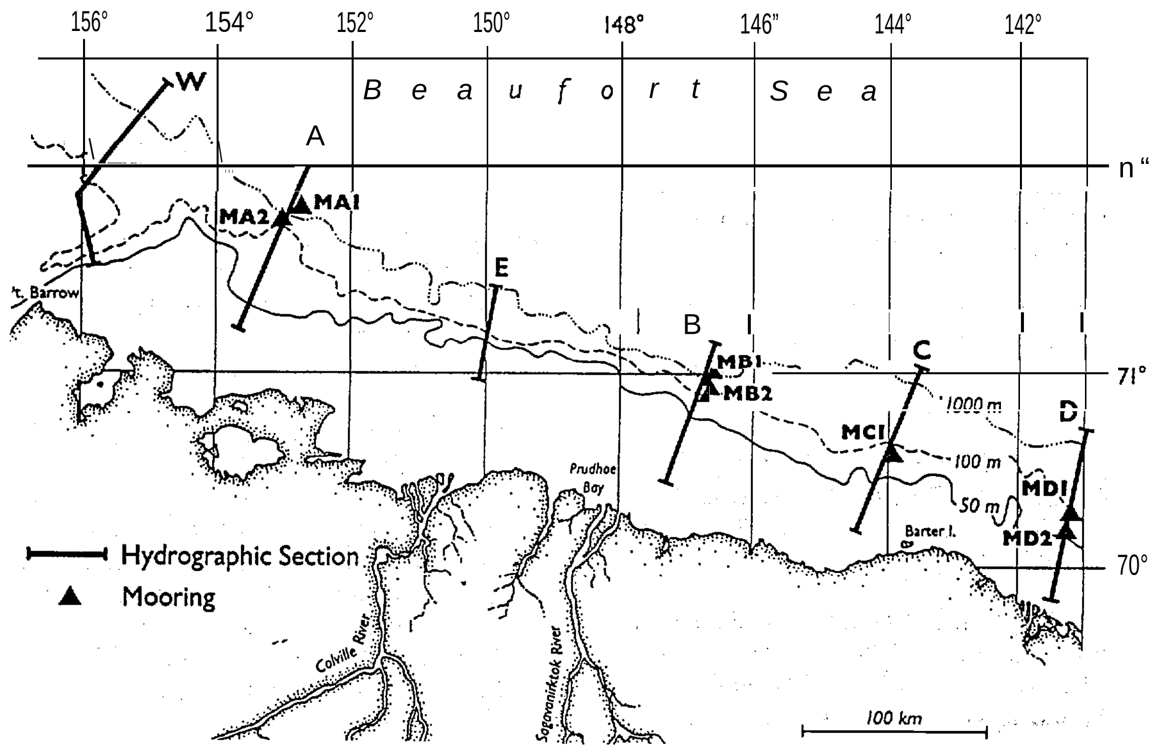

Figure 3-13 Location of October 1986 Hydrographic Sections and Moorings Recovered in 1987 for the Beaufort Sea Circulation Study (Aagaard et al., 1989)

influenced by the circulation patterns of the Arctic Ocean. Surface ocean currents beyond the shelf edge flow eastward between Mackenzie Bay and Point Barrow under the influence of the clockwise Beaufort Gyre. An eastward current along the 50-m isobath has been observed. Nearshore, local summer winds may reverse the general winddriven westward drift and set the current towards the east. The currents influence the extent of ice-free open water in summer. Storms are frequent during summer and occasionally generate storm surges and wave heights that have a large destructive potential.

The Chukchi Sea circulation is influenced by ocean currents flowing predominantly northward from the Bering Sea into the Arctic Ocean. At times, a reversal of flow in the Bering Strait occurs causing a southerly flow of ice and water, but the volume of Arctic water outflow is low. The northward coastal currents, together with a westward drift along the southern margin of the Arctic ice pack, combine to establish a broad counterclockwise circulation in the Chukchi Sea. Wave heights and storm surges are more severe hazards in the Chukchi Sea than in the Beaufort Sea, primarily due to the longer reaches of open water in summer and fall.

The MMS has recently completed a large-scale field program in the Beaufort Sea (Aagaard, 1989). Titled the *Beaufort Sea Mesoscale Circulation Study*, this study calls for an additional study of the circulation of the Beaufort Sea shelf (Figure 3-13). The latter is running concurrently with oceanographic investigations of the northern Bering, Chukchi, and Canadian Beaufort Seas sponsored by other U.S. and Canadian organizations. It will allow for a synoptic scale analysis of continental shelf circulation from

Norton Sound along the Alaskan coast north and eastward into the Canadian Beaufort Sea.

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4. Remote Sensing

General Description

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kiefer, 1979). Using this definition, one could include many topics in this section such as: ship or airplane radio tracking of marine animals through tags, monitoring of vocalizations and underwater sounds, airborne spectrometers and radiometers, side-scan sonar and related systems, and aerial photography. These and other techniques are used in MMS sponsored field research and often represent the standard method for obtaining oceanographic research data. Studies of protected species include many data using aerial photography, sonobuoys, and radio tagging. Sonar was used extensively in studies of submarine canyons, radiometer was used for nearly all physical oceanographic field studies, and, to a lesser extent, spectrometer data were used. This section will not elaborate on all these remote sensing applications, but limit its scope to one major and rapidly developing field, satellite (or spacecraft) remote sensing.

Satellite data, as presently utilized in the ESP studies, consists of two basic types: satellite imagery and satellite tracking. Satellite imagery provides surface pictures of large geographic areas of the ocean and coastline of interest to MMS. In addition to basic Landstat images, used to determine sea and coastal ice coverage, wetland coverage, and other surface features, NOAA satellites provide Advanced Very High Resolution Radiometer (AVHRR) images, used to map surface sea temperature (SST). NASA NIMBUS satellites provide Coastal Zone Color Scanner (CZCS) images, used to map ocean color. From these images chlorophyll concentration and water clarity can be estimated.

Satellite tracking utilizes ARGOS receivers on board NOAA's polar orbiting environmental satellites (POES) and surface transmitters called platform transmitter terminals (PTT's). The ARGOS system was initially designed to track high altitude balloons and meteorological oceanographic buoys. MMS has often utilized these satellite-tracked buoys in physical oceanographic studies and is involved in attempts to develop satellite-linked tags for whales.

The following review highlights types of ESP studies that use satellite data/technology, The review does not identify every MMS-sponsored study that uses satellite data.

Regional Data Availability

Atlantic Region

Satellite imagery has provided significant data for Atlantic physical oceanographic studies. The five-year South Atlantic Physical Oceanographic Study (SAPOS) routinely utilized satellite- derived SST images to study Gulf Stream dynamics (Figure 4-1). Further north, similar data were used during a three-year Mid-Atlantic Slope and Rise Study (MASAR)(SAIC, 1986). More recently, in the Frontal Eddy Dynamics (FRED) Study offshore North Carolina, SST data from the FOES was used to direct ship movements to sampling stations relative to specific G ulf Stream features (FRED Group, 1989). These studies also used the ARGOS system to track drifter buoys to better understand Gulf Stream frontal dynamics.

Further effort has been devoted to evaluate satellite-tracked drifters for use in simulating the movement of spilled crude oil. The primary use of this technique for MMS would be for assessing the skill of the OSRA model (see Physical Oceanography chapter). Seven different buoy designs were selected for detailed evaluation (Figure *4-2).* The Draper LCD and Ferranti Argosphere models were

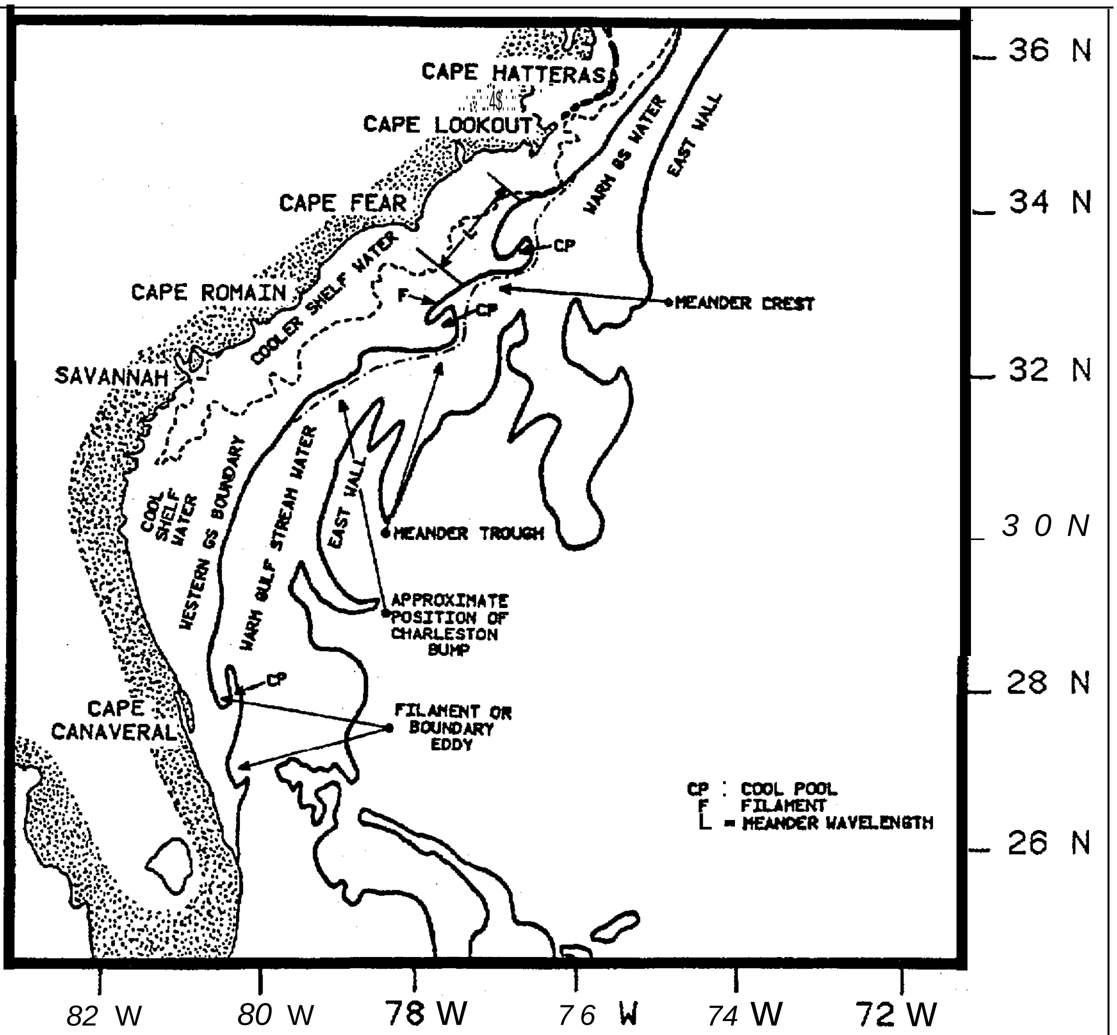

Figure 4-1. Major Gulf Stream Features Outlined from a AVHRR Satellite Image (SAI, 1984)

recommended for further field testing (ASA, 1988).

Gulf of Mexico

Physical Oceanographic studies sponsored by MMS in the Gulf of Mexico have used remote sensing data extensively. Since 1983, MMS-funded satellite-tracked ARGOS drifters have provided data to document movements of Loop Current eddies and related deeper Gulf and slope circulation (Mitchell, 1988) (Figure 4-3). NOAA satellites have provided AVHRR data to map surface sea temperatures and the Navy GEOSTAT satellites have provided sea surface height data (SAIC, 1989).

The Earth Resources Data Analysis System (ERDAS) has been used to study and evaluate Louisiana coastal wetlands (LDNR, 1989). Proposed studies may utilize ARGOS tags to track sea turtles.

Pacific Region

Remote sensing has been an integral part of the major field programs conducted in the Pacific Region, particularly in the physical oceanography programs(*e.g.* Chelton et al.,

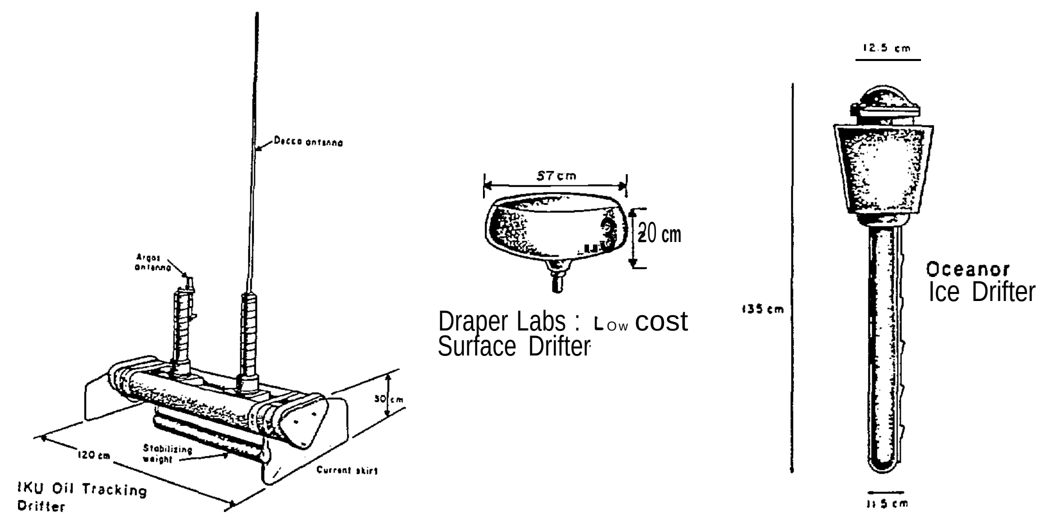

Figure 4-2. Examples of Surface Drifters (ASA, 1988)

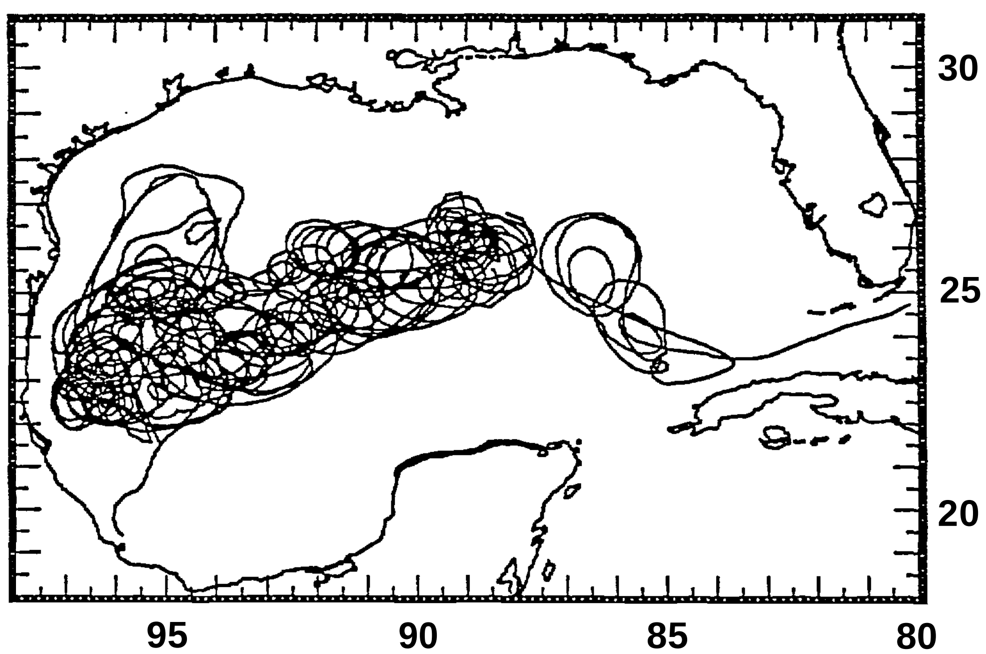

Figure 4-3. Drifter Trajectories of the Gulf of Mexico **Anticyclones** (Mitchell, 1988)

1987). Satellite imagery provides an extremely useful tool to help define the extremely complicated flow patterns off the U. S. West Coast. In addition to use in physical oceanographic studies, a significant effort was made in the California Seabird Ecology Study to determine whether satellite images were useful in the characterization of seabird foraging habitats in Central California (SAIC, 1987). AVHRR and CZCS images were analyzed quantitatively to determine location, persistence and intensity of coastal upwellings. Feeding locations of Cassin's auklets and murres observed from surface vessels were compared with satellite image analyses. Based on this initial study, both birds appeared to have preferred optical depth/temperature gradient ranges for foraging areas.

Alaska Region

An archive of remotely-sensed data in Alaska is funded by NOAA OCSEAP (Stringer, 1988) mainly to provide sea ice coverage for other research efforts (whale migration and seal studies, transportation and platform siting). Currently, the archives, located at the University of Alaska, Fairbanks, hold both a complete set of relevant Landsat imagery and a set of NOAA's AVHRR imagery. Data have been acquired and archived since 1975. Satellites with Synthetic Aperture Radar (SAR) are scheduled for operation in 1989 or later. This will enable images of sea ice to be obtained through cloud cover, a major problem when using Landsat and AVHRR in this region.

Studies on the importance of the eastern Alaskan Beaufort Sea as a feeding area for bowhead whales involved an integrated study of physical and biological parameters. Satellite data were used to determine large scale water mass distributions and upwelling areas. Aerial radiometer and spectrometer transects provided additional finer scale data. All were correlated to surface CTD station data and plankton samples (Richardson, 1987).

All Regions

Satellitederived SST data have been a basic component of physical oceanography studies in all regions. Remotely-sensed data have also been used to delineate suspended sediment plumes, verify the presence of specific ocean circulation features and identify areas of high plant pigment concentration in the sea. SST data combined with other data sets (wind, current meter, drift buoy, hydrography) are used to describe upper ocean variability over a wide range of scales. Satellite data are also being more effectively integrated into ecological studies.

Satellite tracking in correlation with image data has potential for use in studies of marine mammals (Fairfield, 1989) and other biological research. MMS is sponsoring development of satellite-linked methods to track large cetaceans (Mate, 1987). A variety of tag designs have been developed, all using the ARGOS system (Figure 4-4A) to provide location data and other information such as dive times, water temperature etc. (see Mate, 1987 for details). In the case of a captured pilot whale, which allowed a direct attachment of the tag, at-sea performance of the Telonics PTT was outstanding. The tagged whale was tracked for 95 days over a distance of about 7,5oO km (Figure 4-4B). Significant problems remain in designing an effective means to attach and retain a tag on free-swimming cetaceans. Efforts to tag right whales, using newer tag designs delivered by a crossbow, will be initiated in New England during the summer of 1990.

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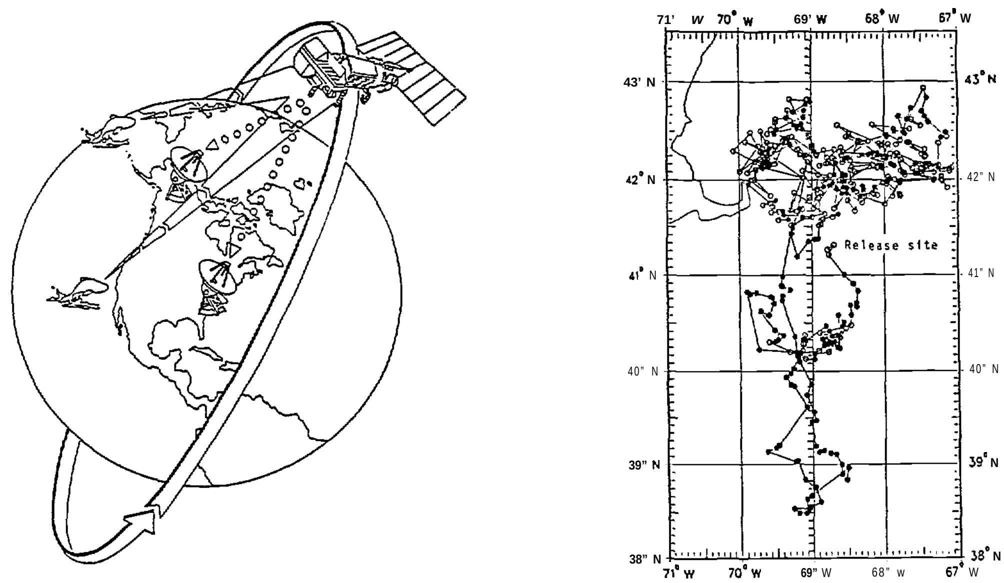

Figure 4-4. Satellite-Linked Whale Tagging. A. Representation of a NOAA TIROS-N Satellite receiving signals from two tagged whales and relaying information to Wallops Island, VA and Gilmore Creek, AK ground stations. B. Satellite determined locations of tagged pilot whale (Mate, 1987)

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5. Air Quality

General Description

The primary objective of the air quality studies funded by the MMS is to gather information necessary to assess the potential impacts that offshore oil and gas exploration and development may have on the air quality of the various OCS lease areas. The MMS also is funding studies to improve the accuracy of models used to predict impacts on air quality from existing and proposed OCS oil and gas activities. In addition to their use in standard MMS decision documents, air quality studies are also used in the DOI regulatory process for OCS air quality permits that MMS requires for OCS oil and gas development activities.

The general strategy for the MMS air quality program is the collection of data needed for state-of-the-art predictive models. Emphasis is placed on accurate field measurements on which to base model input and by which model predictions may be verified. The first phase of the air quality study process involves the characterization of atmospheric dispersion and photochemical processes in coastal environments through the collection and analysis of meteorological and air quality data. The second phase uses the results of the field studies to validate existing air quality models and then modifies the models to improve their applicability and accuracy. Finally, these improved models are used to predict air quality impacts from various types of offshore oil and gas activities. To date, this strategy has only been applied extensively in the Pacific Region. The MMS is currently having several existing air quality models modified and installed on agency computers. These include the Offshore Coastal Dispersion (OCD) model (inert pollutants) and the PARIS and AIRSHED (rural/OCS version) models (photochemical pollutants). These models may be used, as needed, for air quality assessments in all OCS planning areas, provided that sufficient data exist to run the models.

Regional Data Availability

Atlantic Region

To date, air quality has not been of major concern in the Atlantic Region, due to the extremely low levels of projected offshore oil and gas activity within the various planning areas and the distance from shore that activity would likely occur. Therefore, no studies specific to air quality have been conducted or are planned in the region. Some of the meteorological information collected during the various physical oceanographic studies conducted on the Atlantic OCS could be adapted for air quality impact evaluation, should the need arise. Considerable data are available in this region, independent of MMS-funded studies.

Gulf of Mexico Region

Considerable OCS activities occur in this region, and air quality is a concern. Nevertheless, data are limited for detailed (e.g., ozone) evaluations, but available meteorological or emissions data can be used for screening and modeling analyses for inert pollutants.

In general, areas of intense offshore activity are separated from typical coastal hamlets by broad expanses of shallow bays and nearly uninhabited marshlands and swamps. The present monitoring network established by the States, however, is not sufficient to fully evaluate the effects of offshore activity on coastal ozone concentrations, and thus the actual impact of activity on air quality in the region is largely unknown.

The Gulf of Mexico Region has recently completed a review of air quality modeling methodologies, anticipating the need for a study of the ozone formation due to OCS emissions. The MMS has been informed that the State of Louisiana will soon formally request designation of some or all of the coastal parishes or coastal areas as "attainment" areas.

Pacific Region

The Pacific Region has been the most active OCS area in terms of air quality studies. There are basicall y four different types of' information sources: offshore meteorological buoys, atmospheric tracer experiments, detailed field measurement programs to' characterize meteorology and air chemistry, and numerical modeling.

The MMS has contributed to the deployment of meteorological buoys in all of the Pacific OCS planning areas (Figure 4-8). The buoys monitor wind, air temperature, and sea surface temperature and, as of 1988, surface atmospheric pressure, wave spectra, humidity, and solar radiation. These data are recorded continuously and relayed by satellite to the National Data Buoy Center, where the data are stored on magnetic tape. Some of the buoys have also been equipped with sensors to monitor solar radiation and relative humidity. The information is primarily being used for modeling of inert pollutants, but it also plays an important role in photochemical modeling by describing the offshore transport and dispersion conditions. Data have been collected offshore California by these buoys since 1980 and provide the only long-term time series of accurate offshore wind information available for most of the coast.

The MMS has conducted two tracer studies in the vicinity of Oxnard and Pismo Beach. The purpose of these studies was to obtain information' on overwater atmospheric dispersion. Results of these studies were presented by Zannetti et al.(1981) and Dabberdt et al. (1984). The data were used in the development and evaluation of the Offshore Coastal Dispersion (OCD) model. The American Petroleum Institute sponsored a tracer study near Santa Barbara in September 1985 to evaluate inert models as applied in coastal areas with complex terrain.

Several large-scale field studies have been conducted, primarily in the Santa Barbara Channel area. The California Air Resources Board conducted a tracer study in the Santa Barbara Channel in September. 1980. The main objective was to trace the movement of air during periods of relatively high ozone concentrations onshore. The results are discussed by Reible and Shair (1981) and Smith et al. (1983). The Western Oil and Gas Association funded a field study in 1983 to study transport of ozone from the Los Angeles Basin into Ventura County.

The"most comprehensive field study was conducted as part of the South Central Coast Cooperative Aerometric Monitoring Program (SCCCAMP) in September 1985. This study consisted of a detailed aerometric monitoring program conducted in Santa Barbara and Ventura Counties and adjacent offshore areas. The objective was to obtain detailed data on meteorology and air chemistry during a number of characteristic ozone episodes so that photochemical modeling techniques can be thoroughly evaluated. The field program design is described by Dabberdt et al., (1985). The MMS funded contracts for the SCCCAMP archival and data analysis, which has been completed. The MMS is also funding contracts to evaluate the PARIS or AIRSHED model using the SCCCAMP data. Santa Barbara County APCD is using some of the SCCCAMP data in a photochemical modeling study for their Air Quality Attainment Plan update.

In addition, the MMS will be contracting for a study under which the gaseous fugitive hydrocarbon emissions from offshore production equipment will be measured. These data will replace the estimated data currently used in the various air quality models.

The MMS has conducted a number of modeling studies for specific OCS lease sales (lease sales No. 48,53,68,73,80, and 91). Results are presented by Environmental Resources Group (ERG, 1980; 1981), Form and Substance, Inc. (FSI, 1983a, b), AeroVironment (1977), and Jacobs Engineering (1987). A handbook was prepared for estimating air quality impacts from OCS activities off California (FSI, 1983c). The MMS also contributed funding for the Joint Interagency Modeling Study (JIMS). The objective was to assess the effects of existing and future OCS development on ozone levels in Santa Barbara and Ventura Counties. This effort was completed in early 1986.

Alaska Region

There is little or no existing air quality data relative to regulated pollutants for the Alaska OCS planning areas. The few data that do exist come from operations in State waters (Cook Inlet) or from onshore operations (Prudhoe Bay). Industry monitored some air emissions at Prudhoe Bay in 1980 and again at Prudhoe Bay and the adjacent Kuparuk oil field in 1986 and 1987. The specifics of these efforts are kept proprietary by the industry. In order to project air quality, it is now necessary to estimate emissions based upon calculations and monitoring in other areas.

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6. Water Quality

General Description

The general strategy of the MMS water quality studies is to provide supportive research on the fate or behavior of OCS-related pollutants which can be used in conjunction with effects and monitoring efforts to assess impacts. (These are described in greater detail in Ecological Monitoring and Coastal Impacts sections of this teport.) In the early years of the ESP, large-scale multidisciplinary studies designed to characterize the nature, abundance and diversity of the seafloor and overlying waters, and concentrations of certain trace metals and hydrocarbons in the water, sediments, and biota were conducted in all of the OCS areas. These baseline or benchmark studies, which emphasized the chemical characterization of water, sediments and biota, were intended to establish a statistical y significant baseline against which future incremental changes could be measured and associated with the appropriate impact producing agent. During these years, thousands of samples were collected and analyzed for hydrocarbons and a variety of heavy metals. After a program reevaluation, which took place in 1978, the emphasis on chemical indices for assessment of impacts was discarded and replaced with studies that were more directly linked to immediate decision needs. The current program emphasis is towards developing a better understanding of the natural functioning of the ecosystem.

A major element of water quality related studies is the development or modification and use of models that predict the physical and chemical fate of discharged drilling muds, produced waters and spilled oil. Components are under development that describe the interaction of particulate matter with oil droplets and the transport of oiled particulate into the surf zone. Water column measurements have been discontinued for the most part with the cancellation of the baseline programs. They will be continued in conjunction with development monitoring and selected fates and effects studies as the need arises.

Regional Data Availability

The following discussions present information that has been collected throughout the ESP dealing with chemical characterization of the water column and the fate of OCS discharges in the water column. A section on generic information is presented first and followed by the regional discussions.

Generic Information

Drilling mud discharges have been characterized (Ray and Meek 1980; Meek and Ray, 1980; Ayers et al., 1980a,b; Houghton et al. 1980) as separating into an upper plume that contains the liquid fraction and some fine grained silts and clays and a lower plume that contains the majority of the cuttings and drill fluid mass. The lower plume sinks rapidly to the bottom whereas the upper plume spreads laterally and vertically and is transported in the direction of the net current after reaching a depth of neutral density. (The interested reader is referred to *Drilling Discharges in the Marine Environment* (NRC, 1983) and *Drilling Wastes* (Engelhart et al, 1989) for a detailed presentation on the use, fates and effects of drilling muds and their discharges in the marine environment.) Because field studies have consistently demonstrated rapid physical dispersion of the upper drilling mud plume, the NRC (1983) concluded that long-term impacts associated with upper plume materials are insignificant. As with historical baseline studies, current monitoring studies measure particulate barium as a tracer of the drilling fl uid discharge (as opposed to other trace metals) because it usually exceeds other trace metal concentrations by a factor of 100-1000, or more. (its measurement is not at all based on its toxicity potential. Barium is virtually insoluble in seawater-50 ug/l.)

The composition of produced water is as complex and variable as that of petroleum, Neff (1981) presented a summary description of produced water composition based on studies performed by others over the last 18 years. Metals that may be present in produced water at concentrations significantly higher than normally found in seawater include barium, beryllium, cadmium, chromium, copper, iron, lead, nickel, silver and zinc. Soluble nonvolatile organic compounds that are not removed by conventional treatment methods may reach concentrations as high as 500-600 mg/l (Lysyj 1982 as cited in Neff et al., 1987a). Total aromatic hydrocarbons measured in a Buccaneer platform produced water discharge ranged from 12-16 ppm (Middle ditch, 1981; Sauer, 1981; as cited in Neff et al., 1987a). Of the 7500-11,500 metric" tons petroleum hydrocarbons annually discharged into the sea associated with produced waters, about 1/4 will be discharged into U.S. waters (NRC 1985). Payne eta/. (1987) summarized available knowledge regarding the fate of discharged produced waters noting that significant dilution occurs within the immediate vicinity of the discharge point. Also, metals and hydrocarbons are unlikely to achieve high concentrations outside the initial mixing zone because of various removal processes including particulate scavenging, advection, and evaporation of lower molecular weight aliphatic hydrocarbons.

Atlantic Region

Results of baseline studies in the Atlantic Region (ERCO, 1978; ViMS, 1977; MMS, 1979; Texas Instruments, 1979) indicate a relatively pristine environment in terms of petroleum hydrocarbons and heavy metals found in the water column. An earlier survey by Myers and Gunnerson (1976) reported surface and near surface hydrocarbon concentrations in the low ppb range along tanker routes of the Atlantic coast.

To assess the potential for impacts on canyon head communities, the MMS funded Lament-Doherty Geological Observatory to study the biology and associated physical and chemical characteristics in selected canyons of the mid- and north- Atlantic OCS areas. Lament-Doherty (1983) confirmed that concentrated fine sediments and dissolved and particulate nutrients, such as particulate organic carbon (POC), flow off the shelf in the main axes of the canyons. Increased densities of filter feeders in canyons were also observed (Hecker et al., 1983), and their presence tends to support the hypotheses that the canyons are conduits for particulate (including POC) from the continental slope to the abyss.

Several papers have summarized potential pollutant inputs to the North Atlantic area. Presence of several pol ynuclear aromatic hydrocarbons (PAH) in concentrations from 0.0014.1 ppm dry wt. in sediments suggested aeolian transport and deposition of particulate PAHs with potential sources being the incomplete pyrolysis of fossil fuels, and/or long range transport of hydrocarbons associated with sewage sludge or dredged material disposal operations (Boehm and Barrington, 1984). Localized and diffuse sources of anthropogenic hydrocarbons to Georges Bank include inputs of weathered petroleum from tanker ballast washings (Boehm et. al., 1979), dredged material disposal (Boehm and Quinn, 1978), oil tanker spills (Boehm et al., 1979), aeolian transport of pyrolytic materials (Hauser and Patti son, 1972; Boehm and Barrington, 1984), and riverine discharges (VanMeet and Quinn, 1977). Inputs of petrogenic hydrocarbons to various areas of Georges Bank maybe episodic and acute, such as oil spills or tanker ballast discharges, however, most inputs occur on a more continual basis. Clearly, several anthropogenic sources contributed petrogenic hydrocarbons to Georges Bank prior to initiation of OCS oil and gas activities (Boehm et al., 1979).

PAH's are ubiquitous in recent marine sediments (Youngblood and Blumer, 1975) and except in localized situations, such as petroleum hydrocarbon input, the predominant source of PAHs in sedimentary environments is from combustion processes (Hites et al., 1977; Laflamme and Hites, 1978). This has also been established in the Gulf of Maine region (Windsor and Hites, 1979; Boehm and Barrington, 1984). Based on the observed PAH distribution, Windsor and Hites (1979) suggested that two transport mechanisms were at work 1) a long range airborne transport of very fine urban air particulate, and 2) a resuspension and transport of contaminated marine sediments found near urban areas. , Boehm and Barrington (1984) provided evidence for coastal runoff and sediment depositional patterns being largely responsible for the observed PAH distributions on Georges Bank. Localized inputs of PAH's due to oil and gas industry drilling activities are a potential additional source.

With the initiation of exploratory drilling on Georges Bank, the MMS initiated a monitoring program to assess potential impacts. The results of the Georges Bank Monitoring Program indicated that bottom currents were sufficiently strong to disperse muds and cuttings rapidly from the well site. Sea bottom photography, carried out after the completion of drilling, did not reveal any evidence of accumulated cuttings (Maciolek-Blake et al., 1985). Bottom sediments collected adjacent to drilling rigs on Georges Bank were analyzed for accumulations of 12 trace metals. Only barium, which is present in barite (major component of drilling mud), was found to increase in concentration during drilling eight exploratory wells (Bothner et al., 1985). According to Payne et al. (1986), the fate of the petrogenic hydrocarbons discharged into the marine environment during drilling could not be determined during the monitoring program. However, it is likely that hydrocarbons associated with the small clay particles and barite present in drilling muds were rapidly resuspended and transported from the well site. Bothner *et a/.* (1985), concluded that the energy threshold required to resuspend fine grained sediment particles from the ocean bottom was frequently exceeded at the rig site. Therefore, particulate trace metals and hydrocarbons associated with the operational discharges from the drilling rig were probably dispersed to other areas of Georges Bank by the prevailing currents, gyres, and slope water intrusions. No accumulation of petrogenic hydrocarbons associated with discharged materials was observed at the Block312 well site during the Georges Bank Monitoring Program.

Butman et al. (1982a) presented data indicating that most fine grained materials would ultimately (time scale of less than a year) be transported off Georges Bank to the southwest. Preliminary information from the Lydonia Canyon Dynamics Experiment (Butman *et al.,* 1982b) showed that fine grained sediments, some derived from the sheIf, are accumulating in the head of Lydonia Canyon which is located about three miles from the Block 312 well site. Bothner et al. (1985) also reported that the barium concentration showed small increases in the fine grained sediment at the heads of both Lydonia and Oceanographer Canyons.

Localized impacts from discharged drilling muds are strongly dependent upon currents which influence the dispersal rate and the amount of material that accumulates at a drill site (Houghton et al., 1980). In addition to the physical smothering effects, these materials may contribute to el evated concentrations of trace metals (Crippen et al., 1980) and hydrocarbons, particular y PAHs in bottom sediments around drilling rigs. Drilling discharges behave in qualitatively predictable ways when released at or near the surface. Cuttings and some associated drilling fluids settle rapidly to the seafloor. The bulk of drill fluids will behave in two general ways, depending on water density. Studies summarized by the NRC (NRC, 1983) show that roughly 10 percent of the very fine materials will disperse near the surface as the characteristic plume of a drilling operation. [n water less than 50 meters deep, most of the remainder of drilling fluids settle to the seabed within a couple of hundred meters of the drill site. In deeper waters, such as found over

North Atlantic canyons, dispersion of muds in the water column and attainment of neutral buoyancy prevent most of the mud from settling out immediately on the seafloor. Forces of dispersion and current transport continue to act and materials tend to settle out, but over greater distances and time spans.

Whether a depositional environment exists in a specific canyon is a function of many factors which are not well understood at this time. Data from MMS studies indicate that fine grained materials are accumulating at the head and along the axis of Lydonia Canyon but not Oceanographer Canyon. Research by others indicates that there is only limited deposition if any, in Hydrographer Canyon.

During the Georges Bank Monitoring Program (Bothner et al. 1985), a sediment trap located in Lydonia Canyon was examined for barium content from drilling discharges from Sale 42 leases. Some accumulation was found in sediment traps deployed at the head of Lydonia Canyon, which is located about 10 miles south southeast of one drilling operation (Block 312) and 25 miles southwest of another (Block 410). The concentration of barium was found to be enhanced in this same location during drilling of Block 357 and Block 273, both of which are near Lydonia Canyon. Daily net average current velocities in Lydonia and Oceanographer Canyons range from 2-5 cm/see, and peak current velocities approach 30 cm/sec. Since canyons are typically 20 kilometers long, this translates to a flushing time for the shallower portions of the canyon on the order of 5-10 days. The significance of this is that residence time in the canyon (for water-borne suspended particulate matter) and exposure times for potentially affected biological resources to drilling discharged contaminants is limited.

Gulf of Mexico Region

The first baseline study carried out in the OCS program was in the Mississippi-Alabama-Florida (MAFLA) offshore area. Water samples were collected at 65 stations in 1975 using 30 liter Niskin bottles. The samples were analyzed for dissolved oxygen (DO), particulate and dissolved organic carbon (POC and DOC), dissolved low and high molecular weight hydrocarbons, particulate hydrocarbons, suspended particulate matter (SPM), trace metals, phytoplankton, chlorophyll. No petrogenic compounds were found in the water column, but the Mississippi-Alabama shelf did show evidence of hydrocarbon contamination from the Mississippi River (SUSIO, 1977).

Four cruises took place during 1977-78 during which water samples were. collected as part of the Eastern Gulf of Mexico Baseline Program. Samples were collected as in the MAFLA program in depths ranging from 10 to 200 meters. In this area, the water column showed only biogenic sources of hydrocarbons. Water column trace metal pollution was not detected for any station. (MAFLA, 1979).

Field sampling in the South Texas OCS (STOCS) Baseline study began in January 1976. Thirty liter niskin bottles were used to collect water samples in depths ranging from 20 to 183 meters. (UTMSI, 1977) The STOCS area was found to be generally pristine with respect to hydrocarbon and trace metal occurrences in the water column (UTMSI, 1977; UTMSI, 1979; UTMSI, 1980) although micro-tarballs were found to be frequently mixed in with zooplankton samples. The source of the micro-tarballs was presumed to be associated with tanker ballasting activities offshore (UTMSI, 1980). Water col umn levels of dissolved hydrocarbons were similar to those of particulate hydrocarbons, and in both cases the concentrations decreased in an offshore direction (UTMSI, 1977).

Development and production of petroleum reservoirs on the OCS generates a large amount of produced water. Produced water is by far the largest quantity of waste that is discharged during normal oil and gas operations. Gianessi and Arnold (1982) suggest that nearly 1/2 of the OCS produced waters are discharged into coastal waters. Although the amounts of oil and grease contaminates in the discharged waters are regulated, these waters may contain high concentrations of dissolved solids, oxygen demanding wastes, trace metals, aromatic hydrocarbons, and radionuclides. The significance of impacts resulting from the discharge of these substances into estuarine waters is not well known.

The effects of oil field produced waters discharged into estuarine waters in Louisiana was studied by Mackin (1971). These investigations were primarily concerned with the impacts of oil/grease and salinity and did not consider other potentially damaging substances in the water. Gianessi and Arnold (1982) have indicated that large quantities of produced water are piped to the coastal environment with the raw product. This investigation did not evaluate impacts of these discharges on the local environment.

The discharge of produced waters into estuarine and nearshore waters in the Gulf of Mexico has come under considerable scrutiny. Concerns focus on degradation of water quality (resulting from the addition of oxygen demanding substances), and the alteration or death of biotic communities as a result of salinity increases. Neff et al. (1987b) evaluated chemical contamination and effects on benthos of produced water discharges on the inner shelf and in Lake Pelto, Louisiana. More recently the MMS sponsored an analysis of the effects of produced waters discharges in the northern Gulf of Mexico (Boesch and Rabalais, 1989). It was estimated that OCS operations generated about 435,000 barrels/day of discharged produced waters, all in Louisiana waters. Evidence of hydrocarbon contamination in fine-grained sediments and some biological effects were observed near three major discharge sites.

Pacific Region

As a component of the Southern California Bight baseline program, water samples were collected with a modified Bodega Bodman 90 liter sampling bottle at 41 stations in 1975-1976. Samples were analyzed for particulate trace metals and high molecular weight hydrocarbons. Results indicated that refined oil and crude oil can be found most anywhere in the nearshore environment. Trace metal concentrations fluctuate with location, exhibiting enrichments near urban and industrial activity. Nearshore basins appear to be the final residence for these materials (SAI, 1977; SAI, 1978a). In areas of active oil seeps, water column hydrocarbons were 2.5-18 times higher than background values (SAI, 1978b).

Water samples for trace metals were collected using a 30 liter teflon coated top-drop Niskin bottle. Trace metal distributions in suspended particulate matter were highly variable. In general, metal concentrations of water col umn particulate reflect the chemistry of their source materials – nearshore samples reflect coastal input whereas offshore samples reflect material derived from decaying plankton ic organism and debris from islands. In most cases there are slight elevations in metal concentrations of deep particulate relative to surface particulate. Only barium, which decreases in concentration with water depth, and cadmium, which is relatively uniform with depth, depart from this trend. Generally, metal concentrations of suspended particulate from near bottom waters are elevated relative to deposited sediments lying beneath. (SAI, 1978c)

During the Southern California Bight Intertidal Baseline Survey, 90 liter water samples were collected from subsurface, midwater and bottom depths at ten stations for hydrocarbons at two mainland, three insular/bank and five basin sites. Water column dissolved and particulate hydrocarbon levels were about the same as those found in other OCS areas, generally less than 1 ug/l. Basin sites were characterized by a nearly uniform hydrocarbon composition and content throughout the water column. No distinction between petrogenic and biogenic sources could be made (SAI, 1979).

In addition to the baseline studies, the Pacific Region has carried out studies that address relatively small scale circulation and pollutant dispersal around drilling and production platforms. The dispersion of formation waters was modelled by Dickey and Fortin (1981) and the long-term fate of particulate discharged from platforms was simulated in a numerical computer model by Continental Shelf Associates (CSA, 1985). The CSA study summarized available information and applied the Offshore Operators Committee Drilling Mud Dispersion Model (Brandsma et al. 1980) to conclude that most drilling muds and cuttings would eventually be transported off the continental slope or to offshore basins which also receive the bulk of sediments supplied by local rivers, Along the "California coast, sediments are transported in a southerly direction and are eventually intercepted by submarine canyons. The canyons divert sediment (a similar phenomena occurs in the Atlantic) to a row of nearshore basins (unlike the Atlantic) where. the material is likely to remain (CSA, 1985). The CSA study also reviewed various measures designed to minimize the impacts of drilling muds and found that discharge rate and current speed are the major factors that determine the initial dilution rates –thus predilution has little effect on overall dilution rate. Predil uted discharges are less dense than standard discharges and do not generate as much turbulent mixing.

Alaska Region

Since the beginning of the program in 1974, studies have been carried out that synthesize existing information and collect information via field surveys as well as laboratory studies. Ecosystem studies have been carried out in the Yukon Delta and the North Aleutian Basin. Regional water quality is generally considered pristine, based upon the limited and isolated anthropogenic discharges, which are concentrated near a few villages. Turbidity is affected primarily by seasonal variation in discharges from the Yukon River (Cacchione and Drake, 1979). The variation of turbidity throughout Norton Sound is discussed by Feely et al. (1981) and in a study by Ecomar Marine Consulting (1983), Measurements of water column and sediment concentrations of trace metals and hydrocarbons are limited principally to the southeastern Bering Sea (Robertson and Abel, 1979; Vankatesan et al., 1981). Sharma (1979) has summarized available trace metal concentrations in sediment for the entire Bering Sea.

Northern Technical Services (1981) developed a projection of the amounts of sediment that would be disturbed as a result of offshore construction in the Beaufort Sea. Ecomar (1983) presented calculations relative to sediments moved by storms in Notton Sound.

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7. Coastal Impacts

General Description

Coastal zones represent an area of sensitive natural habitats for numerous species and are also the center for intense human activities. Oil and gas activities on the OCS may affect coastal areas in two basic ways. (1) Onshore facilities will add to the competition for land use and may increase the loss of "natural habitats." (2) Oil spills can cause significant impacts either by disrupting coastal infrastructure such as recreational beaches and fishing grounds or by damaging natural resources.

The management of coastal zones is highly complex. Federal, State, and local organizations all are active in conducting numerous research projects and gathering data to make management decisions for coastal resources. This chapter highlights concerns specific to oil and gas operations and studies conducted by the ESF!

Onshore facilities

The potential for long-term effects on coastal ecosystems varies greatly among the OCS regions. The nature of the coastal environments and the numbers and types of pipelines and onshore bases are the principal factors related to potential coastal impacts of OCS oil and gas activities (Boesch and Robilliard, 1987). Some areas such as California are characterized by open coasts and beaches whereas other areas such as the Atlantic coast of Georgia and the Gulf of Mexico coast of Louisiana are characterized by estuaries and wetlands. In the northwestern Gulf of Mexico coastal area, there were approximately 30 supply bases, 13 platform fabrication yards, and over 200 pipeline landfalls (MMS, 1983). In other regions, the remote nature of the resource, or its concentration in a restricted area, will likely result in few supply bases and pipeline landfalls and no platform construction facilities (Boesch and Robilliard, 1987).

Major concerns related to the development of OCS oil and gas resources include the potential effects resulting from physical alteration or destruction of coastal habitats. As discussed by Boesch and Robilliard (1987), physical alteration or destruction of coastal habitats is perceived by many, including fishermen, environmentalists, and public officials in areas with heavy OCS oil and gas development such as Louisiana, as having a greater negative impact than oil spills or drilling discharges. Pipeline placement, construction of coastal supply facilities, and processing plants. are major contributors to the physical alteration and destruction of coastal habitats.

Oil Spills

Oil spills may also cause significant negative impacts to coastal habitats. The National Research Council (NRC) (1985) provides a comprehensive review of current knowledge of the effects of oil on different components of the marine food web from the organism level to the ecosystem level. The following discussion is excerpted from pages 436-487 of the NRC publication.

> Unlike the open ocean, where dispersive forces act relatively rapidly to reduce the concentration of oil following a spill, coastal areas are subject to accumulation of oil as it becomes trapped in sediments where it sometimes remains for many years. Heavy oiling of coastal areas can cause immediate mortality to plants, animals and seabirds from smothering and toxic effects. The long-term effects will be a function of the amount of, and weathering of, the oil. Beached *oil* weathers differently as a function of exposure to dispersive forces, the most significant of which is wave action. Porosity of the substrate will also affect the degree to which oil is subjected to dispersive forces. In

high-energy environments (e.g., rocky shorelines), stranded oil coats the rocks and gradually hardens by weathering into a tough, tarry mat that is gradually removed by wave erosion (as much as 50% being removed in the first 2 years), Pools of oil will coll ect in crevices between rocks where the oil will *skin over,* but otherwise remain relatively unchanged for a long time.

In lower-energy environments such as cobble and sandy beaches, oil can sink into the sediment column where it may persist longer than it would on bare rocks. Wave action becomes less important as an erosive factor, but tidal pumping will cause the buried oil to be released into the interstitial and overlying waters where it can be dispersed over an extended period of time. In low-energy environments with muddy sediments, oil penetration will be relatively shallow, but stranded oil may persist for decades because physical weathering (e.g., dispersion) will be minimal.

in low energy environments such as mangrove forests and salt marshes, severe population and growth rate reductions in macrophytes, and in some cases total decimation of the population, have occurred. Some recovery within a year has been observed for marsh grasses, but recovery for mangroves is much slower and can take 10 years or more.

The rate of recovery following a severe oil spill will be much slower in polar regions than at lower latitudes. Not surprisingly, biological and chemical degradation proceeds more slowly than in warmer climates.

In recognition of the potential impacts of OCS oil and gas activities to coastal habitats, the MMS ESP has sponsored several major environmental studies to characterize coastal environments and investigate possible impacts. Since its beginning in 1973, the ESP has spent approximately $18.4 million on *20* coastal studies. These figures do not include the approximately $8.4 million funding of southern California intertidal baseline surveys, which also included a significant amount of subtidal work.

Regional Data Availability

Atlantic Region

Because the oil and gas industry interest in the Atlantic Region is far from the coastline, environmental efforts sponsored by the ESP have been focused on the outer continental shelf. Consequently, few studies of coastal environmental impacts have been developed by the ESP in the Atlantic Region. Most information is found in broader literature surveys and early workshops and scenario reports.

No crude oil spills of note have occurred in any coastal areas adjacent to the Atlantic OCS planning areas. Perhaps the most noteworthy non-crude spill in coastal waters occurred in September 1969 when the oil barge *Florida* spilled about 2,380 barrels of No. 2 fuel oil in Buzzards Bay, Massachusetts, causing long-term widespread damage. Tidal rivers and marshes that were in the path of the fuel oil were similarly impacted. Because the spilled oil was driven into the sediment column, benthic organisms continued to be affected years after the spill (Sanders et al., 1980). In 1989, MMS approved funds for a study to evaluate some of the initial study sites 20 years after the oil spill.

Other spills of oil products include the *Tamano* tanker grounding in Casco Bay, Maine, in 1972, which released about 2,380 barrels of No.6 fuel oil, and the barge *Bouchard* grounding in 1977 in Buzzards Bay, Massachusetts, which released about 1,93o barrels of No.2 home-heating oil into ice-covered waters.

Gulf of Mexico Region

The ESP has sponsored coastal ecological characterization studies of the northeastern Gulf of Mexico, the southwest Florida shelf, the Texas barrier islands, and the Mississippi deltaic plain. These characterization studies were designed to assemble, review, and synthesize existing biological, physical, and socioeconomic information structured to identify functional relationships between processes and components of the coastal ecosystems. In addition, subsystems, habitats, communities, and key species within the coastal ecosystems were identified and described. Examples of these include community profiles of coral reef, mangrove swamps/communities, and seagrass communities in the south Florida region. Major products of these coastal ecological characterizations include ecological atlases, models, narrative reports, community profiles, and appendices of data sources. These studies are useful tools in assessing and planning for potential coastal impacts related to OCS oil and gas development.

A major study was also designed and sponsored by the ESP to investigate the causes of wetland loss in the coastal central Gulf of Mexico. The objectives of that study were to determine:

- the causes of the high rate of wetland loss (nearly 1% annually);
- what impact OCS and onshore oil and gas development, especially canal construction, has on wetland sinking (subsidence) and wetland building processes; and
- what extent of wetland loss in south Louisiana is due to direct impacts of dredge and fill activities.

Results of this study showed that OCS activities accounted for 11,500 to 13,600 hectares of direct impact wetland loss from 1955 to 1978 in Louisiana (Turner and Cahoon, 1988). This represents 4.0% to 4.6% of total wetland loss attributed to direct OCS impacts in Louisiana during this period. The major OCS-related direct impacts were dredge and fill activities associated with construction of pipelines, support facilities, and navigation channels (Turner and Cahoon, 1988). Indirect wetland loss resulting from OCS activities in Louisiana was estimated by Turner and Cahoon (1988) to be from 4% to 11% of the total indirect impact loss.

An ongoing study sponsored by the ESP, *Impacts of OCS Activities on Sensitive Coastal Habitats*, began in FY 1986 to investigate coastal environments in the Gulf of Mexico not included in the wetlands loss study. Such coastal environments include barrier islands, riverine deltas, lagoons, and estuaries. This study is designed to emphasize the processes and mechanisms that cause environmental change as a result of oil and gas activities.

in an effort to better understand how to reduce the ioss of wetlands, preserve existing productive marsh, and improve future marshlands through effect-he management, the ESP in FY 1988 initiated the study *Mitigation of Wetland Impacts Due to OCS Oil and Gas Activities.* The goals of this study are to assemble information and to analyze and assess implementation techniques of a program that manages and enhances the productivity of the marsh environment in the coastal wetiands of Louisiana. This study wiii include a monitoring component examining the changes resulting from wetland management (LDNR, 1989).

Only a few spills have occurred that would allow the study of oil impacts on the northern Guif of Mexico coastline. In 1979 the *Ixtoc I* oil weil blew out in the Bay of Campeche (Mexico) reieasing over 3.5 million barrels of oil into the Gulf of Mexico (Jernelov and Linden, 1981). An estimated *77,000* barrels reached south Texas beaches with an unknown quantity of oil dispersed in the waters of the continental sheif (Figure 7-1), Aiso in 1979, the *Burmah Agate* oil tanker spilled 250,000 barrels of light crude oil in waters about 5 miles off the coast of Gaiveston, Texas. The Bureau of Land

Management launched a major program (ERCO, 1982) to determine what offshore habitats had been affected by the spilled oil, using standard field sampling techniques and biological and chemical analyses of the samples collected. The study did not assess nearshore impacts.

Other coastal area crude oil spills have occurred in the West Delta area (a Humble Oil pipeline break spilling nearly 160,000 barrels in October 1967), the Timbalier Bay area (a Shell platform blowout and fire spilling 53,000 barrels from December 1970 through April 1971), and the Main Pass area (Chevron platform spilling 30,000 barrels in. February and March 1970).

Currently, the MMS is supporting the Smithsonian Tropical Research Institute (STRI) in assessing impacts resulting from the 1986 rupture of a shoreline storage tank and accidental release of more than 50,000 barrels of crude oil into a complex region of mangroves, seagrasses, and coral reefs just east of the Caribbean entrance to the Panama Canal. Preliminary findings indicate oil had lethal and sublethal effects on many prominent organisms in both intertidal and subtidal areas studied (Burns and Knap, 1989; Jackson et ai., 1989). Oil slicks have persisted for over 2 years, primarily emanating from mangrove areas heavil y oiled during the initial spill. ,

Pacific Region ".

Areas of high interest to the oil and gas industry in the Pacific Region are generally nearer the coastline than in other OCS regions. In recognition of coastal impacts potentially resulting from OCS oil and gas exploration and development activities, the ESP has focused on intertidal investigations. From 1975 through 1978, the ESP sponsored intertidal baseline surveys of the Southern California Bight. These surveys provided an excellent environmental characterization of rocky intertidal and sandy beach "~ communities of the study area, In 1979, the ESP sponsored an ecological characterization of the central and northern

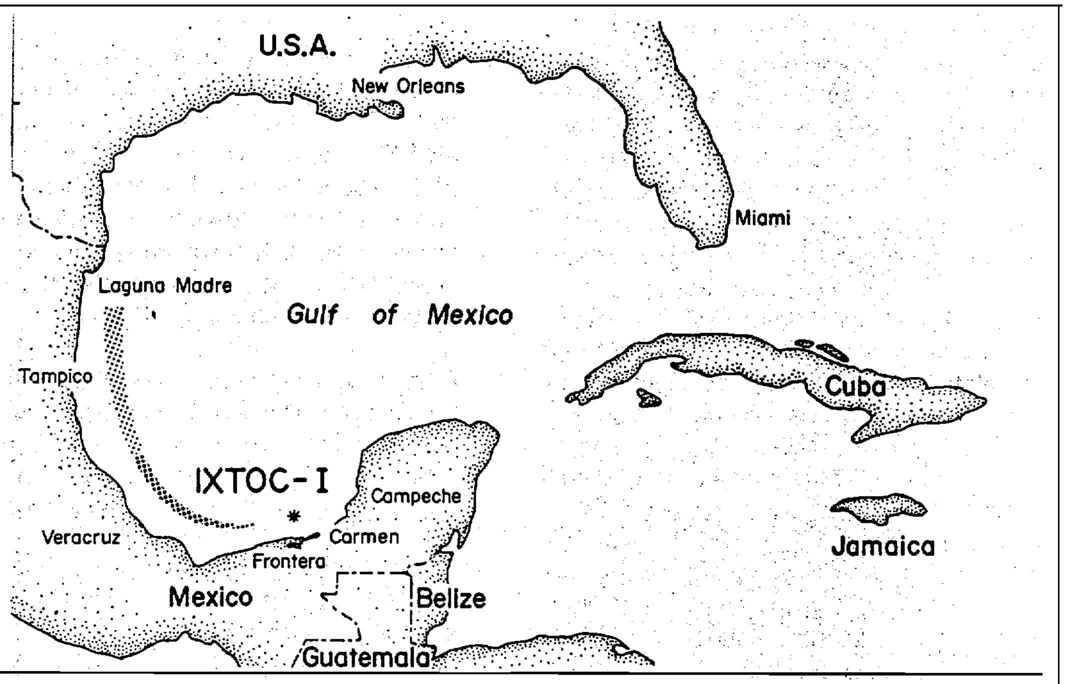

Figure 7-1. Location of *Ixtoc I* Blowout and the initial path of slick movements (NRC 1985).

California coastal region. The objectives of this characterization were similar to those already discussed in the Gulf of Mexico Region section.

A study of oil-spill risk assessment of coastal and marine habitats in central and northern California was completed in 1982. The physical shore-zone character of the study area was summarized for outer exposed coast and for the entire coast including estuaries and embayments. A set of 95 maps based on aerial and groundtruthing surveys was prepared with detailed biological and physical characteristics. Indices for oil residence and biological sensitivity were developed to determine relative risks of oil spills to the various types of coastline. Areas of primary concern were characterized as sheltered environments with low wave energy levels where stranded oil would remain for more than a year and major changes in distribution, size, and structure function of the affected biotic resource would be expected (Woodward-Clyde Consultants, 1982).

A 6 year study of successional/seasonal variation of central and northern California rocky intertidal communities as related to natural and man-induced disturbances began in 1983. This study is investigating six sites located equidistant from one another along the central and northern California coast. Two biological assemblages, characterized as the California mussel (*Mytilus*) assemblage and the red algae (*Endocladia/Mastocarpus papillatus*) assemblage, are studied at each site. Experimental treatments include clearing three plots in the spring and three plots in the fall of 1 year, with additional undisturbed plots serving as controls. Random point contact sampling and counts of motile invertebrates are performed in three randomly selected replicate quadrants within each plot during each sampling period. Sampling is performed semiannually at the time of clearing the plots and 3 months following clearing. Preliminary results indicate substantial variability among sites in initial colonization of cleared plots in both the red algae and California mussel assemblages. Latitudinal gradients were not evident in the initial colonization patterns (Kinnetic Laboratories, Inc., 1986).

Before the *Exxon Valdez* disaster, probably the most infamous oil spill in U.S. history occurred in 1969 in the Santa Barbara channel. This subsurface well blowout released an estimated 10,000 to 77,000 barrels of crude oil during the first 10 days (Harris, 1988). In the first 45 day period, over 100 miles of the southern California coastline was contaminated with oil. Beaches were covered with oil at the end of the winter erosion cycle so that any stranded oil that was not removed by beach crews would be buried with the spring deposition of new sand. Over the course of a year, much of the buried oil migrated to the surface and was washed away. A lack of good baseline environmental information made it impossible to establish definitively the level of impact the oil spill had in the Santa Barbara area; however, it is generally considered to have been relatively mild (Steinhart and Steinhart, 1972).

Alaska Region

Several coastal characterization and reconnaissance studies have been sponsored by the ESP in the Alaska Region. In addition, the ESP cosponsored the international BIOS (Baffin Island Oil Spill) Project, which investigated the experimental release of crude oil and chemically dispersed oil in the nearshore Canadian Beaufort Sea (Sergy and Blackall, 1987; Boehm et al., 1987).

A baseline characterization of littoral biota in the Gulf of Alaska and Bering Sea was completed in 1979. In the eastern Bering Sea north of 56°, scouring by sea ice is an important physical disturbance on most shores. The annual ice scouring can scrape most organisms on rocky shores and can plow up organisms in unconsolidated sediments. Such areas were found to be low in species diversity (O'Clair *et al.,* 1979).

A reconnaissance survey of the intertidal and shallow subtidal habitats of the lower Cook

Inlet was conducted from May through August 1976. An aerial survey of the lower Cook Inlet was conducted to determine the distribution of coastal habitats, and intertidal surveys were performed to determine the nature of the biological assemblages associated with the habitats observed (Lees, 1978). Major points addressed by this study include notable species discoveries and distribution patterns, descriptions of the habitat types and biological assemblages, trophic structure, and energy production and utilization patterns (Lees, 1978).

Surveys of the littoral zones of the Kenai Peninsula and the Beaufort Sea have been conducted. Littoral biota and substrate types were characterized, and populations of the principal species were estimated. Several studies have been completed to establish an oil-spill vulnerability index for coastal areas. Over 10,000 km of Bristol Bay shoreline extending from Cape Vancouver to Unimak Island were characterized (Michel *et al,* 1982). In order of ascending sensitivity to oil spills, the following designations were made:

1. exposed rocky headlands
2. wave-cut platforms
3. fine/mediumgrained sand beaches
4. coarse-grained sand beaches
5. exposed tidal flats (low biomass)
6. mixed sand and gravel beaches
7. gravel beaches
8. exposed tidal flats (moderate biomass)
9. sheltered rocky shores
10. eroding peat scarps
11. sheltered tidal flats
12. marshes.

Salt marshes comprised the largest percentage of shoreline in the study area. A similar study has been performed in the Chukchi Sea coastal area (Woodward-Clyde Consultants, 1985).

In 1987, the *Glacier Bay* spilled over 3,000 barrels of North Slope crude oil in Cook Inlet contaminating more than 35,000 pounds of fish.

The largest tanker spill in U.S. waters occurred in March 1989 when the *Exxon Va/dez* ran aground on Bligh Reef in Prince William Sound, spilling over 262,000 barrels of North Slope crude. The crude washed ashore on the many islands in western Prince William Sound and as the spill began to break up, it drifted in a southwesterly direction, impinging on the shores of the southeastern Kenai Peninsula and eventually entering Cook Inlet and the Shelikof Straits (Figure 7-2). Because of the 5-6 meter tidal range in this area, extensive areas of beach were inundated with oil, and depending on the type of beach, the oil penetrated as much as 2-3 feet into the sediment/cobble. Mortalities to sea birds and mammals occurred and commercial fishing activities were significantly disrupted, but total mortalities and the ecological significance of the losses are inestimable at this time. Extensive studies to assess the damages to the natural resources, and their recovery, are being performed in accordance with existing Federal and State statutes.

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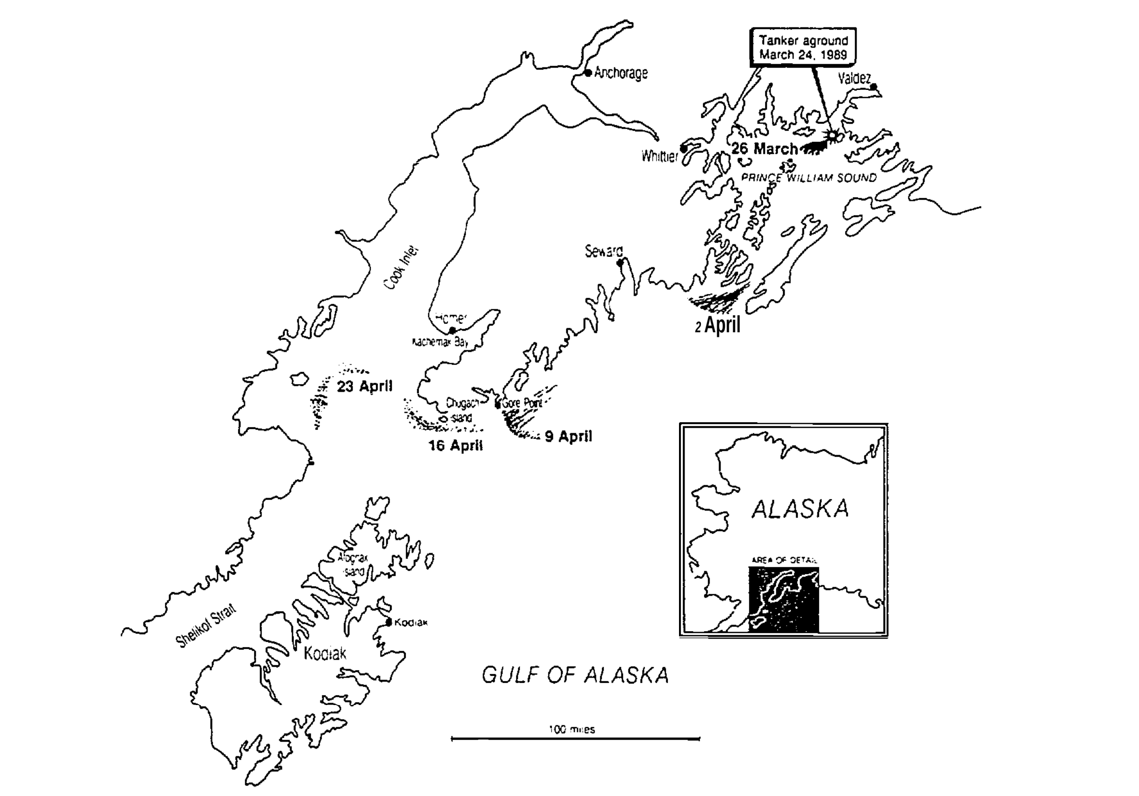

Figure 7-2. Leading Front of Spilled Oil from Exxon Valdez

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8. Ecological Monitoring

General Description

With increased emphasis on the exploration and development of Federal OCS lands for oil and gas resources, concerns have been expressed by environmental scientists and the general public regarding possible effects of these activities on the marine environment. Many of the issues concerned with acute, short-term effects of OCS oil and gas activities have been addressed adequately through credible scientific studies (Boesch and Rabalais 1987). One issue that has not been resolved is that of potential long-term, chronic effects. Our preferred approach to studying both the short and long-term effects is ecological monitoring.

Ecological monitoring studies funded by the MMS Environmental Studies Program (ESP) *are* multidisciplinary efforts involving biological, chemical, geological, and physical oceanographic components. Since the beginning of the ESP in 1973, approximately $21 million has been spent on eight ecological monitoring programs. This figure does not include expenditures directed to the baseline studies of the early ESP or monitoring of OCS impacts on marine mammals, birds, and turtles. Those topics, as well as monitoring of socioeconomic impacts associated with OCS activities, are discussed in other sections of this planning document. Ecological monitoring studies have been focused primarily on assessing the impacts, and understanding the processes causing these impacts, of OCS exploration and development activities on the marine ecosystem. The ESP has also sponsored investigations monitoring the impacts of spilled oil on the marine environment. Information produced by these studies provides a basis for predictive models that can serve to enhance environmental documentation and, consequently, improve the basis for management decisions.

Benthic communities have been the focus for monitoring the effects of OCS oil and gas activities. Because contaminants are often associated with particles, they settle to the bottom and accumulate in bottom sediments. Many benthic organisms are relatively long-lived and sedentary making them more susceptible to effects from accumulated contaminants. On the other hand, plankton and nekton are unlikely to experience significant contaminant concentrations or exposure durations. The benthos can also be sampled with greater statistical precision than water column organisms.

Early MMS ecological monitoring studies primarily were designed to investigate short-term impacts (usually within one year) from OCS exploratory activities. Current and planned MMS ecological monitoring studies are mainly focused on assessing the long-term (3-5 year), as well as short-term, environmental effects associated with OCS production activities. The reason for this change in emphasis is the determination that discharges from exploratory rigs in the OCS environment would not result in significant long-term effects, except possibly in areas with rare, slowl y recovering communities (Boesch and Rabalais, 1987; NRC, 1985). A major ongoing study sponsored by the ESP is monitoring the effects of a large oil spill in Panama on marine habitats and communities, some similar to those of the south Florida area. Other studies considered as part of the ecological monitoring program include experimental field studies dealing with recolonization and recovery of biological communities following anthropogenic disturbances.

From 1973 to 1978, the ESP primarily consisted of baseline and monitoring studies that were designed based on information developed through literature syntheses and supplemented by special studies of topics or sites of interest. The baseline, or benchmark, studies were large-scale, multidisciplinary investigations designed to characterize the nature, abundance, and diversity of biological communities, the physical characteristics of the seafloor and overlying waters, and concentrations of certain trace metals and hydrocarbons in the water, sediments, and selected biota prior to any OCS oil and gas activity in an area. In concept, a series of monitoring studies was to follow each baseline study to provide information on changes in environmental characteristics relative to the baseline data as oil and gas activities proceeded. This program approach was criticized by Department of the Interior decisionmakers as it did not provide timely and appropriate information for prelease and postlease decisionmaking. A National Academy of Sciences review of the program also advised that the marine environment is too variable for a statistically valid, broad-scale baseline to be determined in the timeframe and on the spatial scale necessary for projected post-lease monitoring. For these reasons, the ESP was restructured to answer more immediate pre-lease decisionmaking needs and the baseline-monitoring approach was abandoned. Although the baseline information developed through the early years of the ESP provided a sound environmental characterization of many of our OCS areas, it is not considered part of the ecological monitoring program.

Regional Data Availability

Atlantic Region

In the Atlantic Region, two significant ecological monitoring programs have been sponsored by the MMS. The first resulted from concerns about the potential effects of oil and gas exploration activities on the Georges Bank, one of the most productive commercial fishery areas in the world. In response to the concerns expressed by environmentalists and the commercial fishing industry, a Georges Bank Biological Task Force (BTF) was established. One purpose of the BTF was to design environmental studies and monitoring programs to detect the possible early warning signs of environmental deterioration-on Georges Bank. Based on recommendations of the Georges Bank BTF, the Georges Bank Monitoring Program (GBMP) was implemented by the MMS in July 1981. The GBMP included three coordinated components: 1) benthic infauna monitoring; 2) analysis of hydrocarbons in bottom sediments and analysis of hydrocarbons and trace metals in benthic fauna; and 3) analysis of trace metals in bottom sediments.

The monitoring of benthic infauna was managed by Battelle New England Marine Research Laboratories. This 3-year study was designed to determine both the near-field, short-term and regional, long-term impacts of OCS oil and gas exploration on the benthic infaunal communities. Intensive sampling of the benthic communities was conducted near, upcurrent, and downcurrent of two drilling rigs. As shown in Figure 8-1, a large, radial sampling array of 29 stations was used to assess near-field impacts around an exploratory rig in Block312. Three stations were located from 200 to 2,000 meters up and down current of a drilling rig in Block 410. An additional 14 regional stations covered a broad expanse of Georges Bank and nearby areas of potential deposition of drilling materials.

Results of the infauna monitoring component of the GBMP demonstrated no significant changes in benthic infauna community structure that could be attributed to the drilling of eight dry wells on the Georges Bank (Blake et al. 1983; 1984; 1985). Differences observed in biological communities were related to differences in water depth and substrate type. Clustering analysis showed that each replicate within a station clustered first with the other replicates from the same station before joining those of other stations. The low variability among replicates, together with the demonstrated persistence of these benthic communities overtime, enhanced the possibility of detecting statistical y significant changes in these communities.

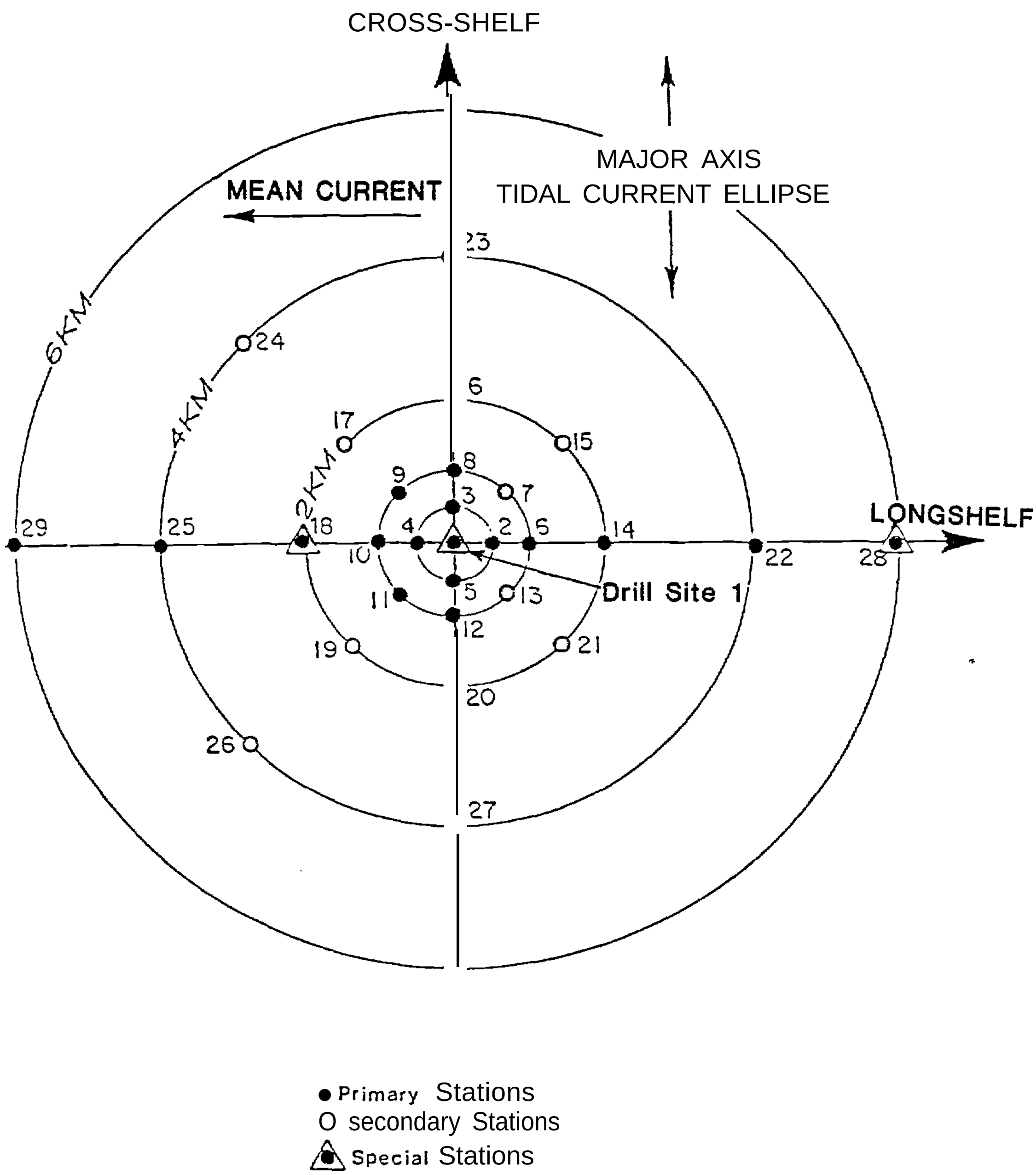

Figure 8-1. Site Specific Sampling Array Established in Georges Bank Monitoring Program Around Oil and Gas Exploration Drill Sites

In support of the infauna monitoring study, the MMS funded a study conducted by Taxon, Inc. to analyze historical benthic infauna samples from Georges Bank (Michael *et al.*, 1983). A major objective of this study was to produce information on seasonal variation of Georges Bank benthic infauna. Analysis of data collected in the 1977-1978 New England OCS Environmental Benchmark Program at 11 Georges Bank sampling stations also served to provide a longer term for comparison of the new data being generated by the GBMP.

The second component of the GBMP was the analysis of hydrocarbons in bottom sediments and analysis of hydrocarbons and trace metals in benthic fauna. This 3-year study was conducted by Science Applications International Corporation. Hydrocarbon analyses of sediments and benthic fauna demonstrated the presence of aliphatic and aromatic hydrocarbons, the majority of which were attributable to anthropogenic activities not related to OCS drilling (Payne et al., 1982; 1983; 1985). Concentrations"and chemical composition of these materials were similar to measurements made during the Benchmark Program of 1977-1978. Short-term deposition of drilling discharge materials was observed in near field bottom sediments (Payne et al., 1985). Petrogenic hydrocarbons were detected in several natural depositional regimes around the periphery of Georges Bank. The concentrations and chemical composition of these materials, however, did not change appreciably after drilling activities. There was no evidence of uptake or accumulation of hydrocarbons in tissues of the two analyzed epifaunal species, Arctics *islandica* (quahog clam) and *Paralichthys oblongus* (four-spot flounder). No evidence of change in the levels of trace metals (aluminum, barium, cadmium, chromium, copper, iron, lead, mercury, nickel, vanadium, and zinc) was detected within the tissues of the two epifaunal species. When compared to measurements made in the Benchmark Program and pre-drilling phase of monitoring, trace metal burdens in tissues of *Arctics islandica* collected after oil and gas exploration on Georges Bank were not significantly different.

The third component of the GBMP was the analysis of trace metals in bottom sediments. This effort was conducted for the MMS by the U. S. Geological Survey at Woods Hole, Massachusetts. Barium, an essentially non-toxic element present in barite, which is a major constituent of drilling mud, is used as an indicator of drilling mud contamination. It was found to increase by a factor of 5.9 in bulk sediments 200 meters from the drill site in Block 410. However, the maximum barium concentration measured after drilling activities was within the range of pre-drilling concentrations measured at other sampling stations of the GBMP (Bothner et al., 1985). At Block 312, it was estimated that 25 percent of the barite discharged on Georges Bank was present in the sediments within six kilometers of the drill site four weeks after drilling was completed (Bothner et al., 1985). No drilling related changes in the concentrations of other trace metals measured (aluminum, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc) were observed in bulk sediments from Block312 or 410 (Bothner et al., 1982; 1983; 1985).

A second major MMS-sponsored monitoring program centered on deep-water (1 ,500 and 2,100 meter water depths) drill sites in the mid-Atlantic. This program, managed by Battelle New England Marine Research Laboratories, was completed in December 1987. It was designed to monitor changes in benthic infauna and epifauna communities,"' and in hydrocarbon concentrations in sediments, adjacent to oil and gas exploration activities in Blocks 372 and 93. Figure 8-2 shows the locations of the 14 sampling stations monitored by this program. Results discussed in the final report include the following:

- Changes in benthic infaunal diversity or similarity over time were explained by changes in the densities of a few dominant species and were often related to

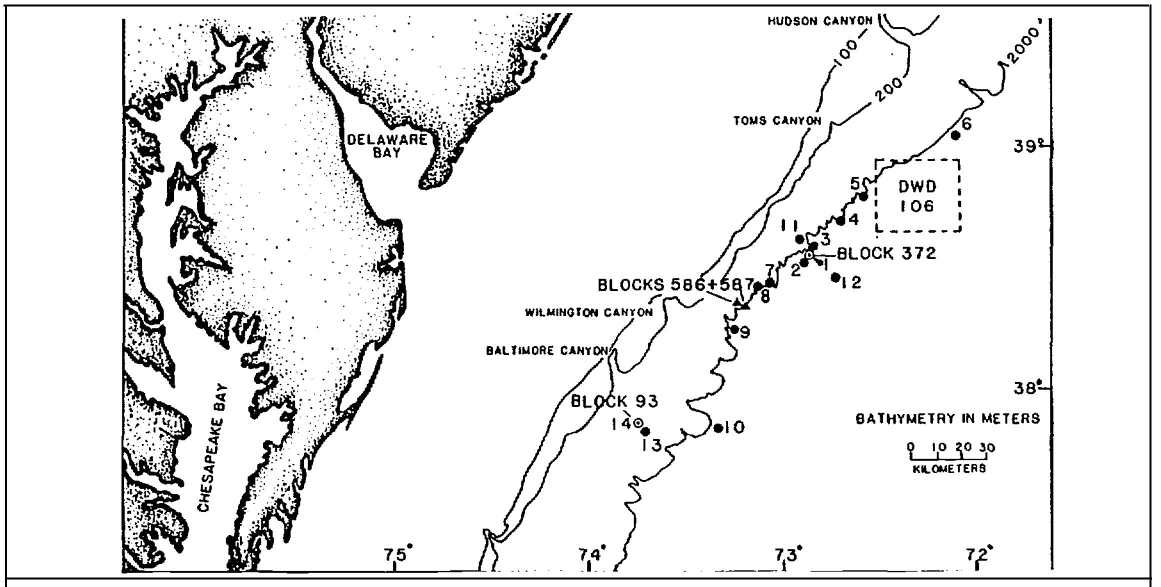

Figure 8-2. Deep-Water Monitoring Program Station Locations on the Mid-Atlantic Continental Slope and Rise

differences in sediment characteristics rather than drilling activities;

- There was no evidence that hydrocarbons detected in the sediments, or hydrocarbons and trace metals in brittle stars and sea urchins, originated from drilling activities; and

- Sea pens observed in high numbers before drilling were reduced in numbers during drilling and found to be abundant again 14 months after drilling. These differences in abundance could not be attributed definitely to drilling activities. Natural faunal patchiness or the occupation of slightly different camera sled paths could explain the faunal abundance-variations observed.

Also in the mid-Atlantic, a study of the short-term effects of exploratory oil and gas drilling discharges on water quality, bottom sediments, and the benthic community was conducted by EG&G, Environmental Consultants (EG&G) for the Offshore Operators Committee (OOC). This program, conducted at Block 684, included a pre-drilling survey, a discharge monitoring study, and two post-drilling surveys (two weeks and one year after drilling) (EG&G, , 1982). Within 100 meters of the drill site, increased barium concentrations were observed in surface sediments. No elevated levels of hydrocarbons were detected in sediments following drilling operations (EG&G, 1982). Of the 10 metals analyzed from tissues of benthic invertebrates, only concentrations of barium were clearly elevated following drilling. In ophiuroids (brittle stars), barium concentrations were elevated throughout the area sampled for these analyses (1.6 kilometers from the drill site). After one year, however, barium concentrations in brittle star and polychaete tissues had decreased to levels typical of pre-drilling conditions (EG&G, 1982). Several near-field changes in the fauna were observed during this study. Mobile megabenthos, including fish and large crustaceans, increased in abundance near the drill site in response to increased environmental heterogeneity resulting from the drill cutting accumulations (EG&G, 1982). Abundance and diversity of infauna and sessile megabenthos around the drill site were reduced by burial and possibly by diminished larval settlement (EG&G, 1982).

Gulf of Mexico Region

The ESP has sponsored two exploration rig monitoring studies in the Gulf of Mexico. The Mississippi, Alabama, Florida (MAFLA) rig monitoring study was to be conducted in the eastern Gulf of Mexico. However, due to a lack of drilling activities in this area during the contractual period of 1975-1976, this effort was relocated to Mustang Island Block 792 in the western Gulf of Mexico off the Texas coast. This study, conducted between November 1975 and April 1976, employed a radial sampling design with biological, chemical, and geological samples collected before, during, and after drilling operations. Sampling was conducted at the drill site and at distances of 100, 500, and 1,000 meters from the drill site. Some near-field environmental effects, including the accumulation of drill cuttings, increased concentrations of barium in sediments, and declines in what were described as already stressed foraminiferan populations, were attributed to drilling activities (State University System of Florida Institute of Oceanography (SUSIO), 1977). Drill cuttings were found at 100 and 500 meter stations after drilling activities were completed. No significant changes in sediment hydrocarbon content were detected (SUSIO, 1977).

A second rig monitoring study sponsored by the ESP was conducted in the western Gulf of Mexico during the period of September 1976 through March 1977. A pattern of stations for sampling before, during, and after drilling operations was established at the drill site and at the intersections of transects emanating from the drill site and concentric circles 100, *500,* 1,000, and 2,000 meters from the drill site. Additional sampling was conducted during drilling in the sediment plume 100 meters from the rig and at 100 meters from the rig opposite the sediment plume (Groover, 1977). Results of this study demonstrated that barium, cadmium, lead, and zinc levels in the sediment increased significantly only at the drill site. Samples taken 1000 meters from the drill site did not exhibit elevated levels of these metals. Although the increases in barium, cadmium, and zinc were attributed directly to drilling operations, it was suggested that the two-fold increase in lead concentrations could be attributed to fuel used by the rig and by supply vessels (Holmes and Barnes, 1977). The occurrence of foreign sediments resulting directly from drilling activities was restricted to the immediate drill site. One of three post-drilling sediment samples taken at the drill site was contaminated with petroleum hydrocarbons, The source of this contamination, whether from drilling operations or some other source, was not established by this investigation (Parker *et al.*, 1977). Benthic infaunal populations were found to be significantly reduced at the drill site after drilling had occurred. Differences observed between other pre-and post-drilling stations were attributed to seasonal variations rather than to drilling activities (Holland, 1977). Pre-drilling epifaunal samples analyzed for hydrocarbons contained no evidence of petroleum contamination. However, post-drilling samples, especially shrimp, exhibited increased hydrocarbon levels suggestive of petroleum contamination (Giam and Chan, 1977).

Three studies of the long-term effects of oil and gas production in the Gulf of Mexico have been conducted. The first was the Offshore Ecology Investigation (OEI) sponsored by the offshore oil industry from 1972 to 1974. This study has been criticized for many weaknesses from poor design and lack of program goals to poor coordination among the various discipline components (Carney, 1987). For these reasons, design and results of the OEI will not be discussed here.

A major ecological investigation of petroleum production platforms in the central Gulf of Mexico was sponsored by the ESP in 1978-1979. Four production platforms were selected as primary sampling locations and were visited during each of the three seasons found to be characteristic of the central Gulf of Mexico. These sampling areas were complemented by four control sites selected to be as far from production as possible, yet with similar environments. In addition, 16 secondary platforms were sampled during the summer season only. Because earlier studies had established that oil and gas production platforms produce effects in the immediate vicinity of the structure, this study was designed to sample a range of distances from the platform to determine if any accumulation of contaminants could be detected in sediments or the food web. At each primary platform, transects were established along the four points of the compass and sampling stations located at 100, 500, 1,000, and 2,000 meters from the platform.

A general conclusion of this study, based on analysis of all biological and chemical parameters, was that the entire region studied could be characterized as contaminated with pollutants from man's activities. Hydrocarbon contamination, however, could not be attributed only to OCS oil and gas production. Many other sources of such contamination were implicated including terrestrial inputs, especially through the Mississippi River. In addition, faunal variations observed could not be distinguished from major periodic environmental fluctuations (Bedinger, 1981). Although this project was considered to be better designed, organized, focused, and coordinated than the OEI, it has been criticized for some fundamental failings including lack of prior hypotheses and a tendency to express equivocal findings as fact (Carney, 1987).

The final of these three studies focused on the environmental effects of nearly 15 years of production in the Buccaneer Gas and Oil Field in the western Gulf of Mexico off the coast of Galveston, Texas. This area was studied between 1976 and 1980. As described by Middleditch (1981), the field sampling design employed in this project consisted of transects radiating from platforms in the producing field. Emphasis was placed on the area within a few kilometers of platforms. Stations were occupied quarterly. Results of this study demonstrated that there was a decrease in faunal density within 100 meters of the platforms. Diversity, however, was not decreased. These results were not attributed solely to effects related to production. It was suggested that current scour was an important factor altering the habitat around the platform. This study continued some of the failings of the studies discussed previously. In addition, faunal and environmental data were collected separately and could not support direct comparisons. Natural variation was not dealt with eff ectivel y through treatment of sample replication or analyses (Carney, 1987).

Evaluations of the weaknesses of the three studies of long-term effects related to OCS production in the Gulf of Mexico can be used for improving the design of future monitoring programs. The earlier studies did provide much valuable information as well as the opportunity to enhance future efforts.

Pacific Region

In the Pacific Region a major long-term monitoring program is currently being sponsored by the MMS off the California coast in the Santa Maria Basin and western Santa Barbara Channel. This program began in 1982 with a workshop held to review marine monitoring methodologies. Recommendations for study design were received from workshop participants. A design for long-term monitoring was then developed based upon the recommendations and review of previous monitoring programs in other OCS areas.

Phase I of the anticipated three-phase program began in November 1983, to broadly characterize the marine communities and associated abiotic factors, to improve the knowledge of taxonomy of organisms in the area, and to provide in a general manner, the identification of platform and comparison areas for future monitoring. Soft-bottom sampling was conducted at 107 stations located along 16 transects. Bottom sediment and faunal samples were collected for trace metal and hydrocarbon anal yses, sediment characterization, and benthic community analyses. Hard-bottom surveys were conducted with a manned submersible. Data were collected along 23 dive transects using videotape, 35-mm still photography, and direct observations.

Results of this pre-production phase of the monitoring program include the following: "

- soft-bottom communities were distributed primarily by depth with some north-south trends noted;
- comparisons with the literature showed that soft-bottom community; composition had changed little over a six-year period; and
- ambient hydrocarbon and trace metal concentrations were associated with proximity to input sources, both natural and anthropogenic, with natural petroleum seeps 'suggested as a primary source (Lissner et al., 1986).

Field sampling for the second phase of this monitoring effort began in October 1986, and continued through October 1990. This phase of the long-term monitoring study is designed to detect and measure long-term or short-term changes in the marine environment near OCS oil and gas platforms and to determine if any changes observed during the monitoring period are caused by drilling-related activities. The sampling includes rigorous spatial and temporal controls, a series of nine regional stations, and two site-specific' sampling arrays around production platforms. Platform Hidalgo off Point Arguello was selected for hard-bottom monitoring and Platform Julius off Point Sal for soft-bottom monitoring. Figure 8-3 shows the locations of site-specific and regional sampling stations. This multidisciplinary, five-year program includes seasonal sampling of hard and soft-bottom biological communities and trace metal and hydrocarbon chemistry. Physical oceanographic measurements include. continuous records of currents, waves, tides, water temperature, and sedimentology. In addition to the time-series monitoring, this program includes several related special studies. These focus on benthic sediment transport and bioturbation, validation of the 00C drilling mud discharge model, and processes of trace metal partitioning and flux in the marine environment.

A 6-year study of successional and seasonal variation of central and northern California rocky intertidal communities is 'currently being funded by the MMS. A primary objective of this study is to monitor the response of rocky intertidal communities to man-induced and natural disturbances and correlate the response with successional, seasonal, and latitudinal variation. The field survey includes six sites along the California coast with two distinct biological assemblages represented at each site. Experimental intertidal plots were completely cleared over a three-day period with hand tools and a propane-powered burner (Hardin et al., 1986). Recovery of these plots is being monitored and compared with undisturbed control plots. Preliminary results based on the completion of the first year field survey are presented in a report prepared by Kinnetic Laboratories, inc. entitled,"Study *of the Rocky Intertidal Communities of Central and Northern California: Year I."*

Alaska Region

Between 1981 and 1986, 17 exploratory oil and gas wells were drilled in the Federal OCS of the Beaufort Sea. An additional *41* exploratory, delineation, or development wells had been drilled in Beaufort Sea state waters by the end of 1986 (Boehm et al., 1987).

In September 1983, a workshop was held in Alyeska, Alaska to appraise the feasibility of conducting a monitoring program in the Beaufort Seato measure changes in the marine environment that might be attributed to OCS oil and gas exploration and production activities: Another function of this workshop was the development of a framework for the design of such a program.

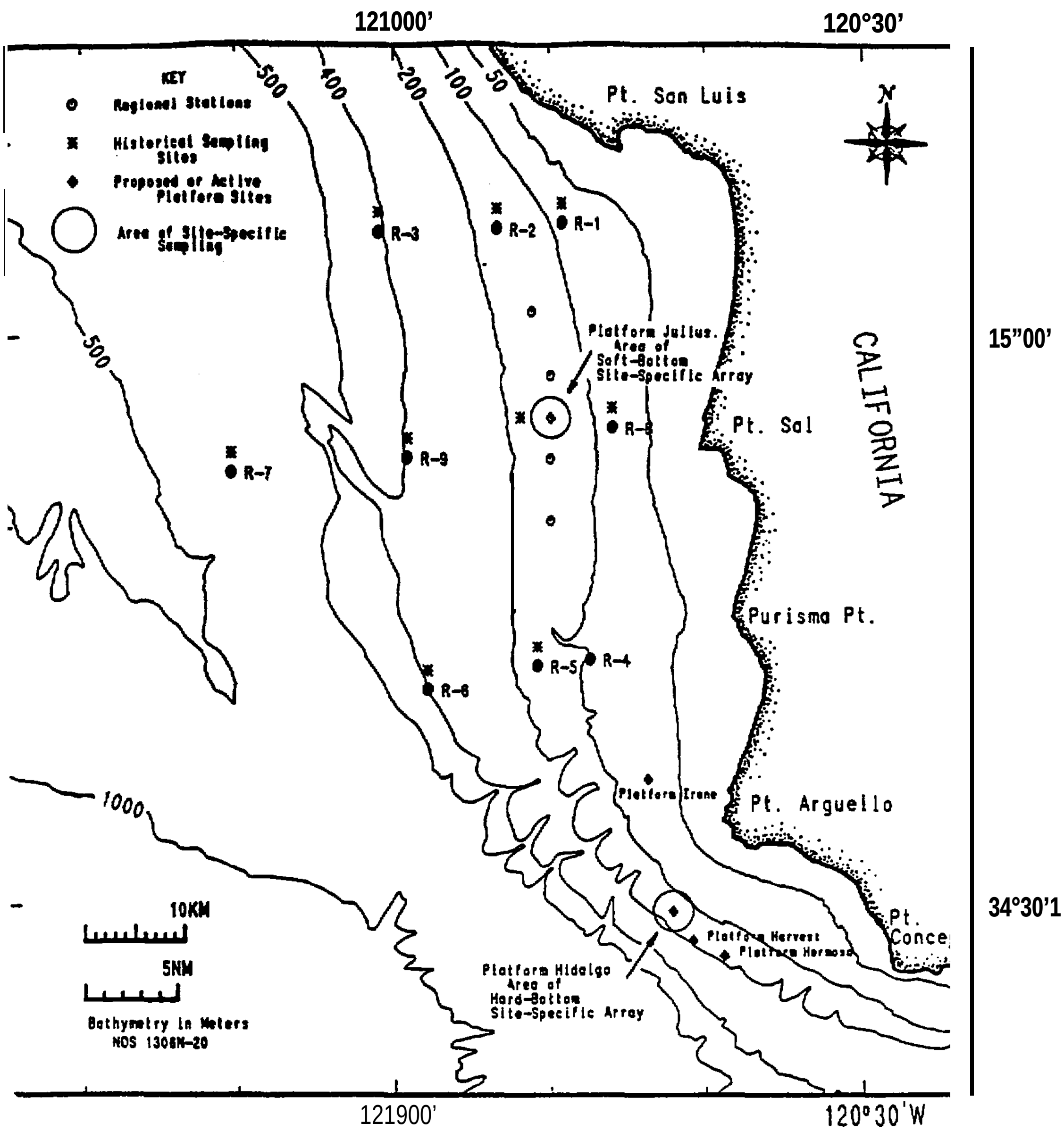

Figure 8-3. Site-Specific and Regional Sampling Stations Established for Phase II of the Long-Term California Monitoring Program

The initial phase of the recommended monitoring program was a three-year study to detect and quantify changes in the concentrations of trace metals and hydrocarbons in Beaufort Sea sediments and sentinel organisms and to identify causes of these changes. Sampling began in September 1984 and was completed in August 1986. Thirty-nine stations were selected in a manner to provide area-wide, area-specific, and gradient-specific assessments of potential changes in trace metal and hydrocarbon concentrations in Beaufort Sea sediments and benthic organisms. Station selection included marine, river, and coastal peat environments. Other important factors considered in the sampling design for this program were the drilling technologies to be used and the physical environment of the Beaufort Sea. Exploration and development drilling in the Beaufort Sea will make use of barrier islands, man-made gravel or ice islands, concrete island drilling systems, or ice-resistant drill ships (Boehm et al., 1987). The OCS of the Alaskan Beaufort Sea is very shallow, with an average depth of only 37 meters and the shelf break in most areas occurring at about a 60 meter depth. Sampling stations could not be established too far offshore due to inaccessibility caused by extensive ice cover. Consequently, marine sampling stations were selected in water depths ranging from 1.2 to 25.2 meters. An oversampling strategy was employed to provide sediment and faunal samples for archival and possible future analyses.

Elevated levels of trace metals and hydrocarbons were detected in some of the sediments sampled during the first year of this program. In an effort to determine possible sources of these materials, river and coastal peat sampling stations were added to the second year of sampling. Analyses of these samples demonstrated that peat contributes to the riverine sediments and that the rivers provide a major source of sediment, trace metals, and hydrocarbons to the Beaufort Sea nearshore zone (Boehm et al., 1987). Trace metal concentrations in bivalve tissues were similar for three years of study indicating that little annual variation had occurred and that these organisms provide a good mechanism for monitoring potential changes related to anthropogenic inputs (Boehm et al., 1987). The data set developed by this program provides a baseline of geochemical characteristics for the nearshore Beaufort Sea that can serve as the basis for future monitoring.

A workshop was conducted in January 1987 to develop a plan for monitoring oil and gas development impacts in the Bering Sea. Although the prospects for oil and gas development in the Bering Sea had declined by the time of this workshop, a decision was made to prepare the plan for monitoring and update it as necessary before implementation.

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9. Fish and Fisheries Resources

General Description

The main goal of the MMS fisheries program is to predict and assess the potential impacts of OCS oil and gas industry activities on fish and fisheries resources. These resources consist of commercially and recreationally important finfish and shellfish. Issues concerning these fisheries are:

I. Multiple-use conflicts

- Elimination/reduction/damage to fishery areas or resources;
- Vessel traffic conflicts;
- Gear conflicts (fouling, loss, damage);
- Competition for support services;
- Vessel damage;
- Aesthetic damage – impacts on the recreational fisheries and associated tourist industries (from spills, structures, and traffic);
- Other – disruptions of established sociocultural patterns related to fisheries.

2. Toxic Effects

- Acute (lethal) – short-term effects on fish stocks, populations, critical habitats, or prey;
- Chronic (sublethal) – lonq-term effects on fish stocks, populations, critical habitats, or prey.

Most of the available databases on fish and fisheries resources have been developed because of the commercial, recreational, or subsistence value of the species considered. Less information is available on species that do not fall into these categories. This chapter is written from the biological perspective and therefore focuses on toxic effects. The economic and social ramifications of oil and gas activities to fish and fishery resources are discussed under other chapters of this report.

The National Marine Fisheries Service (NMFS), the Fishery Management Councils, the U.S. Fish and Wildlife Service (FWS), and State agencies have the responsibility for assessment and protection of the Nation's marine, coastal, and anadromous fish. The MMS often relies on these agencies and academia to obtain basic fisheries information required in support of the oil and gas leasing program.

The MMS fisheries program has focused on:

- studying oil and gas interactions with the environment and fish communities
- supplementing general biology/ecology information in OCS areas with little existing data,
- reducing and synthesizing large amounts of fisheries information into forms more readily incorporated into environmental impact statements (EIS's) or other MMS documents.

The MMS has conducted over $64 million worth of laboratory and field studies on these topics. Additional monies have been spent on socioeconomic aspects of fisheries. Several fisheries impact analysis models have been developed or evaluated by the program (Laevastu et al., 1985; Pacific Consultants 1980, 1981; Spaulding et al., 1982). The MMS has also supported a number of literature and database reviews and syntheses, small conferences and workshops, and database management studies (e.g. Becker, 1987; CSA, 1983; MBC, 1987; Hale, 1987; Pacific Consultants, 1980).

Regional Date Availability

At/antic Region

The Atlantic Region is rich in commercially and recreationally important fisheries. Many studies, funded by MMS, have been conducted throughout the three Atlantic Planning Areas, north, mid, and south. The research was initiated to establish baseline information and generate databases on the fish and fisheries resources.

The north-Atlantic includes one of the most productive offshore fishing grounds in the world, Georges Bank (Backus, 1987). A wide variety of resident species inhabit this highly productive area (Table 9-l). The final EIS for Lease Sale 82 (North Atlantic) (MMS, 1983a) compiles ecological information for many of the important fish and shellfish species of the area. Another good source of fish and fisheries data from Nova Scotia to Cape Hatteras is the Northeast Fisheries Center (NEFC, NOAA) and its component laboratories. The Woods Hole Laboratory issues an annual update of the status of the stocks in this area, including trends in commercial and recreational fishing and the status of the resources. Studies funded by the MMS (TRIGOM, 1974; CNA, 1977) addressed distribution and abundance and environmental parameters of fish species in the North and Mid-Atlantic Planning Areas. Other sources of information focusing on the commercial fisheries include the Fishery Management Councils, the Northwest Atlantic Fisheries Organization, and State departments of Fish and Game. More information can be obtained from Bigelow and Schroeder (1953); Colton and Temple (1961); Gusey (1 977); Grosslein and Azarovitz (1982); Bourne (1 987); and Brown (1987).

Life history information has been provided by the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) surveys of the NMFS, including data on the distribution and abundance of fish eggs and larvae in the north and mid-Atlantic. Reed et al., (1982) carefully selected candidate fish species for Georges Bank to conduct the MMS funded study Assessing *the Impact of Oil Spills on a Commercial Fishery* (Spaulding et al., 1982). The criteria used for selection were the availability of data on early life history stages, the commercial value and high biomass, and the availability of biological information sufficient to build population dynamics models. Four species were selected: Atlantic herring, Atlantic cod, haddock, and yellowtail flounder.

The shelf-slope zone along the edge of Georges Bank (about 200-1,000 m depth) includes a different community from the shelf. Hecker et al. (1'980) conducted an MMS-funded study that provides detailed information on the species inhabiting this area. These species include the commercially important tilefish, red crab, red hake, and squid.

Most members of the boreal fish community of the Gulf of Maine are residents of the area, and they show little movement into adjacent regions. TRIGOM (1976), funded by MMS, provides an inventory of environmental parameters of the shelf and slope for the north and mid-Atlantic. More information about this community can be found in Bigelow and Schroeder (1 953); Grosslein and Azarovitz (1982); and Hare (1 977). Data on spawning have been summarized in Colton and Temple (1961) and Smith (1979, 1980) and Smith et al. (1983).

Wide variations in environmental conditions occur in the mid-Atlantic, and the fish community includes both boreal and subtropical species. There are distinctly different winter and summer finfish communities. Ecological information about these species can be found in the Lease Sale 111 EIS (MMS, 1985a).

The productive bays and coastal regions of the mid-Atlantic area support various life stages of blue crab, weakfish, scup, bluefish, spot, red drum, croaker, menhaden, flounder (fluke), striped bass, hard clam, soft clam, bay scallop, and oyster. Local concentrations of surf clams, ocean quahogs, lobster, Jonah and Rock crabs, and sea scallops are found further offshore. Juvenile stages of these species are generally found closer into the shore than adults. Specific information on the abundance and biomass of shellfish in the mid-Atlantic can be obtained from an MMS-funded study, Azarovitz et al. (1985). Additional information is available in NJDEP (1980); Grosslein andAzarovitz(1982); and McHugh and Ginter (1978).

Seasonal Distribution of Species Based on Bottom-Trawl Surveys

Group 1: residents found on the bank in all seasons

Little seasonal movement (1a)	Seasonal shifts on the bank (1b)
Little skate	Spiny dogfish
Winter skate	Atlantic herring
American sand lance	Goosefish
Sea raven	Atlantic cod
Longhorn sculpin	Haddock
Windowpane	Ocean pout
Yellowtail flounder	Northern lobster
Winter flounder	
Sea scallop	

Group 2: seasonal migrants found only during the warm or cold time of the year

common in the warm season (2a)	common in the cold season(2b)
Silver hake	Pollock
Red hake	American plaice
White hake	
Butterfish	
Four-spot flounder	
Shortfin squid	
Longfin squid	

Group 3: mid Atlantic species that migrate to the bank in small numbers during warmer seasons

- Summer flounder
- Bluefish
- Scup

Group 4 cold-water species common in the Gulf of Maine or deep water but rare on the bank

- Smooth skate
- Thorny skate
- Redfish
- Cusk
- Witch flounder

Abundance of Larval Fish Species from Zooplankton Samples (Backus, 1987)

Season rankina of species	Mean number/10 m^2	Percent
Winter (26 species *recorded)*		
1. Sand lance, *Ammodytes* spp.	55.2	63.51
2. Atlantic cod, *Gladus morhua*	*18.6*	21.40
3. Haddock, *Melanogrammus aeglefinnus*	5.9	6.79
4. Witch flounder, *Glyptocephalus cynoglossus*	1.5	1.75
5. Pollock, *Pollachius Wrens*	0.9	1.03
Spring (32 *species recorded)*		
1. Haddock, *Melanogrammus aeglefinnus*	*95.7*	58.39
2. Atlantic cod, *Gladus morhua*	*35.8*	19.61
3. American plaice, *Hippoglossoides platessoides*	*8.4*	4.99
4. Lanternfish, *Benthosema glacial*	8.5	4.69
5. Redfish, *Sebastes* spp.	3.2	*1.84*
6. Yellowtail flounder, *Limanda ferruginea*	3.0	1.72
7. Sculpins, Cottidae	3.3	1.60
8. Sand lance, *Ammodytes* spp.	3.0	1.24
9. Winter flounder, *Pseudopleuronectes americanus*	2.0	1.16
10. Snailfishes, Cyclopteridae	1.8	1.03

Tab/e 9-1 (continued on next page)

Season ranking of species	Mean number/1 O m²	Percecnt
Summer (35 *species recorded)*		
1. Silver hake, *Merluccius bilinearis*	377.5	60.10
2. Hakes, *Urophycis* spp.	173.0	27.53
3. Yellowtail flounder, *Limanda ferruginea*	23.2	4.02
4. Offshore hake, *Merluccius albidus*	22.3	3.54
5. Four-spot flounder, *Hippoglossina oblonga*	9.8	1.55
Fall (69 *species recorded)*		
1. Atlantic herring, *Clupea harengus*	25.9	49.41
2. Lantern fish, *Cevatoscopehus maderensis*	5.9	11.37
3. Hakes, *Urophycis* spp.	4.3	8.24
4. Windowpane, *Scophthalmus aquosus*	4.2	7.93
5. Silver hake, *Merluccius bilinearis*	3.3	6.24
6. Offshore hake, *Merluccius albidus*	1.1	2.14
7. Gulf Stream flounder, *Citharichthys arctifrons*	0.8	1.50
8. Flounders, *Bothus* spp.	0.7	1.39
9. Barracudinas, Paralepidiae	0.7	1.31
10. Cusk eels, Ophidiidae	0.7	1.27

Table 9-1. Abundant Fisheries Species on Georges Bank (Backus, 1987)

Smith et al. (1980) have studied the distribution of eggs and larvae in this area, most of which are pelagic. Ichthyoplankton were found over the whole continental shelf and peaked in abundance in the spring and fall with the exception of sand lance. Sand lance is an important forage species and its larvae peak in abundance in the winter.

The edge of the mid- and north Atlantic continental shelf contains submarine canyons (e.g. Baltimore, Wilmington, Oceanographer Lydonia). Demersal species such as tilefish, red crab, and lobster congregate in this area of increased topographic relief. Mackerel, tuna, squid, billfish, swordfish, and butterfish also occur in the canyons and intercanyon areas. Because of the potential for canyon heads to “funnel” drilling discharges and the biological enrichment associated with canyons, MMS has sponsored numerous studies on the physical conditions and biological communities associated with canyons. An MMS-funded study by Hecker et al. (1980) on canyons concluded that these areas represent heterogeneous environments that afford a variety of substrate types in comparison to similar depths on the slope. Therefore, canyon fauna may diner from slope fauna by being composed of a wider variety of trophic types. A 1983 study by Hecker et al. further identified that canyons having outcrop exposures have large populations of filter-feeding species whereas comparable slope areas are dominated by mobile scavengers. Further discussions on faunal densities and depth range can be found in Hecker et al. (1983).

CSA (1983), completed an extensive review of literature and unpublished data concerning North Carolina fisheries and the marine environment. A further review and compiling of information on fish and fisheries resources in the south Atlantic is available in the MMS EIS for Lease Sale *90* (MMS, 1984a). The fish communities in this area are categorized into three (nearshore, outer shelf, and oceanic pelagic) groupings, based on their distance from shore. Changes in community structure, with increasing distance from shore, reflect both the differences in bottom substrate and an increasing influence of the Gulf Stream,

Nearshore species consist of many of the species often considered, by the public, as representative of south Atlantic fishery resources. These species generally tolerate a wide range of temperatures, salinities, and oxygen levels. Year-round inhabitants of this area include pink and white shrimp, blue crab, spotted seatrout, black drum, and southern kingfish. They are usually found over soft-bottom sediments or in association with algae or attached vegetation.

The primarily nearshore, but spawn offshore group includes brown shrimp, menhaden, croaker, spot, summer flounder, and striped mullet. Spawning peaks during the winter and species return to the nearshore region for the rest of the year.

The outer shelf and shelf-edge live-bottom area attract species that associate with hard-bottom substrates, rocky outcropping, wrecks, coral growths, sponges, and other bottom anomalies. Species common in this area generally belong to the "snapper-grouper" complex. The MMS study efforts through the Marine Resources Research Institute (MRRI) (MRRI, 1981, 1982); Sedberry and Van Dolah (1984); and Sedberry (1 883, 1985, 1987, 1988 and 1989) have further identified fish communities, such as sheepshead, black seabass, and whitebone porgy, in these areas and their feeding habits.

Ocean pelagics or blue water species often migrate from the South Atlantic Bight as far north as Georges Bank and the Gulf of Maine. These species are often associated with the Gulf Stream and include dolphin, yellowfin tuna, little tunny, sailfish, swordfish, and white marlin. The deep-water species assemblage includes lanternfish, anglerfish, rattails, grenadiers, blue hake, and some deep-sea eels.

Substantial fisheries information is available for the Straits of Florida. Groupers, snappers, grunts, jacks, marlins, sailfish, mackerels, drums, bluefish, mullets, pink shrimp, stone crabs, and spiny lobsters are of commercial and recreational importance. Spiny lobsters, snappers, and groupers inhabit the reefs. Jacks, Spanish and king mackerel, sailfish, and white and blue marlin are principal oceanic species. The extensive estuaries, tidal marshes, seagrass beds, mangrove swamps, mud and sand flats, and coral reefs provide breeding, nursery, and feeding grounds for life stages of almost all of the species listed for this area.

Gulf of Mexico Region

Oil and gas leasing activities have been ongoing in the Gulf of Mexico and OCS waters many years, resulting in thousands of offshore drilling and production structures. The MMS has addressed the question of impacts from these structures on fish ecology and distributions through studies and synthesis papers (Gallaway and Lewbel 1982; CSA, 1982).

With this long history of coexistence between the petroleum and fishery industries, many issues relating to potential impacts or conflicts have been resolved or accepted in some fashion. However, with a change in emphasis from prelease studies to long-term impacts of postlease activities, this region is a logical area for closer evaluation. The detection of impacts of specific environmental stresses on fish populations is difficult because of the large natural variability in fish populations and the lack of a quantitative, predictive relationship between numbers of marine pelagic larvae and the size of the recruitment population. These difficulties are compounded in the Gulf of Mexico due to the significant input of potential environmental pollutants from industrial and municipal discharges. Further, in all regions where there is a major commercial fishing industry, fishing pressure may significantly impact fish species of commercial importance and also noncommercial species, the victims of by-catch.

The MMS has conducted studies to investigate the distribution and abundance of various life history stages of commercially and recreationally important fishes. Studies have been undertaken to document the movement of commercially important snappers and groupers off Texas (USDOC, 1979a). In addition, studies have investigated the temporal and spatial fluctuations in zooplankton populations both in the western and eastern Gulf of Mexico (USDOC, 1979a, b; Houde et al., 1979).

Other significant contributions to fisheries information have been made by the four NMFS laboratories in this region. The Galveston NMFS laboratory provides the Gulf Regional Fishery Management Council with information on the Gulf shrimp fishery. The Pascagoula and Bay St. Louis laboratories survey resources of fishery stocks of the southeast and develop forecast models for commercial fisheries. The Panama City laboratory researches on the distribution and abundance, migrations, coastal ecology, and predator-prey relations of commercially and recreationally important species of fish.

Nearly all of the species significantly contributing to commercial catches are estuarine dependent. With some exceptions, most species leave the estuaries as juveniles or subadults and spawn at sea after becoming reproductive adults. The eggs of the majority of these species hatch in the waters of the open Gulf, and the developing larvae become part of the offshore planktonic community. Under the influence of tides, currents, and winds, the young eventually arrive at the estuarine nursery grounds where they feed, grow, and mature before migrating out to seato repeat the spawning process. A major description of the life cycle of individual species of demersal fishes and penaeid shrimp was sponsored by the MMS in the western Gulf from the Rio Grande River to the Mississippi River delta (Darnell et al., 1983) and in the eastern Gulf from the Mississippi River delta to the Florida Keys (Darnell and Kleypas, 1987).

An overview of fisheries information of importance to MMS is emphasized in the Final Regional Environmental Impact Statement for this region (MMS, 1983d). Characteristic fisheries are associated with the various Gulf environments. The low salinity estuaries are generally dominated by finfishes such as croakers, spot, sand trout, anchovies, mullet and menhaden, and shellfishes such as oysters and crabs. The shallow Gulf characteristically contains such fishes as the Gulf whiting and the Atlantic threadfin. The bottom becomes muddier outside this zone and includes such fishes as the croaker, spot, star drum, silver trout, and longspine porgy.

Farther offshore toward the middle shelf, the number of sciaenids (drum family) is drastically reduced, and the fish community is dominated by small flounders and searobins. The offshore reefs support such fishes as snappers and sea basses, whereas oceanic fishes such as bluefin tuna and broadbill swordfish inhabit the offshore open ocean waters (USDOC, 1979d). Platforms on the OCS may essentially serve as artificial reef habitats and alter the local ecosystem (Ditton and Auyong, 1984).

Nine species of penaeids contribute to the Gulf of Mexico's shrimp fishery. Brown, white, and pink shrimp are the three most important commercial species. Brown shrimp are centered in the northwestern Gulf, whereas white shrimp are principally found on the mud and sand bottoms off the coast of Louisiana. Pink shrimp have an almost continuous distribution throughout the Gulf, but consistent commercial pink shrimp catches are made on the shell, coral sand, and coral silt bottoms off southern Florida.

Gulf menhaden occur in the shallow waters of the north central Gulf from eastern Florida to eastern Texas with about 93 percent of this fishing effort occurring within 10 miles of shore. Also, the industrial bottomfish trawl fishery exists in the nearshore waters of the north central Gulf. Generally, the following fishes contribute 95-98 percent of the trawl fishery catch: croaker, spot, sand seatrout, silver seatrout, silver eel, catfish, and longspine porgy. Croaker, the largest component of the catch, prefer a mud bottom and are generally not found in depths exceeding 60 m. Approximately 50 species of food finfish are harvested in the Gulf. Some of the more important ones include croaker, snapper, grouper, white mullet, red and black drum, spotted and silver seatrout, Spanish mackerel, spot, pompano, flounder, crevalle, Gulf kingfish, sheepshead, and king mackerel. The majority of food finfish are caught in coastal waters with the exception of such fishes as snappers, groupers, mackerels, tunas, and billfish.

Pacific Region

Much of the Pacific Region's information needs on fisheries has been obtained through interagency cooperative work and data compilation. For example, the NMFS centers and laboratories provide technical advice and conduct a wide range of research including economics, effects of pollution in the marine environment, and survival of anadromous fish.

The Washington and Oregon offshore marine environment supports about 400 fish species including both year-round residents and seasonal migrants (Schultz, 1936; Miller and Lea, 1972; Hart, 1973). Most species inhabit the entire length of the area and many are of commercial and recreational value.

An Interagency Agreement (1A) with NOAA-NMFS was initiated to describe the spatial and temporal distribution, early life history, and recruitment patterns of economically and ecologically important fishes in the Pacific OCS of northern California, Oregon, and Washington. An additional sampling for Dover sole is being conducted in conjunction with the 1A. The results of these studies will be available in July 1991.

The NMFS and Oregon State University (OSU) compiled fish catch statistics and conducted ichthyoplankton and/or trawl surveys in the Washington-Oregon Planning Area. Summaries of relevant information on the ecology, distribution, and catch statistics of fishes include Glude (1971), Hart (1973), Browning (1980), and Miles et al. (1982). The Washington-Oregon Planning Area is particularly important as a fishery center for salmon, Pacific whiting, rockfishes, sole, albacore, herring, and a variety of shellfish including shrimp, crab, and oysters (Parmenter and Bailey *1985).* To further the information gathered in this area, MMS has funded the study of fish assemblages found on the rocky banks of the northwest Pacific. The results of this study should be available in July 1991.

The Northern California Planning Area includes roughly 485 fish species and is to be similar to the Washington-Oregon Planning Area in species composition (Miller and Lea, 1972; Winzler and Kelley, 1977). The MMS funded MBC Applied Environmental Sciences (1987a) to conduct a literature search on 32 target species. These species included, red abalone, prawns, shrimp, Dungeness crab, albacore, sole, Pacific salmon, and northern anchovy. The search revealed that there is considerable information available about the general ecology of most of the target species.

Further work (MBC, 1987b) looked at the development of platform fish communities. Fishes begin to aggregate near or recruit to new platforms even as they are being constructed. Transforming juveniles of species with pelagic eggs and larvae recruit to the platform from the plankton. Pelagic schooling species such as mackerals and jacks were often the first attracted to offshore structures.

Major epipelagic fishes include Pacific herring, Pacific sardine, northern anchovy, Pacific salmons (mostly chinook with some coho), jack, mackerel, and albacore tuna. Common offshore benthic species include white sturgeon, Pacific hake, Pacific cod, rockfishes, sablefish, lingcod, and flatfishes. Shallow (inshore) benthic species common to sandy bottoms include sharks, skates, rays, sturgeons, smelts, white croaker, surfperches, and flatfishes. Rocky bottomed shallow benthic areas are frequented by rockfishes, lingcod and other greenings, sculpins, blennies, and eels.

The Central California Planning Area includes approximately 500 species of fish (Miller and Lea, 1972; Winzler and Kelley, 1977). Several references that summarize information on commercial and recreational fisheries are Frey (1971), Fitch and Lavenberg (1 971), Miller and Lea (1972), Eschmeyer et al. (1983), California Department of Fish Game (CADFG) (1985), and Ahlstrom (1965).

Common epipelagic fish species in this region include the northern anchovy, Pacific herring, Pacific sardine, chinook and coho salmon, albacore tuna, and market squid. Shallow benthic species commonly associated with sandy benthic environments include surf perch, flatfishes, sharks, skates, rays, croakers, and several epipelagic species. Rocky shallow benthic areas are commonly inhabited by sharks, greenings, sculpins, rockfishes, sea basses, various ells, and gobies. Offshore benthic areas support sharks, sablefish, lingcod, rockfishes, and flatfishes.

The Southern California Coastal Water Research Project (SCCWRP) has conducted ichthyoplankton and trawl surveys for several years that include the Southern California Planning Area. Additional references for commercial and recreational species include Frey (1971), Fitch and Lavenberg (1971), Miller and Lea (1972), Eschmeyer et al. (1983), and CADFG (1985). References on abundance and spawning distribution include Ahlstrom (1965), Mais (1 974), MacCall et al. (1976), Mearns (1979), Gruber et al. (1982), Loeb et al. (1983), and MMS (1983d).

Eighty-seven percent of the species of coastal marine fishes known to occur in California are found in the Southern California Planning Area (Miller and Lea, 1972). Approximately 485 species, exclusive of deep-sea species, are found in southern California waters.

The MMS recently funded a study to provide preliminary information on the species composition, abundance, movements, and biology of fishes in the vicinity of a platform and rocky reefs in southern California. In addition, the study will assess various research techniques and other research methodologies that may be used in future studies. The information will be available in June 1991.

Common epipelagic species in this planning area include common thresher, Pacific herring, northern anchovy, surfsmelt, Pacific saury, sablefish, and greenings. Species inhabiting shallow sandy benthic areas include Pacific electric ray, round stingray, surfsmelt, and California grunion. Inhabitants of the shallow rocky benthic environment include rockfishes, greenings, and cabezon. Offshore benthic species include Pacific electric ray, round stingray, rockfishes, sablefish, and greenings.

The MMS Pacific regional office has funded the CADFG to review and synthesize information on selected commercially, recreationally, and ecologically important fish species found off the coast of California. The contractor is also developing software for MMS staff to access various fisheries databases from NMFS and CADFG. This contract is expected to be completed in early 1991. Marine Biological Consultants (MBC) has been contracted to incorporate Washington and Oregon fish data with the CADFG database. This product is also expected to be available in early 1991.

Alaska Region

The MMS has conducted major studies on the fish and fisheries related research in the waters off Alaska. In addition, the NMFS Northwest and Alaska Fisheries Center of NOAA and the Alaska Department of Fish and Game (ADFG) are a prime source of fisheries data.

The following narrative consists of brief descriptions of fish resources in several of the MMS Alaska Region Planning Areas, taken from the 5-year EIS (MMS, 1987c), and individual lease sale EIS's, referenced when cited. These discussions focus on species of commercial importance because most of the fisheries information available is on commercial species. A good source of additional information on the marine fisheries of the Gulf of Alaska Planning Areas is the MMS synthesis book, *The Gulf of Alaska - Physics/ Environment and Biological Resources,* edited by Hood and Zimmerman (1987).

The Gulf of Alaska, Kodiak Island, and Cook Inlet Planning Areas contain extensive and diverse fishery resources. Approximately 365 species of vertebrates and invertebrates inhabit this area. The EIS for Lease Sale 88 (MMS, 1984b) should be consulted for more details and references.

All five species of Pacific salmon (sockeye, coho, chinook, pink, and chum) are found in the Gulf of Alaska. Salmon are generally found in the upper 10 m of the water column, and follow extensive feeding and spawning migrations. Other common pelagic species include the steelhead trout and the Pacific herring. Steelhead trout are anadromous and may foil ow migratory patterns similar to those of salmon. Herring are an abundant and widespread forage fish that occur in dense schools, providing food for marine fish, mammals, and birds.

Groundfish make up the largest numbers and biomass of species harvested from this area. Common species include atka mackerel, walleye pollock, Pacific cod, sablefish, Pacific halibut, arrowroot flounder, flathead sole, rock sole, Dover sole, yellowfin sole, and rockfishes. Descriptions of the life histories and distributions of these species can be found in Hart (1 973), Pereyra et al. (1976b), and Ronholt et al. (1976).

Several species of crustaceans are of major commercial importance in this area: red, blue, and brown king crab; Dungeness crab; and pink shrimp. Some of the most productive shrimp fishing grounds are found in areas of submarine canyons that extend shoreward into deep-water bays. Mollusk species of commercial importance include clams, scallops, abalone, octopus, and squid.

In the Shumagin Planning Area, groundfish are of major economic importance. Pacific cod, sablefish, halibut, and several other flounder species are the dominant groundfish species; red king crab and pandalid shrimp were the shellfish species of major economic importance until recent population declines. All species of Pacific salmon are harvested from these waters, and there are rearing populations of this group as well. Sockeye, pink, and chum salmon predominate in the commercial catches from the inshore fisheries.

An excellent source of information on the fisheries resources of the eastern Bering Sea Planning Areas is the book, produced by MMS, *The Eastern Bering Sea Shelf: Oceanography and Resources,* edited by Hood and Calder (1981). In addition, the lease sale EIS for Sale 92, North Aleutian Basin (MMS, 1985 b), and the special paper prepared by the Alaska regional office, *Summary of Fisheries Information for the North Aleutian Basin,* (MMS, 1985e) should be consulted. These sources contain extensive lists of additional references.

The fisheries resources of the Bering Sea (North Aleutian, St. George, and the Navarin Basins) are diverse and extensive with over 300 species of fish inhabiting the area. Benthic species, generally found on the continental shelf and slope at depths of less than 300 m account for over 50 percent of the marine fish species. There are about 40 species of pelagic and bathypelagic fish (including most of the anadromous species). The eastern Bering Sea also supports over 251 pelagic and 472 benthic invertebrate species. Species of commercial value in this area include the five species of Pacific salmon, Pacific cod, yellowfin sole, walleye pollock, Pacific halibut, Pacific herring, rock sole, flathead sole, Alaska plaice, red king crab (recently depressed, but thought to be recovering), and tanner crab. The fisheries resources of this planning area are of major commercial importance, and U.S. fishermen harvest over 100,000 metric tons of fish and shellfish here.

Pacific salmon undertake extensive spawning and feeding migrations. The salmon runs fluctuate greatly from year to year, however, about 88 percent of all salmon entering streams bordering on the Bering Sea cross through the North Aleutian Basin waters on their spawning migrations (Thorsteinson, 1984).

Pacific herring are a pelagic species of commercial importance and are also an important forage fish in the Bering Sea. They overwinter in offshore waters near the edge of the continental shelf and migrate into nearshore waters to spawn in the spring. Pacific sand lance are important forage fish in this area as well.

Other major fish species in this planning area include rainbow smelt, eulachon, walleye pollock, Pacific cod, rockfish, Pacific" ocean perch, atka mackerel, sablefish, yellowfin sole, Pacific halibut, Greenland turbot, rock sole, Alaska plaice, flathead sole, and arrowtooth flounder.

Bivalve mollusks are concentrated in the midshelf region of the Bering Sea (North Aleutian Basin), but some species are found in the near surf zone (Pacific razor clam and surf clam). There are four commercially important crab species in this area (red king crab, currently depressed; two species of tanner crab; and Dungeness crab), and two commercially important species of pandalid shrimp.

The St. George Basin Planning Area occupies almost 28 million hectares of the Bering Sea between the lower Alaskan Peninsula, the eastern Aleutians, and the Pribilofs. This area is noted for its vast fisheries resources, producing large annual harvests of groundfish (mainly pollock), and smaller harvests of shellfish (mainly blue king crab). Details on the fisheries of this area can be found in Higgins (1978); Bakkola and Smith (1978); Pereyra et al. (1976 a); Best (1 979); Wespestad and Barton (1981); Straty (1975); USDOC (1980); State of Alaska (1983); McMurray et al. (1984); and Armstrong et al. (1981). Information on Bering Sea invertebrates can be found in Feder and Jewett (1 980). The EIS for Lease Sale 89 (MMS, 1985c) should be consulted as well.

Major groundfish species in this planning area include walleye pollock, yellowfin sole, Pacific halibut, Pacific cod, sablefish, Pacific ocean perch, Greenland turbot, rock sole, and flathead sole. Herring, capelin, smelt, and sand lance are important forage fish, and herring are valuable commercially as well. All five species of Pacific salmon are found in this area, and migrating adults are present from mid-May to mid-September Shellfish and mollusk species include red and blue king crab, tanner crab, Korean hair crab, several species of pandalid shrimp, snails, surf clams, and razor clams.

Relatively little information is available concerning benthic communities within the Navarin Basin Planning Area. Some information exists concerning fish species of potential commercial importance, and many of the references already cited for other Bering Sea planning areas apply here as well. Walleye pollock is harvested intensely at this time. Other important species include Pacific halibut, yellowfin sole, Greenland turbot, arrowtooth flounder, flathead sole, Alaska plaice, rock sole, Pacific cod, sablefish, rockfish, atka mackerel, Pacific sal mon (how many of the five species is uncertain), and herring. All of the Bering Sea crab species occur here; however, blue king crab and tanner crabs predominate. Three species of pandalid shrimp and several species of large snails and squid are of commercial importance as well. The EIS for the lease sale proposed in March 1984 (MMS, 1983c) should be consulted for details.

The fishes in Norton Basin Planning Area are derived from both subarctic-boreal and arctic-marine communities. The approximately 87 fish species can be divided into three distinct groups: (1) coldwater fishes indigenous to arctic-marine waters (arctic cod, longhead dab, and Arctic flounder; (2) sub-arctic boreal fishes whose distribution is centered south of Norton Basin in the Bering Sea or the Pacific Ocean (salmon, saffron cod, yellowfin sole, starry flounder, Pacific herring); and (3) anadromous freshwater fishes (char, whitefishes, and smelts). The density of fishes and epibenthic invertebrates, especially of demersal populations, is considerably lower than in the northeastern Gulf of Alaska or the eastern Bering Sea (Wolotira, 1981). Pelagic resources of the Norton Basin also appear less abundant than in other Alaskan regions, as suggested by multiyear catch statistics. The demersal fishes of Norton Basin are dominated by cods and flatfishes, which comprised over 75 percent of the demersal-fish biomass estimated in 1976 (Wolotira et al. 1977). Saffron cod and starry flounder are the predominant demersal species. Several other demersal species are relatively abundant, including the shorthorn sculpin, yellowfin sole, and Alaska plaice. Arctic cod was estimated to be the second most numerous fish in Norton Basin, even though it had a relatively low estimated biomass.

Pelagic fishes include five species of Pacific salmon, Pacific herring, rainbow or toothed smelt, capelin, other salmonids (char and whitefish), and other smelts. Pacific herring is the most important marine-pelagic species in the Norton Basin (Burns et al., 1982), and is an important link in the marine food web. Two other relatively important pelagic species are rainbow (toothed) smelt and capelin. The EIS for Lease Sale 100 (MMS, 1985d) should be consulted for additional details and references.

The fish resources of the Chukchi Sea Planning Area include marine, anadromous, and freshwater species. Trawl surveys supported by MMS have found a total of 54 marine fish species representing 13 families. Compared to the Bering Sea, this fish fauna is poor in terms of both species diversity and numerical abundance. It is, nevertheless, apparently larger than the fish fauna of the Beaufort Sea. Four fish species contributed to over half of the total fish biomass in the 1976 BLM OCS trawl surveys (Wolotira et al., 1977) in waters of the southeastern Chukchi Sea: starry flounder, Pacific halibut, saffron cod, and Pacific herring. Arctic cod, despite being the most frequent and abundant fish caught, ranked fifth in biomass because of its smaller individual size. The distribution of many of the marine species appears to be governed by temperature and salinity. The marine fish populations are important primarily as a food resource for marine mammal and seabird populations of the region. Sixteen anadromous fish species have been reported from the Chukchi Sea region, including 12 salmonids and 2 smelts. All five species of Pacific salmon common along the Alaskan coast are known to spawn in freshwaters of the Chukchi Sea coast. The pink and chum salmon are most abundant. The runs of salmon in Chukchi Sea tributaries are greatest in rivers entering Kotzebue Sound, especially the Noatak and Kobuk Rivers.

Marine fish resources sampled, during MMS investigations, by trawl surveys taken in the northern Chukchi Sea were described by Frost and Lowry (1983) and Fechhelm et al. (1984). Fyke- and gill-net samples from the coastal waters were described by Fechhelm et al. (1984) and Kinney (1985). Studies of the food habits of seabird colonies at Capes Thompson and Lisburne have also contributed to the knowledge of marine fish of this area (Springer and Roseneau, 1978). Forty-one marine fish species have been reported for the Chukchi Sea, representing 11 families (Morris, 1981). Distribution of marine fish species in the Chukchi Sea appears to be governed by temperature and salinity, Yellowfin sole and saffron cod occupy the shallower, seasonally warmer waters, whereas Arctic cod and Bering flounder are usually found in deeper, colder waters.

Arctic flounder, starry flounder, and fourhorn sculpin frequent low-salinity waters near estuaries and mouths of rivers. The majority of marine fish in this area are demersal as adults, with the exception of Pacific herring, capelins, and Pacific sand lance, which are pelagic as adults.

Higher salinity waters are preferred by most of the other marine fish species that probably occur throughout the broad coastal shelf (Morris, 1981). Generally, marine fish in this region are smaller than those in areas farther south, and densities are much lower (Bowden and Moulton, 1981). Many of the marine fish populations may be maintained by recruitment of eggs and larvae transported north from the Bering Sea by the Alaska Coastal Current.

Arctic cod was the dominant offshore demersal fish in the northeastern Chukchi Sea during a late summer-early fall trawl survey in 1977 (Frost and Lowry, 1983). Arctic cod; Pacific sand lance, capelin, Pacific herring, saffron cod, sculpin, and smelt are important prey of marine mammals and seabirds in the Chukchi Sea (Seaman and Burns, 1981; Lowry et al., 1979; Springer and Roseneau, 1978). Thirteen anadromous fish species have been reported from the Chukchi coast and freshwaters (Morrow, 1980), including pink salmon, chum salmon, Arctic char, cisco, whitefish, and smelt. Sockeye, coho, and king salmon are occasionally caught in coastal waters, but they generally reach their northern spawning limit in the Point Hope-Point Lay coastal sector at Cape Lisburne. The draft EIS for the Chukchi Sea Lease Sale No. 109 (MMS, 1987b) should be consulted for additional information and references.

The fish resources of the Alaskan Beaufort Sea have been described by Craig (1984a, b, 1987) and Dome Petroleum et al. (1982). Much more is known about the coastal species than those species found in offshore waters (see Craig references; Envirosphere, 1985; Cannon and Hachmeister, 1987; Moulton et al., 1985). Three basic groupings of fish occupy this area during some part of their life cycle: freshwater species that make short excursions from coastal riiers; anadromous species; and marine species. The low temperatures, low productivity, and harsh ice conditions of these waters seem to make them relatively unattractive to fish. Excluding freshwater species, only 43 species of fish have been recorded in the Beaufort Sea, compared to nearly 400 for the Bering Sea and the Gulf of Alaska.

Distribution of anadromous fish depend on the freshwater input of major coastal rivers, local wind patterns, and ice formation in winter. A narrow band of warm brackish water forms nearshore from the riverine input and greatly affects the movement of anadromous fish. Freshwater species found in the coastal waters include Arctic grayling, round whitefish, and ninespine sticklebacks. Anadromous species include Arctic char, Arctic cisco, least cisco, Bering cisco, rainbow smelt, broad and humpback whiting, and boreal smelt. The most important marine species, in terms of abundance, include Arctic cod, twohorn and fourhorn sculpins, saffron cod, Canadian eelpout, capelin, several species of snailfish, Arctic flounder, and starry flounder. For more details, the EIS for the Beaufort Sea Lease Sale No. 97 (MMS, 1987a) should be consulted,

Generic Discussion of Potential Effects of Oil and Gas Industry Activities on Fish and Fisheries Resources

To assess and predict the impacts of oil and gas activities on fish, MMS analysts review information on:

- spatial and temporal distribution “and abundance of species (all life history stages);
- short- and long-term environmental effects of oil and gas activities on the fish and their critical habitats and prey and;
- probability of discharge of oil, etc., and its trajectory and behavior in the environment.

This section includes a general discussion of the potential impacts of OCS oil and gas activities on fish based mainly on the book, *Oil in the Sea* (NRC, 1985) and the report prepared for the Interagency Committee on Ocean Pollution, Research, Development and Monitoring (Boesch and Rabalais, 1987).

The potential short- and long-term, and direct and indirect biological effects of oil and gas industry activities on fish and fish resources may be caused by the following agents: acoustic signals from seismic surveys; drilling muds, cuttings and formation waters; dispersants; physical structures such as platforms and pipelines; and oil.

Seismic Effects

In response to concerns about potential seismic effects, there is no experimental evidence to indicate that sounds from nonexplosive survey devices have lethal effects on adult finfish (Falk and Lawrence, 1973; Weaver and Weinhold, 1972). So far, the effects observed are behavioral, such as startle responses, alarm, avoidance, changes in aggregating behavior, and change in feeding behavior. These potential impacts are of concern to the fishing industry, but are not expected to pose any threat to the fish resources themselves.

Fishermen in California have been concerned about the perceived impact of acoustic seismic surveys on their fishing activities. This concern was a major reason for the *Pilot Study on the Dispersal of Rockfish by Seismic Exploration Acoustic Signals* (Greene, 1985). Although the results were equivocal, this study suggested that seismic survey sounds may affect the hook and line rockfish fishery through dispersal of fish.

Subsequent to the pilot study, an MMS study was conducted by Battelle Memorial Institute (Battelle and BBN Laboratories, 1987) to determine whether acoustic devices can affect the hook and line rockfish fishery through effects on fish aggregations and/or on catch-per-unit-effort (CPUE). The study did detect a change in CPUE under the specific conditions of the experimental trials using a single airgun. The potential exists for a decline in fishing success during and following seismic testing using airguns.

A study has also recently been completed by Tracer Applied Sciences (Holliday et al., 1987; funded by American Petroleum Institute and the State of California in response to concerns expressed by the commercial fishing industry) to examine the effects of seismic surveys on northern anchovy eggs, larvae, and adults. The final report concluded that worst case impacts to eggs and larvae would only occur if they were subjected to nearfield (i. e., 3 m or less) multiple exposures from a full seismic array.

Drilling Muds and Formation Waters

Two excellent reviews of this topic are available and should be consulted for specific information: *Drilling Discharges in the Marine Environment* (NRC, 1983) and *The Biological Effects of Drilling Discharges* (Neff, *1987),*

The major environmental concerns about the effects of drilling discharges are that they may kill marine organisms or produce sublethal, harmful effects on the organisms or ecosystems, and that metals and/or organic compounds may accumulate in marine organisms and have harmful effects on consumers. Both of the studies cited reach the conclusion that most water-based drilling fluids used in the United States have low acute and chronic toxicities to marine organisms. Only those muds designated by the EPA to be environmentally acceptable, as determined by bioassay test results, can be discharged on the OCS. Effects are primarily restricted to the ocean floor in the immediate vicinity of the platform and a short distance down-current from the source of the discharge. Therefore, large motile organisms such as marine pelagic fish are not likely to be affected by these discharges.

The NRC report indicates that drilling should be conducted in a manner to prevent muds and cuttings from burying sensitive biota and that the more toxic additives to drilling fluids should be monitored or their use should be limited. Neff (1 987) concludes that no further studies on the effects of drilling fluids from exploratory rigs are needed, except in particularly sensitive environments. In most situations, routine operational drilling discharges from exploratory drilling do not appear to have any significant direct effects on fish or fisheries resources.

In addition to oil and gas, produced (formation) water also is recovered during petroleum production. Produced water is interstitial water present under natural conditions in a geologic formation. The discharge of these waters is subject to EPA NPDES permit regulation.

Produced waters contain dissolved inorganic salts in concentrations that vary widely, depending on the formation. The most common chemical constituents found in produced waters are iron, calcium, magnesium, sodium, bicarbonate, sulfates, and chloride. The produced water properties that may adversely affect the marine environment are entrained oil or petroleum hydrocarbons, high trace metal concentrations, and low dissolved oxygen concentrations.

Usually, this water is removed at the production site and disposed of by injection into disposal wells or discharged into the marine environment after treatment. Produced water is diluted very rapidly following discharge. Because of this rapid mixing with seawater, most physical and/or chemical features of produced water do not pose a hazard to water column biota, fish, or fishery resources.

Physical Structures and Habitat Alterations

Concerns have been raised on the effects structures may have on habitats – this concern varies considerably. Boesch and Robilliard (1987) present a comprehensive review of this topic. They conclude that most of the effects from emplacement of structures, deposition of cuttings, construction of gravel islands, and emplacement of pipelines in the offshore environment are not serious on a regional basis. It is not known whether the platforms actually enhance populations of the fish they attract or concentrate existing resources. They will (or can) enhance shellfish populations (e.g., California harvest of mussels). The effects of both platforms and drill cuttings are highly localized. This conclusion is also true for artificial islands. Pipelines may cause problems for fishermen, but they are unlikely to significantly impact fish resources.

The enhanced numbers of fish near platforms, whether increasing the population or merely concentrating it, does raise issues of debate. In the event of an oil spill, the populations will beat particular risk, Under normal conditions, prey species may be subject to enhanced predation (or fishing). The sudden removal of platforms following years of operations may also have effects on the local resources that are difficult to predict.

Coastal impacts from support activities onshore may be more significant than offshore impacts, depending on the nature of the coastal environment and the degree fishery species use near coastal waters for nursery grounds. With both extensive wetlands and years of offshore oil and gas production activities occurring in the northwestern Gulf of Mexico, the potential for coastal impact is greatest in this area. "Wetlands loss" is a significant environmental concern, and further aspects of this problem are discussed in the chapter "Coastal Impacts."

Oil

There are several excellent review documents on this topic to consult for detailed information and extensive lists of references (Malins and Hodgins, 1981; Rice et al., 1984; NRC, 1985; Anderson et al., 1986; Capuzzo, 1987). They conclude that most of the long-term effects from OCS oil and gas activities of concern will be caused by the chronic, sublethal discharges, rather than the infrequent blowout or oil spill. The following discussion is taken from these review documents.

The effects of oil on fish, whether from an oil spill or from chronic input, depend on the external conditions such as the geographic location, dosage and impact area, oceanographic conditions, meteorological conditions, season, and oil type. The impacts may result from direct ingestion of oil or oiled prey – uptake of oil through gills or epitheliums, effects on developmental stages, or effects on the ecosystem upon which the fish are dependent in any life stage. Other stresses in the environment (changes in temperature, salinity, food supply, presence of other pollutants, etc.) as well as intrinsic factors (level of feeding and reproductive activity) may influence the susceptibility of the fish to the oil.

According toCapuzzo(1987): *Biological effects of contaminants can be manifested at biochemical, cellular and organismal /eve/s of organisms before disturbances are seen at the population /eve/. The initial responses in each case are inductions of mechanisms to resist or reduce the toxicant impact, as by induction of toxicant metabolizing processes (at the biochemical level) or by selection of toxicant resistant forms (at the population level). Adaptive processes are capable of countering disruptive processes until the system reaches a toxicant threshold, at which point the adaptive potential is completely overridden* by *the degeneration imposed on the system by disruptive effects. For predictive purposes, it is important to understand the early warning signs of stress at each /eve/ of organization before compensatory mechanisms are surpassed.*

Many studies have been conducted on the lethal and sublethal effects of hydrocarbons on fish. The majority of these studies have been conducted in the laboratory rather than the field, and the exposure doses were often unrealistically high. It is difficult to extrapolate the results from laboratory to field conditions, and so there is only a poor understanding of the effects of oil on fish in the field. Organisms from different geographic locations generally do not appear to differ physiologically in their lethal toxic concentration thresholds or their toxic responses in the laboratory. However, environmental factors existing in cold regions influence both the impact and biological recovery. Cold temperatures decrease the rate of degradation, and hydrocarbon pollutants may remain in the environment for long periods of time; reduced temperatures would also affect hydrocarbon volubility in the water column. Ice cover can interfere with the evaporation of volatile components of spilled oil. Also, the low species diversity in polar regions can affect patterns and rates of recovery following an oilspill.

Capuzzo (1987) states that the nature of the long-term effects of hydrocarbon depends on the persistence and availability of the hydrocarbons, the fate of metabolized products, and the interference of hydrocarbons with metabolic processes that affect the potential for survival and reproduction. Specific chronic effects include impairment of feeding, growth, development, energetic, and recruitment. These effects may lead to changes in community structure and dynamics, as well as alterations in reproductive and developmental success.

Some generalizations can be made about the potential impacts of oil on fish:

- The most sensitive life stages of marine fish occur during the development of gonadal tissue, development of early embryonic stages, and larval transition to exogenous food sources and metamorphosis;
- Eggs and larvae floating near the surface are more sensitive than mobile pelagic adults;
- Pelagic species are more tolerant than benthic species;
- Intertidal species are more tolerant than others; however, the benthic intertidal species are more at risk to chronic exposure from oiled sediments;
- Many fish and some invertebrates accumulate and metabolize (through the mixed function oxygenase system) hydrocarbons; fish can excrete metabolizes and parent hydrocarbons via the liver and

gills; some metabolizes may be toxic or mutagenic both internally and externally;

- Both vertebrates and invertebrates are subject to tainting; however, tainting is unlikely under natural conditions, even after an open ocean oil spill; 'tainting is' more likely to occur in enclosed bays or estuaries;
- No mass mortality of finfish has been observed as a result of open ocean oil spills;
- Mass mortalities of intertidal shellfish have been documented;
- Polar species appear more sensitive than' temperate species, but this sensitivity may be due to the persistence of hydrocarbons in cold environments;
- Polar species may also be especially sensitive to impairment of energetics because of the sporadic seasonal abundance of food, their reliance on stored energy reserves, and "slow recovery rates, as a result of lower fecundity, dispersal, and growth rates;
- Although adult finfish have the ability. to avoid oil in the open ocean, there is not much experimental evidence to indicate whether they do so; ,
- Shellfish are more vulnerable due to the relatively poor or absent motility in adults;
- Salmonids and other anadromous fish may be vulnerable to spilled oil during their spawning migrations when hydrocarbons could interfere with chemical cues used to locate home stream systems;
- Direct effects on fishery stocks have not been observed as a result of mortality of eggs and larvae; and
- It is difficult to assess the impact of an oil spill on finfish populations, which already show large-scale, unpredictable fluctuations in year-class size.

In conclusion, future research efforts should focus on the ecosystem effects of the sublethal, chronic, long-term exposure of marine fish to petroleum hydrocarbons. Some research areas are considered intractable at this point in time because of the large natural variability of fish populations, limited understanding of the recruitment process, and the unpredictable fluctuations in year-class size.

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10. Coastal and Marine Birds

General Description

Birds are often a significant and highly visible component of marine and coastal habitats potentially affected by offshore oil and gas development. It is well documented and highly publicized that an oil spill will severely affect birds that contact surface oil directly (Hooper et al., 1987). The images of oiled birds lying on beaches have become a symbol of the negative impact of oil and gas operations.

An oil spill, particularly resulting directly from OCS operations, is a statistically rare event. Although effects of oil spills on birds and means to rehabilitate oiled birds have been topics of numerous studies, within the context of the OCS Program, less obvious effects from normal day-today operations may be of more concern. Chronic disturbance of key nesting, breeding, or feeding areas is often a potential problem in the site selection of support facilities and logistical supply routes. Fundamental information for most impact analyses concerning birds includes knowledge of key habitats and seasonal use of these locations. Identification of key species or populations, particularly those designated as threatened or endangered, is also essential (see Chapter 11, Protected Species, for legal implications). Finally, determination of the dynamics of bird populations is needed to detect possible chronic impacts from OCS operations and also to estimate the long-term damage to a population in the event of an oil spill.

Through FY 1988, MMS spent about $22.5 million on studies of coastal birds and seabirds. This figure includes major survey efforts combining marine mammals and seabirds under one study contract but excludes additional literature syntheses completed in several multidisciplinary studies. Roughly 5% of the ESP studies budget has been invested in bird research. MMS studies have concentrated on the west coast with 93% of funds spent in the Alaska and Pacific Regions. The remaining 7% represents survey work in the Gulf Region (including the South Atlantic Planning Area).

Many of these studies are interagency agreements (1A's) with the Fish and Wildlife Service (FWS). In general, the MMS has relied on the FWS for much data because of its lead role in the management and study of migratory birds. 1A's between the MMS and the FWS have enhanced and/or accelerated field research in areas of sparse information or of particular concern to the MMS. The majority of MMS funds (56%) have been spent on survey work to *map* species distributions, nesting sites, and habitat utilization. Detailed ecological studies of trophic and population dynamics represent the second most funded research topic (29%), followed by studies on effects of oil and disturbances (visual and noise) (10%). Some effort has been made to combine available data into predictive computer models (3%). Finally, a small amount (1%) has been spent on synthesis and review of existing literature.

The following section identifies available information on marine birds generated by MMS sponsored studies and other sources that have provided data for environmental assessments. The initial question of what species are present in OCS operating areas and the identification of their habitats has been addressed by a variety of information sources and is discussed for each OCS Region. Following these regional accounts, more generic information on effects of OCS activities on birds is reviewed at a national level. Most often, MMS information needs focus on open water areas and seabirds or coastal and island waterbird colonies potentially subject to oil spills and/or disturbance effects.

Regional Data Availability

Atlantic Region

Except for limited survey work by Fritts *et al.* (1 983) and a major literature synthesis including the South Atlantic by Clapp *et al.* (1982 a,b;1983), MMS has funded no specific bird studies in the Atlantic Region. MMS environmental summary studies along the Atlantic coast include sections on birds (TRIGOM 1976; Adamus and Drury 1977; Forsythe and Adamus 1979; MGA 1984). The Department of Energy funded a major study on seabird distributions off the northeast coast (Powers, 1983), and the FWS has done considerable work on coastal and estuarine habitats (Cortese and Groshek, 1987; Spendlow and Patton,'1 988). Powers (1987) noted that much data remains scattered in unpublished reports, personal files, and current research.

In part due to the human population density along the North Atlantic seaboard and relatively intense bird observation activities coordinated through the National Audubon Society (Temple and Wiens, 1989) and State agencies, considerable additional information is available to supplement formal research programs (Heppner and Gould, 1973). Between North Carolina and Massachusetts, 380 species of birds are reported (Heppner and Gould, 1973). The FWS (Erwin and Korschegen, 1979) mapped breeding colony locations for 30 species of coastal and seabirds from Virginia to Maine. In addition to concentrations of birds in breeding colonies there are critical assembly and concentration areas for migrations. Many of these areas are incorporated into the National Wildlife Refuge system while others, such as Block Island (RI), remain predominantly in private ownership (Heppner and Gould, 1973). In general, relatively good data exist for coastal birds in the North Atlantic Planning area.

Less is known about pelagic distributions of seabirds, although available information has increased rapidly in the past decade (Powers, 1983; 1987). Some of the largest aggregations of marine birds in American waters occur on Georges Bank each fall (Powers and Van 0s, 1979). Thirty-two species regularly occur on Georges Bank; all except one are migrants or": nonbreeding residents (Powers and Brown, 1987). The most abundant bird in summer and fall is the greater shearwater. Distributions of several species of marine birds appear to' be influenced by fishing fleets, especially during the winter. The largest U.S. nesting populations of Atlantic seabirds are found along the coast of Maine (Fefer and Schettig, 1980).

TRIGOM (1976) provides considerable information on species and distributions of marine birds along the Atlantic seaboard. Adamus and Drury (1977) updated North Atlantic information and noted the lack of information on pelagic seabirds and the relationship between offshore structures and seabirds.

Gusey (1976) reports that 380 bird species have been observed within the Mid-Atlantic Bight (Cape Cod to Cape Hatteras), with approximately 80% occurring regularly during some portion of the year. The mid-Atlantic coastline is deeply indented by a series of wide estuaries and bays. These features present obstacles to migrating landbirds, but havens for wintering ducks and geese. Rowlett (1980) summarizes observations of marine birds on the OCS between 37 and 39 degrees North from 1971-77. He reported 56 species of sea birds, excluding nearshore species, within 8 km of the coastline. Gulls dominated in the winter months while Wilson's storm petrel was the the most common summer species. Nearshore, Erwin and Korschgen (1979) provide an inventory of seabird and wading bird nesting colonies for 28 species. Virginia and New Jersey harbored the largest populations of waterbirds along the Northeast shoreline from Virginia to Maine.

In general, the mid-Atlantic shelf waters appear to have lower numbers of seabirds relative to the North Atlantic, particularly Georges Bank and the Gulf of Maine. Conversely, the mid-Atlantic coastline appears particularly rich in coastal and nearshore avian resources (shorebirds, wading birds, waterfowl). The numerous bays and estuaries are essential to migratory waterfowl. Cape May, New Jersey is well known to birdwatchers for the spectacular concentrations of migrating shore-and song-birds.

The South Atlantic coast includes extensive saltwater marshes, barrier islands with bays and sounds, maritime forests, and mangroves. Similar to the mid-Atlantic area, the coastal zone is critical for migratory waterfowl with large numbers of birds overwintering in bays and estuaries. The waters within North Carolina's barrier islands harbor overwintering waterfowl in numbers second only to the Chesapeake Bay along the Atlantic coast (Clapp et al., 1982a) waterbird colonies have been mapped from North Carolina to Key West, Florida (Osborn and Custer, 1978; Portnoy et al., 1981), with North Carolina and Florida having the greatest number of breeding colonies. Old rice fields in coastal South Carolina, initially dammed in the 1800's, and dredged soil disposal sites have created artifical pond-like habitats that appear to be important breeding areas for numerous aquatic birds (Forsythe and Adamus, 1979). Farther south, the Florida mangrove communities are particularly diverse and productive, with birds as a conspicuous component.

Although a relatively good knowledge of nearshore and coastal birds exists in the region, "information on seabirds is notably sparse (Forsythe and Adam us, 1979; Clapp et al., 1982). Forsythe and Adamus (1979) characterize the summer community as mainly post-breeding visitors from the Southern Hemisphere (e.g., Wilson's storm petrel, Cory's shearwater, royal tern). The winter community includes the pomarine jaeger, but information is fragmented with no detailed understanding of the entire community.

Gulf of Mexico Region

The MMS has funded several cooperative efforts with the FWS to study birds in the Gulf of Mexico (GOM) Region. From May 1980 to April 1981, three aerial transects in the GOM and one on the Atlantic coast of Florida were conducted by the FWS to study seabirds and marine mammals (Fritts et al., 1983; Chapman, 1984; Woolfenden, 1983). A major review and synthesis of information on birds and effects of oil was conducted from 1978 to 1980 resulting in a three volume report that, for many species, represented the first compilation of information for the southeastern U.S. (Clapp et al., 1982a,b; 1983).

In addition to these dedicated studies, information on birds was included in several FWS *Ecological Characterization* studies co-funded by MMS (Shew et al. 1981; Schemer and Drew 1982; Drew and Schemer, 1984).

The eastern GOM (Florida Gulf coast) includes mangrove swamps, salt marshes and extensive beaches from Naples north to Alabama. Fritts et al. (1983) noted terns as the most numerous offshore bird and sighted relatively large numbers of loons as far as 114 km offshore. The Everglades and Florida Keys, including Florida Bay, represents a unique U.S. habitat for birds. Woolfinden (1983) reports 32 species of birds along the southwest Florida coast either listed as endangered/threatened or considered rare and potentially threatened. Of almost *400* species reported in the eastern GOM, Woolfenden and Schreiber (1973) considered 81 species to be *significant/y affected by saline habitats* in the region.

The central GOM (Alabama, Mississippi, and Louisiana) is characterized by extensive wetlands. Louisiana is second to Alaska in square miles of marshes and estuaries. These wetlands support enormous wintering populations-of waterfowl, perhaps up to seven million ducks and geese (Bellrose, 1976). In addition, coastal islands provide key habitat and breeding sites for seabirds. Portnoy (1977) mapped 186 colonies for 26 species of seabirds and wading birds in the central GOM. Louisiana herons were the most common wading bird, laughing gulls and sandwich terns were the most common seabirds. Keller et al. (1984) updated Portnoy's survey work and noticed significant desertion of 1977 colonies, but additional surveys revealed new colony locations. They estimated a 14% annual change in colony distributions but could not determine any net changes in populations.

The western GOM (Texas) includes extensive sandy beaches and barrier islands. Lagoons, in particular the upper and lower Laguna Madre, provide an important wintering habitat for waterfowl. An estimated 80% of the world's redhead ducks winter in Texas. In 1986, Pelican Island was the only nesting site for brown pelicans along the Texas coast.

The literature review and analysis conducted by Clapp et al. (1982 a,b; 1983) for the entire GOM and South Atlantic includes species accounts for 39 species of pelagic seabirds, 41 species of waterfowl, and 22 species of gull/terns. Among their findings were comments on the dearth of information on feeding habits of birds in the southeastern U. S., and *especially weak and even less satisfactory* knowledge of the distribution and numbers of pelagic seabirds relative to the Atlantic coast.

The Clapp et al. analysis of potential effects of oil and gas operations identified some species as particularly susceptible to OCS oil spills. Loons and grebes were considered the *species most threatened from oil in the southeast U.S.* Blue-faced boobies appear to be attracted to offshore platforms. Sea ducks and diving ducks, with large winter rafts of individuals in open coastal waters and sometimes near platforms are a concern. Scoters and lesser scaups appear to be the most likely ducks to contact an oil spill.

Finally, Clapp et al. (1983) identified gull/tern species for which over 80% of the U.S. breeding populations were concentrated in the southeast. These were the laughing gull, royal tern, black skimmer, Forster's tern, sandwich tern, and gull-billed tern. Of these species, the gull-billed tern has a relatively small and declining population.

Over a dozen endangered or threatened bird species may occur along the GOM coasts (see Table 10-1). The brown pelican is a particularly well-studied species. Populations have made a strong recovery in Florida, and breeding birds appear to be expanding northward along the Atlantic coast. Nevertheless, the species remains on the list for other GOM states. The least tern and piping plover occur on open beaches and have been listed following recent steady., declines in population numbers.

Pacific Region

MMS has sponsored several large survey efforts along the Pacific coast for both seabirds and marine mammals. Southern California was surveyed from 1975-78 (Briggs *et al.,* 1981; Hunt et al., 1981). Central and northern California were surveyed from 1980-83 (Briggs et al., 1983). Washington and Oregon coasts are the target of a similar survey which statted in 1989.

In 1979, MMS initiated a cooperative study with FWS to catalog seabird colonies along the California coast (Sowls *et a/., 1980).* An. update of this effort began in 1989 with colony surveys in central and northern California including the first detailed survey of San Francisco Bay (Carter *eta/.,* 1990).' Survey work in Southern California is anticipated for 1991. Further studies on the feeding ecology of common murres and Cassin's auklets and aspects of coastal upwellings were conducted by the University of California, Santa Cruz under an MMS contract begun in 1984 with major field studies in 1985 (Briggs et al., 1987a).

Additional studies were conducted by the Pacific Region on the effects of oil on seabirds, The behavior of seabirds around

Common Name	Scientific Name	Status	Region
Crane, Mississippi Sandhill	*Grus canadensis*	E	GOM
Crane, Whooping	*Grus americana*	E	GOM
Curlew, Eskimo	*Numenius borealis*	E	AK
Eagle, Bald	*Haliaeetus leucocephalus*	*	All
Falcon, American Peregrine	*Falco peregrinus anatum*	E	All
Falcon, Arctic Peregrine	*Falco, peregrinus tundris*	T	All
Goose, Aleutian Canada	*Branta canadensis leucopareia*	E	AK, PAC
Kite, Everglades Snail	*Rostrhamus sociabilis plumbeus*	E	GOM
Pelican, Brown	*Pelecanus occidentalis*	*	All
Pelican California Brown	*P.O. californicus*	E	PAC
Petrel, Bermuda	*Pterodroma caliow*	E	ATL GOM
Plover, Piping	*Charadrius melodus*	*	ATL, GOM
Rail, California Clapper	*Rallus longirostis obsoletus*	E	PAC
Rail, Light-Footed	*Rallus longirostus levipes*	E	PAC
Sparrow, Cape Sable seaside	*Ammodramus martinus mirabilis*	E	GOM
Sparrow, Dusky Seaside	A. *m. nigrescens*	E	GOM
Sparrow, San Clemente Sage	*Amphispiza belli clementaea*	T	PAC
Stork, Wood	*Mycteria americana*	E	GOM, ATL, PAC
Tern, California Least	*Sterna antillarum browni*	E	PAC
Tern, Least	S. *antillarum*	E	ATL, GOM
Woodpecker, Red-Cockaded	*Picoides borealis*	E	GOM

• Status varies with geographical area: (E) endangered, (T) threatened.

Table 10-1. Federal Endangered Species Act Listed Species of Birds of Potential Concern to OCS Operations (FWS, 1989)

natural oil seeps in the Santa Barbara Channel was studied during 1980-82 (Varoujean, 1983). Short and long-term effects of oil exposure on Cassin's auklets, common murres and wedge-tailed Shearwaters were studied using both field and laboratory tests (Fry, 1987). Finally, four seabird species were selected for computer simulations of oil spill effects on populations (Woodward-Clyde Consultants 1983).

The large MMS-sponsored bird studies in conjunction with active State and FWS research projects, and long-term research on the Farallones (Ainley and Lewis, 1974; Ainley and Boekelheide, 1990) has made the seabird fauna of the California coast *perhaps the best known in the world* (Briggs et al., 1987 b). Thirty species are numerous with four species (or species groups) having populations exceeding one mill ion (sooty sheatwater, phalaropes, common murre, Cassin's auklet). Foraging habitats and relationships between seabird communities and the California Current System are relatively well documented. The recent monograph by Briggs *et a/.* (1987b) provides an excellent synthesis of MMS and FWS field data.

For seabirds breeding in California in 1979, the common murre was most numerous followed by Cassin's auklet, Brandt's cormorant and the western gull (Figure 10-1). The 1979 population estimate for breeding seabirds in California was about 700,000 with a *disproportionately large percentage of this*

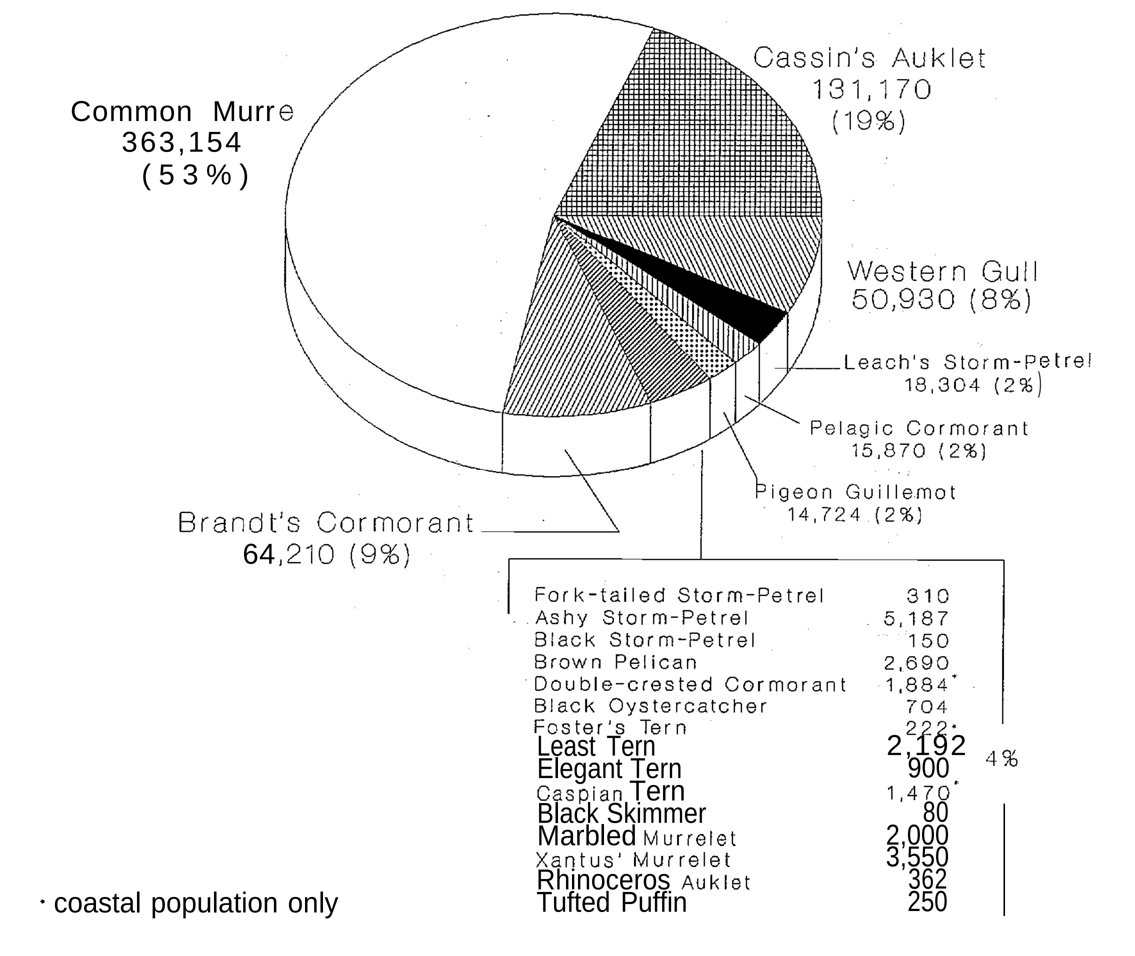

Figure 10-1. Populations of Breeding Seabirds and Percents of Total Number (Sowls et al. 1980)

population breeding at only a few locations. Preliminary results of the 1989 FWS surveys in northern and central California were just becoming available at this writing. A first look at data indicates lower overall numbers (about 543,000) with obvious declines in numbers of breeding common murres and Leach's storm-petrels while double-crested cormorants and rhinoceros auklets were notably increasing (Carter et al., 1989).

The Farallon Islands (Figure 10-2) is the largest California colony and is also the largest colony in the contiguous US (Haley, 1984). Castle Rock (Figure 10-2) is the second largest seabird colony in California, however, the colony is one part of a relatively heavy concentration of breeding birds north of Cape Mendocino that, in total, contains more birds then the Farallons (Sowls et al., 1980). The size of major colonies tends to increase northward. Three Arches Rock and Goat Island in Oregon and Protection and Destruction Islands in Washington exceed Castle Rock in numbers of birds while Triangle Island at the northern end of Vancouver Island, British Columbia, has an estimated *800,000* birds (Haley, 1984). Alaskan 'megacolonies' (see below) exceed a million birds.

While large concentrations of birds are of obvious concern for oil and gas operations, the relative proportion of a species at potential risk is also highly important. The more southern Channel Islands (Figure 10-2) have far fewer numbers of birds, but the vast majority of breeding California populations of black storm petrels, brown pelicans, and Xantus' murrelets plus significant numbers of ashy storm-petrels and Cassin's auklets nest there, making these islands significant sites in terms of species importance. A topic beyond the scope of this brief overview is the considerable information that now exists and ongoing efforts that will allow for increasingly better assessments of the relative importance of breeding and foraging areas at the individual species level.

Alaska Region

In reviewing the status and distribution of bird species in Alaska, Kessel and Gibson (1978) recognized six biogeographical regions. The eleven planning areas of the Alaska OCS Region can be grouped to closely approximate four of these biogeographical regions for the purposes of discussing Alaskan seabirds:

- Northern Region - Beaufort and Chukchi Sea Planning Areas
- Western Region- Hope, Navarin, and Norton Basin Planning Areas
- Southwestern Region - St. George Basin, N. Aleutian Basin, and Shumagin Planning Areas
- Southcoastal Region - Kodiak, Cook Inlet, and Gulf of Alaska Planning Areas

By 1983,405 bird species had been identified in Alaska (Armstrong 1983), including 50 *accidental* (not normally occurring) species. In addition to northern species and summer migrants, two groups are unique to Alaska, within the U.S. These are *Bering/a* species which apparently differentiated in isolated glacial refugia of the Bering-Chukchi area and remain restricted to Alaska and Siberia (e.g., Emperor Goose, Red-1egged Kittiwake, Aleutian Tern); and *Asiatics* which have their origins in Asia, and can only be seen in Alaska in North America.

In view of the vast coastlines of Alaska and sparse human population, the contributions of Audubon sponsored birdcounts and similar data prevalant in the "lower 48' states is conspicuously absent. The voids in bird data for key OCS planning areas and more specific sites of concern have led to a relatively large MMS investment in Alaskan bird studies and a substantial output of original field data, reports, and publications. The following account highlights major results but does not include all reports produced by ESP Alaskan bird studies.

MMS [BLM]sponsored bird studies in Alaska were initiated in FY 1975 with numerous

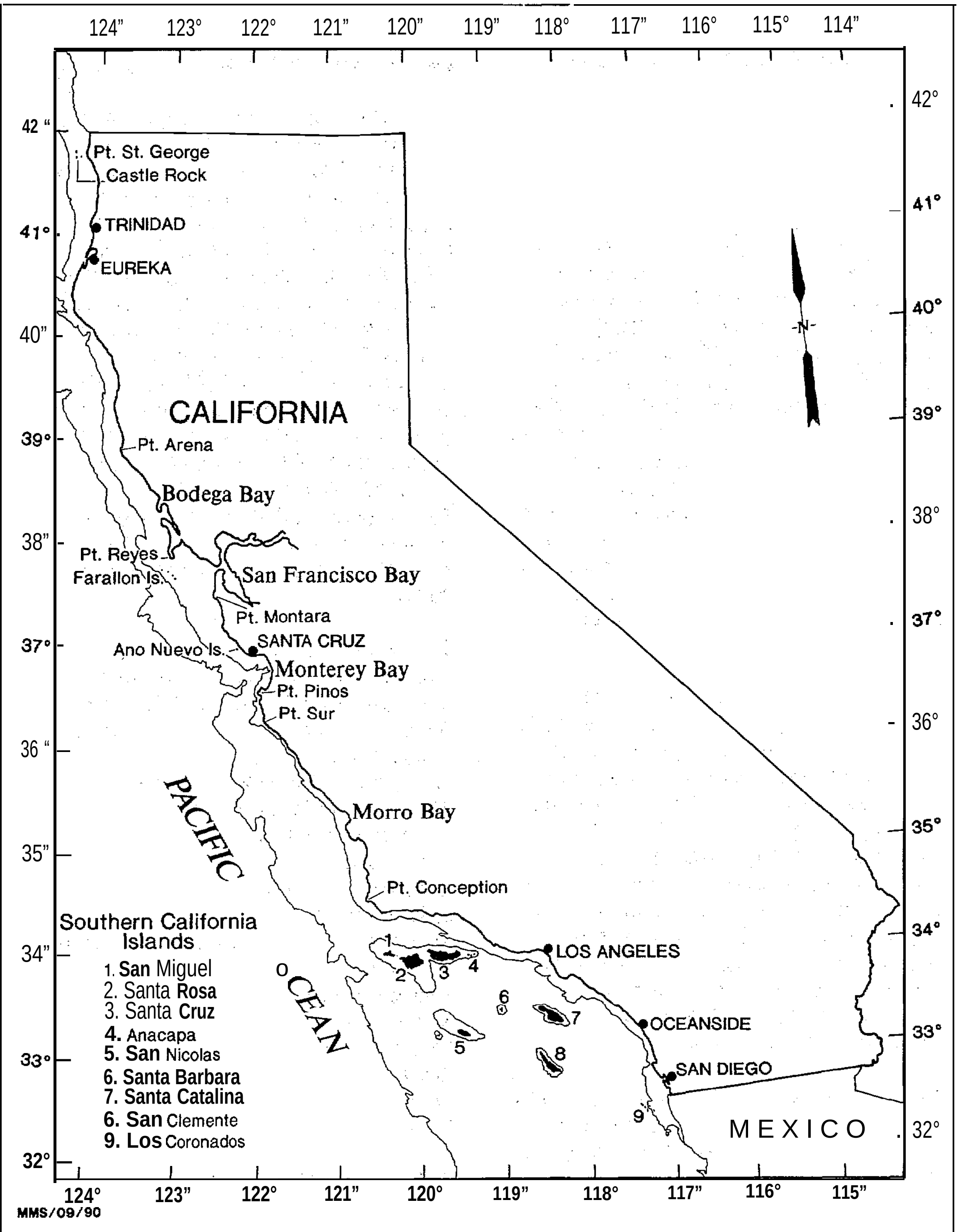

Figure 10-2. Coastal California with Significant Place Names and Undersea Topography (Briggs et al., 1987)

multi-year field studies and interagency agreements with FWS. The Southcoastal Region of Alaska was the target of a six-year FWS study on breeding biology and feeding ecology of marine birds (Baird and Gould, 1983; Krasnow and Sanger, 1982; Sanger, 1983; Sanger and Jones, 1982). Additional field observations were conducted on distribution of seabirds in the Gulf of Alaska (Gould et al., 1982; Harrison, 1982) and the seasonal use of coastal habitat by waterbirds in the Yakutat Bay area (Patten, 1981). Guzman and Myres (1 982) conducted more detailed studies on shearwaters from 1975 through 1977 while Patten and Patten (1 979) studied both the breeding ecology and effects of petroleum on breeding for large gulls. Although oil and gas interests in the Southcoastal Region have declined, resulting in no new MMS initiatives, FWS has continued to build on earlier MMS studies. For example, black-legged kittiwake colonies have been monitored for over ten years (1 rons et al., 1987).

In FY 1976, ESP bird studies were further expanded. FWS initiated a review of available marine bird literature and unpublished data, cul minating in an annotated bibliography y of literature on Alaskan waterbirds (Handel et al., 1981). MMS also began funding of FWS coastal migratory bird habitat studies beginning with an initial assessment of species and habitats subject to influence by OCS development (Lensink and Bartonek, 1978). A major portion of the documentation of coastal habitat was conducted by the Alaskan Department of Fish and Game from 1976 to 1979 (Arneson, 1980).

MMS has continued to contribute to coastal habitat studies in the northern Bering Sea (Lensink and Jones, 1977), Kodiak Island (Forsell and Gould, 1981), Yakutat Bay (Patten, 1982), and Yukon Delta (Eldridge, 1987). Bird studies/literature reviews were also a significant component of recent studies to better understand the environmental significance of Unimak Pass (Troy, 1986) and North Aleutian Shelf/Bristol Bay area (Troy and Johnson, 1989).

Also in FY 1976, MMS[BLM] initiated-what has evolved into a multi-year agreement with FWS to conduct a seabird monitoring program, *Monitoring Seabird Populations in Areas of Oil and Gas Development on the Alaskan Continents/ Shelf.* This program includes a series of studies to continue monitoring population trends in several seabird colonies in the Bering Sea and Chukchi Sea (Figure 10-3). Work began in 1977 with field studies at several sites including St. Lawrence Island, the Pribilof Islands, St. Matthew and Hall Islands, Cape Pierce and King Island. With co-funding from MMS [BLM], the FWS produced a catolog of Alaskan seabird colonies in 1978 (Sowls et al., 1978). From 1976 to 1984, LGL Ecological Consultants joined this effort (Springer et al., 1985). From 1985 to present, FWS and the University of Alaska have continued the work (Murphy et al., 1987; Piatt et al., 1988, Fadely et al., 1989).

The studies completed to date have addressed seabird colonies, pelagic distributions, and coastal habitats. Most of the studies have also addressed trophic relationships and the ecological implications of observed distributions and productivity. The majority of basic initiatives and study topics were established in 1975-76 and many of the initial field efforts evolved into expanded or longer-term studies. Shifts in industry interest have created some basic changes in study emphasis. As previously mentioned, MMS has stopped new field efforts in the Gulf of Alaska. However, in the Arctic, new efforts to characterize coastal lagoons are in progress and a monitoring program including avian species is being developed. Seabird colony studies in the Bering Sea are continuing. The following paragraphs elaborate more on results obtained by biogeographical regions. Only selected references are cited and considerable more data on species and locations are contained in additional reports listed in OCSEAP (1988).

Little information on the biology of marine birds in the Gulf of Alaska was available prior

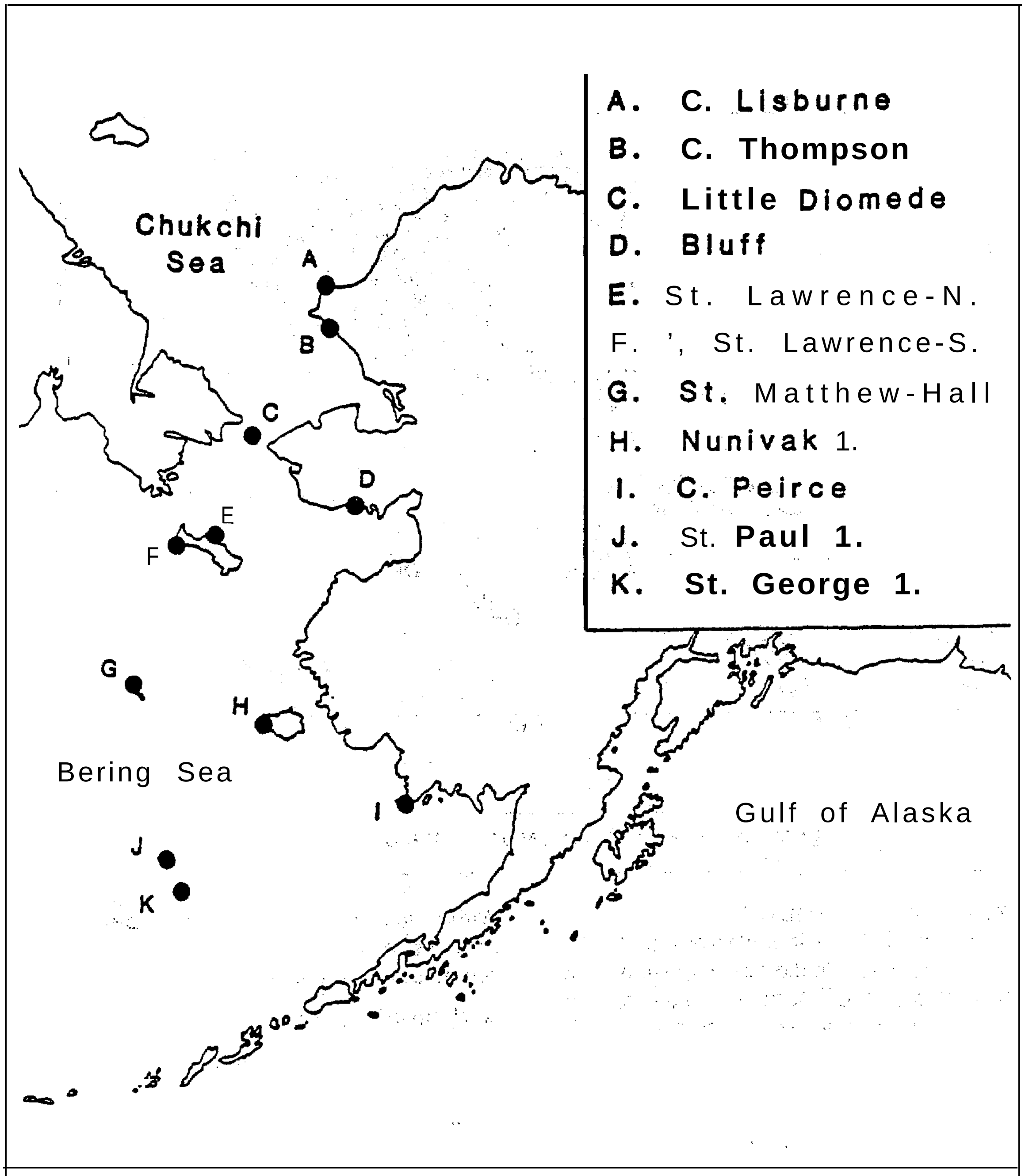

Figure 10-3. Locations of Established and Potential Study Sites for Seabird Monitoring in the Bering and Chukchi Seas (Piatt et al., 1988).

to 197o although general information on abundance and distributions of birds had been collected since 1918 (Kessel and Gibson 1978). The burst of MMS funded “. studies and co-funded studies conducted by OCSEAP and the FWS in the late 1970's and,, earl y 1980's still remain as key sources of available data for the region. DeGange and Sanger (1986) effectively summarize much of these data.

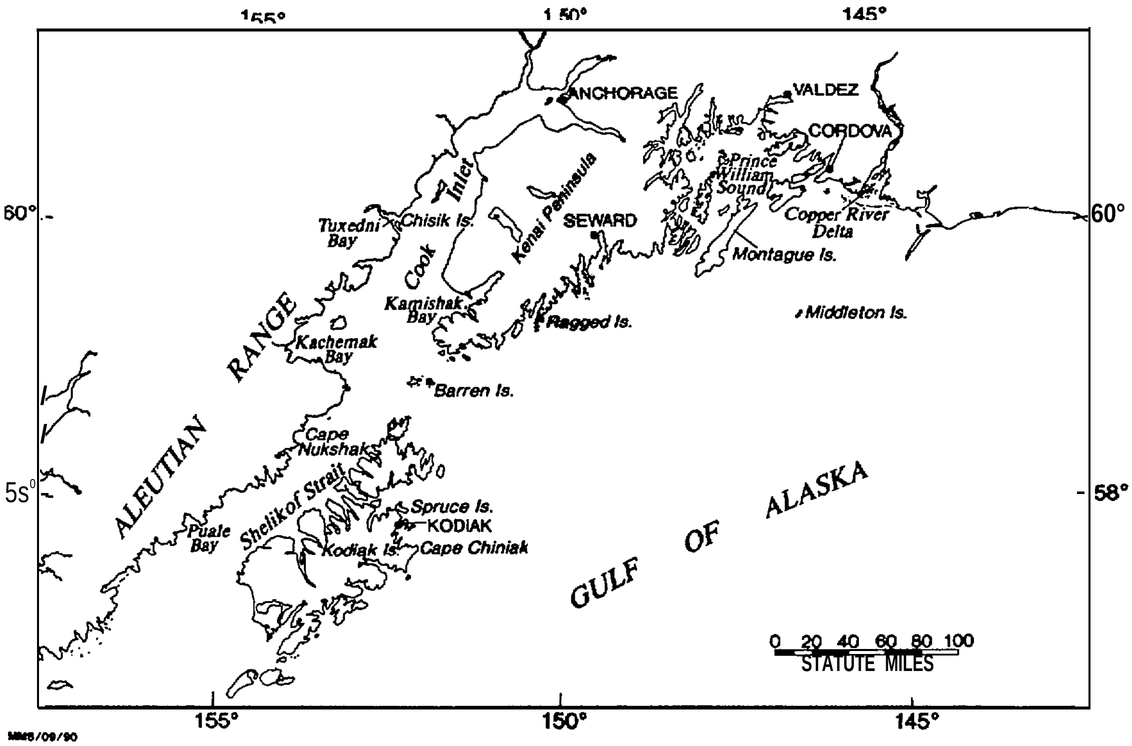

Figure 10-4. Geographic Locations for the Central Gulf of Alaska

Over 147 bird species have been documented in the Gulf of Alaska. With a population number in the millions, marine bird resources are *unquestionably* some *of the largest in the Northern Hemisphere* (DeGrange and Sanger, 1986). Approximately 100 species of marine and coastal birds occur regularly in the region including 39 seabirds, 35 waterfowl, and 28 shorebird species. The Gulf is an important breeding site for large numbers of seabirds and provides migration routes and wintering habitat for waterfowl and shorebirds. The Copper River Delta is a critical habitat for migrating waterfowl and shorebirds and its importance *cannot be overemphasized* (DeGrange and Sanger 1986)."

Within the Gulf of Alaska, 15 species of seabirds were targeted for studies on productivity and feeding ecology:

- Northern Fulmar
- Storm Petrels (Leach's, Fork-tailed)
- Cormorants (Double-crested, Pelagic, Red-faced)
- Gulls (Glaucous-winged, Mew)
- Black-legged Kittiwake
- Terns (Arctic, Aleutian)
- Murres (Common, Thick-billed)
- Puffins (Horned, Tufted)

These species account for about 90% of the total Gulf of Alaska breeding seabird population. Detail accounts for each species can be found in Baird et al. (1983).

In general, more breeding birds are found west of the Kodiak Islands. In the central Gulf of Alaska (Figure 10-4) the largest colony was on the Barren Islands (850,00 nests). Effects of the *Exxon Valdez* oilspill on the longer-term fate of this colony need to be determined. The *Exxon Valdez* oil spill eventually spread over 30, 000 km^2 of coastal and offshore waters in Prince William Sound and the Gulf of Alaska, an area occupied by about a million birds. More than 30,000 dead birds were recovered, mostly murres. FWS early estimates are that the Barren Islands murre colony (1 29,000 birds) was *probably devastated* and total kill from oil pollution was in the order of 100,000-300,000 birds (Piatt et al., 1990). Many of the data collected under the OCSEAP/FWS studies sponsored by MMS will be important in assessing the longer-term impacts of the spill on birds.

Other large colonies include the Chisik Islands, Middleton Island, Puale Bay, Dry Bay, and the Amber Bay area. During the late 1970's, the most abundant breeding seabirds in descending order were:

- Fork-tailed Storm Petrels
- Tufted Puffins
- Leach's Storm Petrels
- Common Murres
- Black-legged Kittiwakes
- Horned Puffins

During the summer, in terms of numbers of birds at sea, the influx of foraging (nonbreeding) shearwaters dominate Gulf waters. Study results have presented a better understanding of foraging behavior, diets, food-chain dynamics, and expected productivity for key species. Numerous external factors will influence seabird productivity. Of interest is the apparent different response of species to these factors. Extremes are the black-legged kittiwake with a 'boom and bust' productivity cycle and the tufted puffin with an extremely consistent annual productivity. The continued monitoring of colonies over long periods coupled with better means to correlate data from other field efforts in physical oceanography, fisheries etc. may lead to some better understanding of seabird ecology and ultimately increase the utility of seabird monitoring efforts as indicators of environmental stress.

Relative to seabirds, considerably less data exists for Gulf shorebirds and waterfowl. The Gulf of Alaska is important for millions of migratory waterbirds; coastal landfalls for exhausted shorebirds have been particularly noted. The Copper River Delta Complex alone may harbor over 20 million migratory birds annually. Other key sites are the lower Cook Inlet (Kachemak Bay flats and western shores) and the Stikirre River Delta. Dominate migrating species are the western sandpiper, dunlin, and northern pintail. Breeding waterbirds are common in the Gulf of Alaska, yet total numbers are far less then the more northern Alaska breeding areas. The northern pintail is perhaps the most abundant species for the entire Gulf of Alaska population of breeding waterfowl and shorebirds but other species will dominate locally depending on habitat and feeding areas. Patten (1981) noted the world's largest known concentration of Aleutian terns (3,000) near the mouth of the Situk River. It is estimated that at least one million waterfowl overwinter in the Gulf of Alaska. Winter concentrations of ducks are known to occur in the Shelikof Strait and Kodiak Island waters; however, the difficulties of conducting winter field work have limited data.

In the Bering Sea (southwestern and western biogeographical regions), the University of California, Irvine, conducted a large study on the pelagic distribution of nesting seabirds on the Pribilof Islands from 1975 to 1983. Results included pelagic distributions of seabirds and risk analysis for the southeastern Bering Sea (Hunt et al., 1982), North Aleutian Shelf (Epply et al., 1982), and central Bering Sea (Eppley and Hunt, 1984). Results of nesting and feeding studies on the Pribilof Islands are included in reports by Hunt et al. (1981) and Kinder et al, (1983). Further north, Drury studied the ecology of seabirds in the Bering' Strait region from 1975 to 1980 (Drury et al., 1981). In FY 76, further studies on avian community ecology were conducted at Kotzebue Sound (Schamel et al., 1978) and Norton Bay (Shields and Peyton, 1978).

In the northern region, Connors studied the shorebird communities along the Chukchi and Beaufort Sea coasts in a series of studies from 1975 through 1982 (Connors et al., 1981; Connors and Connors, 1982; Connors, 1984). Concurrent with this effort, Divoky and co-workers studied pelagic and nearshore birds (Divoky et al., 1978; Divoky, 1983,1987).

Most of the early (1975-80) MMS-sponsored research on waterbirds in the Bering Sea is summarized in five chapters of *The Eastern Bering Sea Shelf: Oceanography and Resources* (Hood and Calder 1981). In general, the OCSEAP/FWS/MMS studies have made major contributions to studies on seabirds and significantly enhanced information or-t waterfowl and shorebirds. The Bering Sea is noted for large numbers of breeding seabirds concentrated into a few very large colonies, extensive expanses of intertidal habitat and lagoons, and as a focal point for large migratory flocks flying between Arctic tundra and the Pacific Basin.

The Bering Sea supports one of the largest aggregations of seabirds in the world. Over 90% of these birds inhabit colonies of over one million birds. These *megacolonies* include outershelf colonies (Pribilof Islands, St. Matthew and Hall Islands), northern colonies (St. Lawrence, Little Diomede/King Island), and eastern colonies (Nunivak Island, Cape Newenham) (Figure 10-5). About 45 species of seabirds occur in the region; with about 20% occurring as nonbreeding visitors. Two species, whiskered auklet and red-legged kittiwake, are endemic. Eleven species exceed one million in number: short-tailed shearwater, least auklet, thicked-billed murre, common murre, forked-tail storm-petrel, Leach's storm petrel, crested auklet, tufted puffin, northern fulmar, black-legged kittiwake, and sooty shearwater.

Considerable data on abundance, pelagic and colony distributions, and productivity is summarized for most of these species (Hood and Calder, 1981). In addition, study efforts have attempted to better understand the trophic relations of marine birds in the Bering Sea and prey critical to the success of breeding colonies. Fifteen common species including kittiwakes, murres, storm-petrels, shearwaters, auklets, and puffins, were targeted for feeding and diet studies. Early results clearly demonstrated that a very few species of fish and invertebrates provided major portions of food used in any one region. Walleye pollock was the most important prey fish.

The now active FWS seabird monitoring program has continued many aspects of the initial field studies. More recent data have indicated a "pervasive syndrome of failure" in breeding for black-legged kittiwakes in many Bering Sea colonies. In many cases chicks appear to starve due to inadequate food supplies during mid- to late season. Nevertheless, the black-legged kittiwake population has remained stable through 1988; either breeding failures have not yet registered on a long-lived adult population and/or breeding success continues in areas not studied. Other recent field studies of nearshore zones around Bristol Bay (Troy and Johnson 1989) indicate seabirds in eastern Bering Sea colonies exhibit a "radical switch" in diets from mainly euphausids in May to all fish by July. Despite large numbers of smelts in local waters, salmonids were rarely part of seabird diets. Also in the more shallow eastern waters, sandlance are the primary fish prey.

The Bering Sea has a diversity and numbers of shorebirds unequaled in Alaska (Hood and Calder, 1981). For both shorebirds and waterfowl the southern Bering Sea, notably Unimak Pass, is *a* major corridor for north-south migrations. The extensive marshes and lagoons of the northern shores of the Alaskan Peninsula provide critical resting, feeding, and staging areas. In the north, the Yukon Delta region is also a nesting

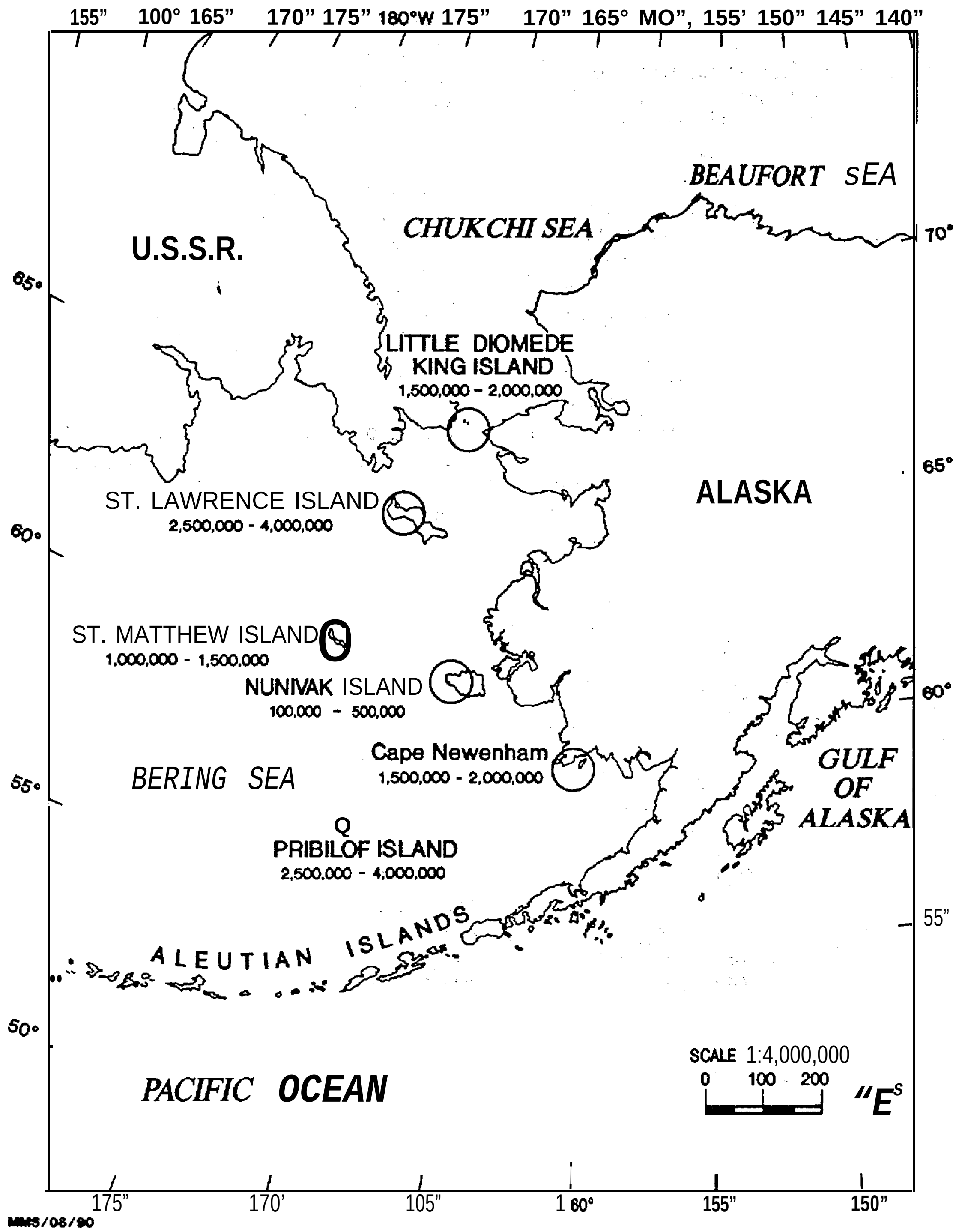

Figure 10-5. Megacolonies of Nesting Seabirds in the Bering Sea

area - "one of the largest areas of productive breeding habitat for waterfowl and cranes in North America."

Several of the key coastal habitats have been subjects for field studies or information synthesis. Unimak Pass (Figure 10-6) is a key migration route for birds and marine mammals. A detailed analysis of existing data for Unimak Pass was conducted in 1985-86, with an analysis of marine and coastal birds conducted by Troy (1986). The Pass can contain up to 1.1 million shearwaters in the fall and during the summer, about 700,000 birds typically inhabit or transverse the area. About 1.4 million seabirds colonize the Fox Islands southwest of the Pass (Figure 10-6) with puffins and storm-petrels predominating. Northwest of the pass, the southern Alaska Peninsula coast has numerous lagoons and wetland areas, Izembek and Nelson lagoons of particular note (Figure 10-6). Recently completed year-round aerial surveys, some ship surveys, and feeding studies (Troy and Johnson, 1989) have contributed new information for this region (North Aleutian Basin) particularly on winter utilization of habitat. The region appears especially important for several species of geese and eiders (Table 10-2). Recent aircraft disturbance studies on geese at Izembek Lagoon (Ward and Stehn, 1990) also includes considerable work on habitat utilization. The lagoon is a key habitat for Pacific black brants with nearly the entire Pacific Flyway population feeding on eelgrass in the Fall to build fat reserves for the 3000 mile migration flight to Mexico.

The Yukon Delta has also been the subject of an information synthesis effort (Thorstein et al., 1989). The region has been characterized as *America's greatest goose nesting*

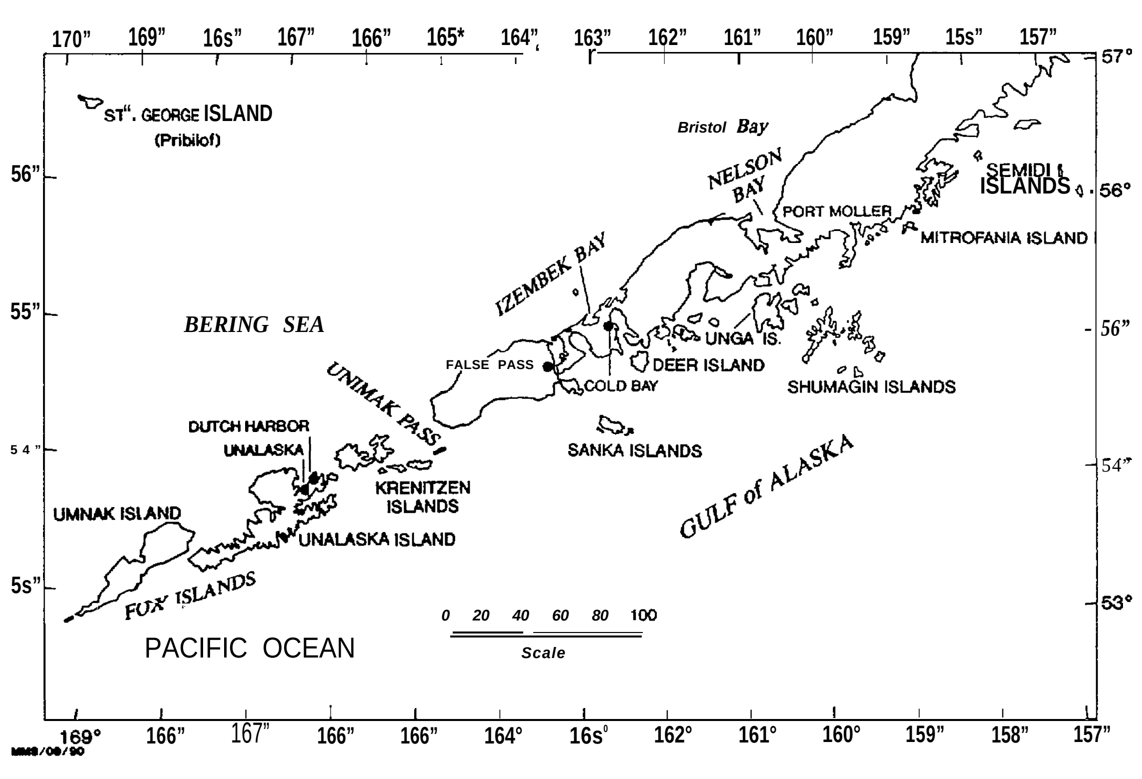

Figure 1 0-6. Unimak Pass and Adjacent Areas

Species	Population (1,000s)	Percent Pacific Regional Population	Period of Use	Important Use Areas
Emperor Goose	, 79	100	Spring-Fall	Ugashik Bay-Izembek Lagoon
Brant	120-150	100	Spring-Fall	Izembek Lagoon
Taverner's Canada Goose	80	75	Fall	Izembek Lagoon Area
Cackling Canada Goose	27	100	Spring-Fall	Pilot Point (Ugashik Bay)
White-Fronted Goose	80	30	Fall	Pilot Point
Steller's Eider	200	100	July-Fall	Izembek-Nelson Lagoons
King Eider	375-650	75	Winter	Nearshore, Offshore Areas

'able 10-2. Waterfowl Species with Major Segments of Their Population Dependent on Areas Within and Adjacent to the North Aleutian Basin (Troy and Johnson, 1989).

concentration and also an important nesting and foraging area for shorebirds.

In the northern biogeographic region (Chukchi and Beaufort Seas, Figure 10-7), seabird colonies become of minor importance north of Cape Lisburne. Ice dominates aquatic environments most of the year and the vast majority of birds occuring in the region are a "transient phenomena."-The arctic tundra is a vast breeding ground for numerous migratory species and the 2-3 months of arctic breeding, molting, and feeding are critical aspects of the annual cycle for many avian species. Tundra areas are normally of little concern for offshore oil and gas operations and MMS sponsored studies have concentrated on studies of littoral, nearshore, and pelagic habitats. In the northern Chukchi and Beaufort Seas, these habitats support bird populations from about July through early September, predominantly as migratory routes, staging areas, and post-breeding feeding areas. Shorebirds often comprise a major segment of coastal avifauna (Connors et al., 1981). In addition to seabird colony studies in the southern Chukchi Sea (e.g. Cape Thompson, Fadley, et al., 1989), MMS has completed several dedicated studies on shorebirds (see Connors, 1984), and the pelagic distributions of all species (Divoky, 1983; 1987). Bird studies have also been a component of environmental characterization studies of several key coastal habitats (Schamel et al., 1978; Johnson and Richardson, 1981; Johnson, 1983; Kinney 1985). Not only has a truely significant increase in data on avian utilization of Arctic coastal habitats resulted, but studies have also led to better understandings of the natural history of some species, notably Ross' gull (Divoky et al., 1988) and oldsquaw ducks (Johnson, 1990). The oldsquaw is now a focal species for monitoring effects of oil and gas activities in the Beaufort Sea (Johnson, 1990).

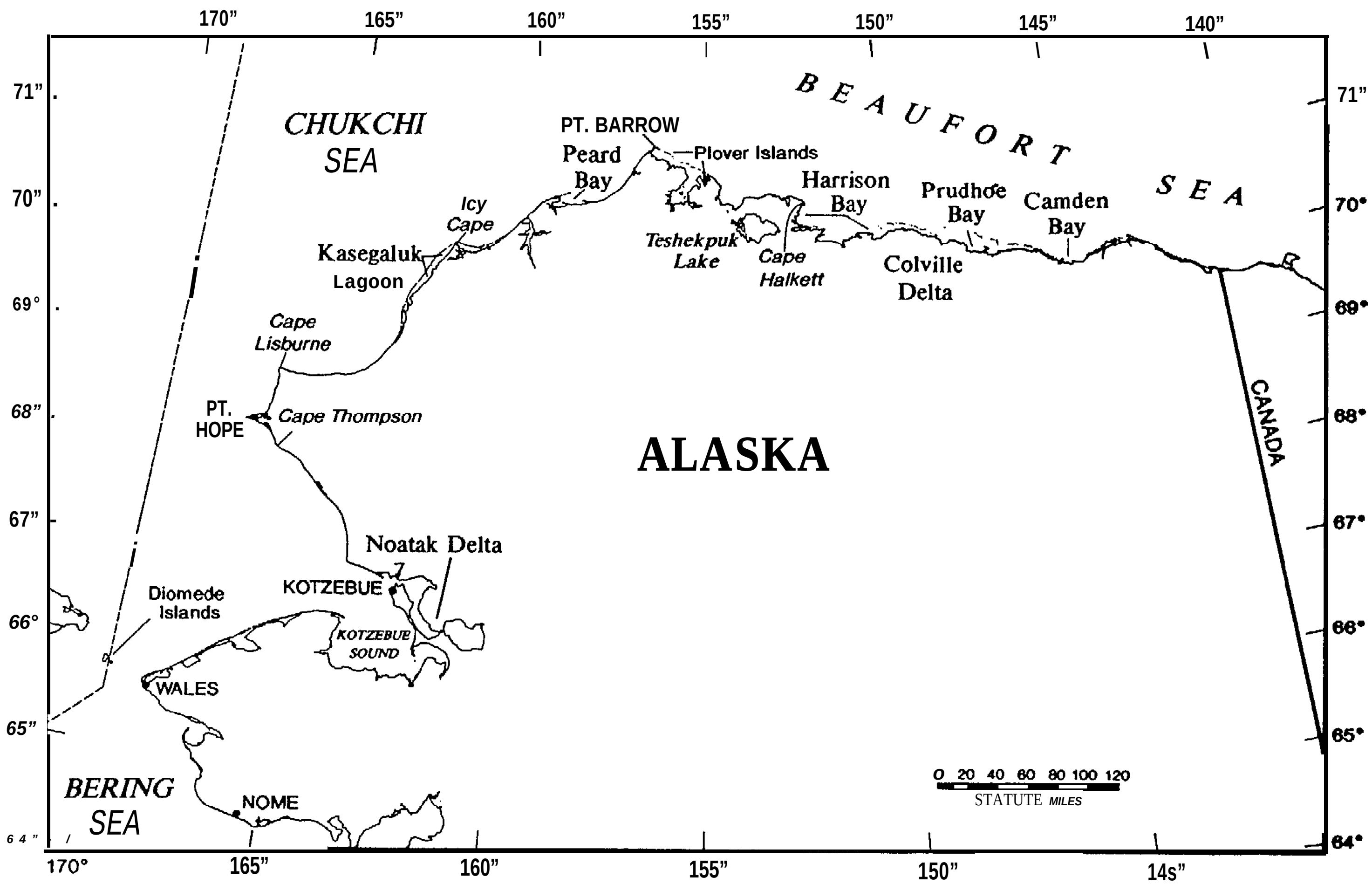

Figure 10-7. Key Names and Locations for Bird Studies in the Chukchi-Beaufort Sea Region

The northern extreme of large seabird colonies is the Cape Lisburne and Cape Thompson area. Farther north, a few barrier islands will support colonies of waterfowl of local importance, however, the numbers and densities of birds are far below those encountered in the Bering Sea. Divoky's (1987) pelagic data reflects coastal observations. The pelagic avifauna is a mixture of arctic and subarctic components. In early summer murres, kittiwakes, and phalaropes are most common. The two colonial seabird species are at the northern end of their breeding range and tend to move south by late August. The tundra breeding phalaropes remain longer but during maximum ice retreat(late August-early September) perhaps as many as two million shearwaters and lesser numbers of auklets enter the Chukchi Seato dominate' abundance data. After late September, the high arctic breeding Ross' and ivory gulls and black guillemot remain. In the Beaufort (Divoky, 1983), the density of pelagic birds decreases further with only the extreme western area approaching figures in the Chukchi. Common species in pelagic waters are all surface feeders (Table 10-3). Limited feeding data indicates arctic cod as the dominant prey. Diving ducks and lesser numbers of diving seabirds are regularly encountered near shore (Table 10-3). The Beaufort has an overwhelming abundance of oldsquaws (Johnson, 1990) that, except for local concentrations of other species such as phalaropes or eiders, account for over two-thirds of sightings in averaged data.

Although colonies of breeding birds occur in nearshore and littoral areas (e.g. eiders at Solovik and Cross Islands, snow geese at Howe Island), overall, the coastal habitats appear more important for summer feeding and migratory staging. Conners (1984) presents a pattern of habitat usage (more pronounced northward) that has most species initially nesting and raising young in tundra regions, then shifting to littoral regions in mid-to late summer for feeding and staging. Connors et al. (1981) list 31 species of birds regularly observed in Beaufort littoral zones. For shorebirds this includes 20 breeding and 7 migrant species with Phalarope, Dunlin, and Semipalmated Sandpiper the most abundant. Farther south along the Chukchi coastline, the Golden Plover and Pectoral Sandpiper also become major users of the littoral zone (Connors and Connors 1984). Late summer coastal concentrations of birds (feeding, molting, staging). have been documented in the cited studies and other reports not reviewed (see OCSEAP 1988). Areas often noted include Peard Bay, Plover Islands, Simpson Lagoon, Teshekpuk Lake, and Kotzebue Sound.

Surface Feeding Species	Diving Species
Red Phalarope	Arctic Loon
Northern Phalarope	Red-throated Loon
Pomarine Jaeger	Short-tailed Shearwater
Parasitic Jaeger	Oldsquaw
Long-tailed Jaeger	King Eider
Glaucous Gull	Common Eider
Black-1egged Kittiwake	Thick-billed Murre,
Sabine's Gull	Black Guillemot

Table 10-3. Species Regularly Encountered in the Pelagic and Nearshore Alaskan Beaufort Sea

The Alaska Region has also sponsored several bird studies primarily concerned with effect of OCS activities. Closely linked to feeding study results (Kaiwi and Hunt, 1983), Ford, Wiens, and Heinemann conducted simulation modeling of marine bird populations and their sensitivity to oil spills (Ford et al., 1982; Wiens et al., 1982).

In 1977-78, the Point Reyes Bird Observatory conducted studies on the effect of petroleum on reproductive success in seabirds (Ainley et al., 1981). Boersma (1984) reported on the potential use of storm petrels as *biological indicators* of environmental conditions including petroleum pollution. In two recent studies at Izembek Lagoon and Teshekpuk Lake, FWS has investigated the effects of human activities, primarily aircraft disturbance, on migratory waterfowl (Derksen et al., 1989; Ward and Stehn, 1989).

General Discussion Of The Effects Of OCS Oil And Gas Industry Activities On Marine Birds

Potential threats to marine birds from OCS oil and gas industry activities include noise and other physical disturbances, spilled oil, and habitat loss. Although mortality among susceptible marine birds especially alcids, loons, grebes, and seaducks, may appear high as the result of an oil spill, it is uncertain that such mortality has affected species on a population level. This has led certain researchers to question whether impacts are significant in the U.S. OCS or the North Sea (Dunnett, 1987; Hunt, 1987; NRC, 1985). In contrast, Piatt et al. (in press) and Takekama et al. (1990) have documented population declines at certain colonies in the English Channel, Newfoundland, and California, in which mortality from oilspills is a significant contributing factor. The key question for the MMS is whether a situation could occur in which the local effects of an oil spill or other OCS activities lead to impacts of a population level.

There are many obstacles to the successful resolution of this question. Researchers have had difficulties estimating absolute population size, and measuring change in relative population size with statistical confidence, for most seabird species. In addition, there are no standard definitions of what constitutes a *significant* change in population numbers, and what is an *acceptable* length of time for the recovery of the population (or habitat).

This section includes a discussion of the different potential direct and indirect effects on marine birds from OCS oil and gas activities and the vulnerability and risk factors that determine the severity of effects. Much of this discussion is taken from the comprehensive chapter by Hunt (1987) in *Long-term Effects of Onshore Oil and Gas Development* and from *Oil in the Sea* (NRC, 1985).

Development of onshore facilities may lead to increased intrusion into local bird colonies. The presence of airplanes, boats, people, discharge of firearms, and operation of facilities equipment all create additional noise and physical disturbances. Aircraft can cause considerable damage to chicks and eggs of cliff dwelling species. Hunt (1987) states that murres are the most vulnerable species in North America because they lay their eggs on cliffs, do not build any nests, and incubate the eggs by holding them on top of their feet. There is evidence for large losses of chicks and eggs in Alaska from airplane overflights; however, in California there was no evidence of damage to colonies near airports. An additional concern is that adult birds may abandon colonies as a result of repeated disturbances.

Several studies have been conducted in Alaska (Ward and Stern, 1989; Derkson et al., 1989) to analyze the effects of different types of disturbances from aircraft overflights and other human activities on black brant and other waterfowl. Results show birds responded more strongly to natural predators overhead than planes or helicopters.

Hunt (1987) does not consider studies of these types of disturbances a high priority because they can often be successfully mitigated. Personnel can be instructed to avoid colonies; aircraft buffer zones can be placed around colonies; and birds seem to habituate to some disturbances. He does recommend that reproductive rates of disturbed and undisturbed colonies be compared to detect any population level impacts.

The potential direct and indirect effects of spilled oil on marine birds tend to be of much greater concern to the public and the scientific community than the effects of noise and other physical disturbances. Before describing these effects, the following caveats' should be noted:

- No relationship has been established between the sub-lethal (indirect) physiological effects documented in the laboratory (which is where most of these effects were observed) and effects which could occur under field conditions;
- Many of the laboratory studies of the sublethal effects of oil on individual birds have been conducted on domestic varieties such as mallards because seabirds are difficult to maintain in captivity (although there is an increasing trend toward the use of seabirds in natural habitat studies);
- The sublethal effects documented in the field could not be linked directly to the presence of petroleum hydrocarbons, and may have been reactions to general stress;
- The sublethal effects documented are generally not related by additional experiments to population level parameters such as mortality, survival, growth, reproductive rates, etc.;
- There is only baseline information on population size and natural mortality, and the common methods of conducting censuses (colony counts, pelagic surveys, beached bird surveys) have several sources of bias associated with them. It is therefore difficult to make inferences about the overall impact of petroleum related mortality on the overall population size and "health" of most seabird species.

The lethal or direct effects of oil on marine birds include physical fouling of feathers and ingestion of oil through preening and feeding on oiled prey. Oil clogs the fine structure of the feathers, and leads to a loss of buoyancy and the loss of ability to thermoregulate. In arctic waters, the loss of thermal insulation would obviously be more critical than in other locations. Autopsies of oiled seabirds have revealed a variety of abnormal conditions which might be due to ingestion of spilled oil:

- wasting of fat and muscle tissue;
- abnormal conditions in the lungs, adrenals, kidneys, liver, nasal' salt gland, and gastrointestinal tract;
- reduction in white blood cell count; and
- elevation in levels of mixed function oxidase.

In addition, experimental studies have shown the following effects:

- retardation of weight gain in growing birds;
- induction of hepatic enzymes;
- generalized pathologic effects;
- decrease in egg laying;
- decrease in hatching success of eggs laid;
- interference with water and salt transport by the intestine and salt excretion by-the nasal gland.

Nero and Associates (1983) conducted field and laboratory studies to investigate short-and long-term effects of exposure to sublethal and lethal doses of weathered crude oil on Cassin's auklets, wedge-tailed, shearwaters, and common murres. The laboratory experiments produced results similar to the effects listed above. The data from the field experiments led the authors to conclude that the sublethal effect of breeding failure after oiling caused mate switching and an overall decline in breeding success.

It is generally assumed, that, to produce the effects listed above, direct contact is made with the oil. There are a number of factors, in the natural setting, that affect the degree of risk to populations of marine birds and their vulnerability to spilled oil. These factors can be grouped into several categories:

- Behavior of the species, including breeding, reproductive strategy, feeding, ability to avoid oil, colony type, habitat use, etc.;
- Geographic location, including temperature, climate, winds, currents, water depth, inshore or offshore; proximity to offshore oil production areas and tanker routes and terminals;
- Human activities, and other stresses in the area, including oil and gas industry activities, proximity of shipping lanes, and commercial fishing activities; and
- Type, amount, and timing of oil spilled.

Several investigators have attempted to incorporate this type of information into risk assessment models (Ford, 1985a, 1985b; Ford et al., 1982; Samuels and Lanfear, 1982; Wiens et al., 1979; Woodward-Cl yde Consultants, 1983;). Hunt (1987) concludes that much of the information required by the models is lacking. However, he recommends that this approach to predict how marine birds will respond to acute and long-term effects of oil be pursued using the present models as guides to critical information needs. Recent damage assessment models have incorporated many of these factors in estimating the total numbers of birds impacted (Ford et al., 1987, Page et al., 1990).

According toNAS(1985) the most vulnerable seabirds are the gregarious, diving species which spend most of their time on the water. Auks are very vulnerable when they form large aggregations on the water at their summer breeding colonies, and on their wintering grounds. Diving ducks such as scoters, oldsquaw, scaup, canvasbacks, mergansers, and common eiders are also very vulnerable. Grebes and loons aggregate in coastal waters in the winter, and phalaropes concentrate in narrow zones of convergence at sea in the winter making them vulnerable as well. Most waterfowl and shorebirds flock on salt marshes and mudflats and are vulnerable to oiling by direct contact and indirectly through food and habitat contamination and loss. Tropical birds are generally less vulnerable than temperate or cold climate species because they do not hunt prey under water (except for cormorants and anhingas). It should be noted that because diving ducks have a very high breeding potential in contrast to other seabirds they are more likely to recover faster from large mortalities.

In parts of the North Sea, Gulf of Alaska, and off the Atlantic and Gulf coasts, bird colonies are small and widely dispersed, and an oil spill would probably affect only a small part of the population. In contrast, in the Bering Sea, and offshore of parts of the California and Oregon coasts seabirds concentrate in a relatively small number of large colonies, and an oil spill could potentially result in significant damage if it came in contact with one of these colonies (Hunt, 1987). FWS field researchers have noted a decrease in the number of Atlantic bird colonies, with a possible trend toward fewer colonies of larger size.

Varoujean (1988) and Nero and Associates (1983) summarized the results of their research on seabird behavior in response to spilled oil; they found that seabirds avoided or tried to avoid spilled oil. Diving was a much less effective means of avoiding oil then flying away. They also found that previous exposure to oil (assuming no serious damage occurred) makes birds more likely to avoid it.

Arctic species are more at risk than other species for several reasons in addition to colony size and number. Ice may trap oil and release it gradually, over a long period of time, with each thaw. The ice and cold temperatures inhibit the dispersion of oil and the evaporation of the more toxic volatile components. Because of the presence of sea ice, birds are concentrated in limited areas of open water.

Pacific populations in the Gulf of Alaska and in southern, central, and northern California are most at risk due to greater proximity to offshore oil production areas and tanker routes, terminals and refineries.

Newfoundland and Gulf of Mexico populations are most at risk in the Atlantic for the same reasons. In other areas, less frequent tanker spills only are expected.

In the natural environment, there are many other stress factors acting upon seabirds, in addition to spilled oil. The commercial fishing industry is a major competitor for food with many species of marine birds. Some species of seabirds (*eg.,* murres) are killed in fishing gear in very large numbers (Takekawa et al., 1990. According to Hunt (1987), fishing grounds frequently coincide with areas of oil and gas industry activities, and there is a need to be abie to separate effects from each of these industries on seabirds with statistical confidence.

Discussions of the toxicity, persistence, and bioavailability of different types of oil can be found in other sections of this report, as well as in NRC (1985), and Boesch and Rabalais (1987), and will not be repeated here.

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11. Protected Species

General Description

For the purposes of this report, *protected species* are those species given special protection under the Endangered Species Act of 1973 (ESA) and the Marine Mammal Protection Act of 1972 (MMPA). The MMPA establishes a moratorium on the "taking" (actual or attempted harassing, hunting, capturing, or killing) of marine mammals in U.S. waters or by U.S. citizens and the importation of marine mammals products into the United States (except under special circumstances).

Similarly, the ESA prohibits the "taking" of species or certain populations of species listed as endangered or threatened by any person subject to the jurisdiction of the U.S. with special specified exceptions. All Federal agencies are required by the ESA to ensure that any actions they conduct, fund, or authorize will not jeopardize the continued existence of listed species or destroy or adversely modify their critical habitats. Also under the ESA, these Agencies *shall seek to conserve endangered and threatened species and shall utilize their authorities in the furtherance of the purpose of this Act.*

The unique protection given to marine mammals and endangered or threatened species under the MMPA and ESA, and the associated legal requirements, has created special information needs, Eight of the nine species of great whales found in the world are listed as endangered (Braham, 1964a). All marine turtles and manatees found in U.S. waters and the southern sea otter are listed as threatened or endangered, as are several species of bkds and mammals found in coastal, aquatic, or marine habitats (FWS, 1989). All marine mammals found in U.S. waters, which include cetaceans (whales, dolphins, porpoises), pinnipeds (seals, sea lions, walruses), sea otters, manatees, and polar bears, are protected under the MM PA.

In response to this situation, endangered species studies and additional marine mammal studies have become a significant component of the ESP. This section puts all marine mammal and marine turtle studies under the category of Protected Species Studies. To date, the ESP has not funded research specific to endangered or threatened species of birds; however, considerable research has been accomplished on waterbirds in general. These studies may include data on ESA listed species of birds. Marine mammal and seabird survey work have also been combined under one study in several cases. Protected species and bird studies tend to overlap and the reader should also refer to Chapter 10, Coastal and Marine Birds.

Through Fiscal Year (FY) 1989, approximately $60 million (12% of total ESP expenditures) have been invested on studies dealing predominantly or exclusively with marine mammals. Annual MMS expenditures between FY 1975 to FY 1986 are estimated to account for 20 to nearly 50% of the total annual federal money spent on marine mammal research (Table 11-1). Additional money has been spent on marine turtle studies and studies of broader context which include collation of data for protected species.

About two-thirds of protected species funds have been spent on studies in the Alaska Region, followed by 18% in the Pacific Region, 12% in the Atlantic Region, 3% in the Gulf of Mexico Region, and some additional small expenditures by Headquarters, mainly for publication or equipment costs in support of existing regional studies. Each region tends to have distinct groups of protected species of particular concern; however, similar types of studies have evolved. For conceptual purposes, Protected Species Studies are grouped into four basic types.

All regions have initiated general survey studies at the onset of the program to provide fundamental information on the types of

Fiscal Year	Total Cost ESP	Marine Mammal Studies MMS-ESP	Percent MM Cost	Estimated Federal MM Expd.[1]	Percent MMS of Federal
7 3	366,300	0	0	0	NA.
74	1,383,200	o	0	0	NA
75	24,083,200	1,051,400	04	5,013,300	21
76	55,589,800	2,965,500	05	7,748,500	38
77	44,811,900	2,092,500	05	8,953,200	23
78	40,916,200	3,152,300	08	10,164,000	3 1
79	31,298,700	6,416,300	21	16,696,000	38
80	44,721,500	5,381,000	12	18,079,500	30
81	37,511,100	4,806,700	13	14,449,000	33
82	30,954,300	6,336,100	20	13,478,700	47
83	33,551,300	6,157,800	18	14,188,400	43
84	28,782,300	3,617,800	13	13,425,200	27
85	26,291,800	5,837,200	22	14,445,600	4 0
8 6	25,398,900	3,086,400	12	14,423,300	21
Total	*425,660,500*	50,901,000	12	151,064,700	34

[1] from Waring (1987)

Table 11-1. Summary of Expenditures for Marine Mammal (MM) Studies Within the MMS Environmental Studies Program (ESP) and Contribution to All Federally Funded Research

protected species found in planning areas, their distribution, and sometimes additional natural history information. These studies tend to cover large geographical areas and provide survey data on all marine mammals,. turtles, and birds found in that area. Opening a new planning area can initiate this type of study at anytime (e.g., Washington-Oregon).

Once potential interactions of protected species with OCS operations are identified, directed survey studies often follow to obtain detailed data on a specific species (e.g. bowhead whale) or group of related animals(*e.g.* endangered whales) in geographical areas of particular concern. Generally, interactions represent an overlap in time and space of proposed or actual industry activities with likely locations of concentrated protected species or of habitat of particular importance to one or more species. Migration routes, feeding areas, and breeding and haulout sites are often further studied in areas of known industry interest. These studies can be further grouped into whale, seal, and sea otter studies.

In support of these studies, tagging studies have been conducted to develop radio tags for use on whales. To date, these studies have been devoted to developing reliable tags and a means to attach them to free-swimming cetaceans. Once a tag is perfected, the monitoring of whales using these tags should become an additional technique to be used in directed survey studies. In addition to whales, MMS has sponsored tagging of sea otters and seals in the Pacific and Alaska Regions.

Although determination of the proximity of offshore oil and gas operations to protected species provides some indication of the potential environmental impact, a more precise evaluation addresses actual effects. Effects studies were developed to study real or modeled impacts on protected species such as effects of oil, noise, and underwater explosions. In support of this work, studies on natural causes of mortality and histology and pathology have been funded.

The final type of study is multidisciplinary field studies or habitat characterization studies. These studies typically integrate detailed marine mammal survey and behavioral observations with plankton or plankton productivity studies and physical oceanographic measurements to evaluate how marine mammals are utilizing the study area.

Since the MMPA and ESA are bases for the approval and conduct of Protected Species Studies, further information on these Acts will be provided prior to reviewing existing protected species information. Brief reviews of survey/natural history and habitat information obtained in each region are then presented. Tagging studies and effects studies are reviewed as separate topics at a national level.

Endangered Species and Marine Mammals Protection Acts

Beginning in 1966 and culminating in 1973 with enactment of the Endangered Species Act (ESA) of 1973, the Federal Government established the *first truly comprehensive federal effort at wildlife preservation* (Bean, 1983). Authority to list species as endangered (in danger of extinction throughout or in a significant portion of its range) or threatened (likely to become endangered within the foreseeable future) and the responsibility for the protection and conservation of listed species was given to the Secretary of the Interior (Fish and Wildlife Service (FWS)) for terrestrial species, the southern sea otter, sirenians (manatees and dugongs), and marine turtles (onshore). The Secretary of Commerce (National Marine Fisheries Service (NMFS)) is responsible for endangered cetaceans, pinnipeds, and marine turtles (at sea).

Section 7(a)(2)of the ESA requires that any action authorized, funded, or conducted by a Federal Agency (unless specifically exempted through a detailed process explained in the Act) will not jeopardize the continued existence of endangered/threatened species or result in the destruction or adverse modification of their critical habitat. A Federal *action* agency must consult with the resource agency (FWS or NMFS) when species under their respective jurisdictions may be affected by a proposed action. The resource agency must issue its biological opinion on whether or not an action would likely jeopardize a species within 45 days of the close of a 90 day formal consultation period unless a longer (or shorter) period is mutually agreeable to both parties. If the resource agency determines that a jeopardy situation exists, it must identify reasonable and prudent alternatives, if any, to the action that would preclude jeopardy. If incidental (but not intentional) take of listed species is involved, the resource agency must also include an incidental take statement. This statement must describe the extent of expected impact and reasonable and prudent measures, terms, and conditions necessary or appropriate to minimize take and to report on it should it occur. Each action agency is required to provide, as a basis of the formal consultation, the best scientific and commercial data available on the proposed action, the species it may affect, and the potential impact of the action on the species. The resource agency also must base its biological opinion on such data.

Although the ESA exists to preserve any endangered plant or animal species, marine mammal species (cetaceans, pinnipeds, sea otters, and polar bears) were given separate, special protection under the Marine Mammal Protection Act (MMPA) of 1972. To prevent the further depletion of marine mammal populations as a result of man's activities, the Act declared a moratorium on the taking (actual or attempted harassing, hunting, capturing, or killing) of marine mammals in U.S. waters or by U.S. citizens (other than Natives) and the importation of marine mammals and marine mammal products into the United States. At the other extreme, a species may be determined as *depleted.* A procedure to remove the moratorium on a species or population exists. In effect, this allows the Act to evolve from protection to controlled harvest for a species believed to be in excess of its optimum sustainable population. Passage of the MMPA has. committed the United States to *long-term management and research programs to conserve and protect these animals* (NMFS, 1987b).

As with the ESA, administration of the MMPA is shared by FWS and NMFS. NMFS has authority with regard to all cetaceans and pinnipeds except walruses. FWS has authority with regard to walruses, sea otters, sirenians and polar bears. For the activities specified by the MMPA (1981, 1986 amendments) .both Secretaries can allow, by special regulations and appropriate letters of authorization, incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens engaged 'in commercial fishing, and non-fishing activities such as offshore oil and gas exploration and development.

For marine mammals not designated as depleted, exceptions are specified to allow taking for public display, scientific research purposes, and incidental takes by the fishing industry and in specified activities other than commercial fisheries. All endangered/ threatened marine mammal species are considered depleted under the MMPA, but can be taken for subsistence (Native hunting). Takes incidental to fisheries and other activities are allowed under special regulations and letters of authorization. Depleted species cannot be taken for public display and can be regulated for subsistence takes. Of particular importance to the MMS is a 1981 Amendment creating more flexible and effective means of regulating incidental take for nonfishing activities. Of note are requirements to determine that proposed activities will have negligible impact on the availability of the species (or stock), on the habitat, and on subsistence use (Bean, 1983). In 1986, Congress further amended the MMPA to allow a *small* incidental take of depleted marine mammals. The ESA was also" amended to allow this take (NMFS, 1987b).

The 1986 amendments of Section 101(a)(5) of the MMPA and Section 7 of the ESA to allow *a* small incidental take of endangered," threatened and depleted species under certain conditions appear to remove a possible *zero impact standard* application of the Acts in which unintentional taking of even one individual of a listed species would require shutdown of the activity in question. New standards for review of permits stress impact on the total population rather than individuals. ,

On October 7, 1988, the ESA was reauthorized through FY 1992 and on November 23, 1988, the MMPA was reauthorized through FY 1993. Amendments to the ESA establish new requirements for preparing and implementing recovery plans (MMC, 1989). Amendments to the MMPA are directed mainly at interactions between commercial fishing and marine mammals. Some aspects of the many amendments enacted, (MMC 1989) have a direct effect on proposed ESP actions.

NMFS is presently listing all U.S. fisheries as one of three categories for takes of marine mammals:

- frequent incidental takes
- occasional takes
- remote possibility of takes

NMFS **must establish** an observer program for Category 1 fisheries under which 20-359. of operations will be monitored and data entered into an information management system. A new permit category, enhancement permits, was created, and scientific research permits may be issued only to proposed research projects that further a bona fide scientific purpose and do not unnecessarily duplicate other research.

The new observer program and information management system needs to be considered in planned MMS field programs that coincide with Category 1 fishery operations. The MMPA amendments for scientific research permits did not clearly define bona fide research or adequately account **for sample** replication as opposed to duplication. NMFS has released a document that reviews the permit process, highlights implications of the new amendments, and solicits comments **for revisions of the permitting process** (NMFS, 1989). The outcome of this effort may effect MMS protected species research.

In response to the special considerations involved under the ESA and the MM PA, the early ESP established a group of endangered species studies. In May 1980, the MMC formally requested BLM (the predecessor to MMS) to designate marine mammal studies coordinators in Headquarters and all regional offices. Many ESP studies have been funded in direct response to information needs defined by NMFS, FWS, and the MMC. Compliance to ESA/MMPA has been a major issue for **one** or **more** sales in the Alaska, Atlantic and Pacific planning areas. Permits for operational aspects of oil and gas activities have triggered information needs and studies in the Gulf of Mexico, Pacific, and Alaska Regions.

Regional Data Availability

Atlantic Region

The Atlantic Region covers the North Atlantic, Middle Atlantic, South Atlantic, and Straits of Florida Planning Areas. For this discussion, the North and Mid-Atlantic will be considered as one area and the South Atlantic and Straits of Florida will be combined as a second area.

In contrast to the Alaska Region, the Atlantic coastline is well-populated, and relatively numerous data on strandings and observations exist (CNA, 1977). Nevertheless, comprehensive surveys for marine mammals were notably absent in 1977. The abundance of cetaceans in nearshore waters of New England was essentially re-discovered by the BLM-sponsored Cetacean and Turtle Assessment Program (CETAP) conducted from 1978 to 1982 (Winn, 1981a, 1981 b, 1982; Winn et al., 1987). CETAP conducted aerial and ship surveys over much of the North and Mid-Atlantic Planning Areas (Figure 11-l). Results yielded 26 cetacean species and 4 marine turtle species in these areas (Winn, 1982). Five species of pinnipeds have also been recorded in the region, mostly in **northern extremes (Katona et al., 1977).**

Six endangered whale species occur in the North Atlantic region, including the right, humpback, fin, sei, sperm, and on rare occasions blue whales, with fin whales being the most abundant species (Table 4-2). Sperm whales tend to remain along the shelf edge, whereas the other endangered whales occur throughout the shelf region. Seasonalities and distributions are concisely reviewed by Winn et al. (1987). Some whales of all species persist in winter months, but winter distributions are not well documented.

As stated in the biological opinion of NMFS for Sale 52, the Great South Channel (Figure 11-2) appears to be an area of particular importance to right, humpback, and fin whales (Kenney and Winn, 1986). Georges Bank appears to be both a feeding ground and migration corridor to more northern waters for large whales.

Humpbacks migrate into the region in spring, and although widely distributed in the summer, tend to concentrate in the western Gulf of Maine (see Figure 4-18) (Winn et al.,

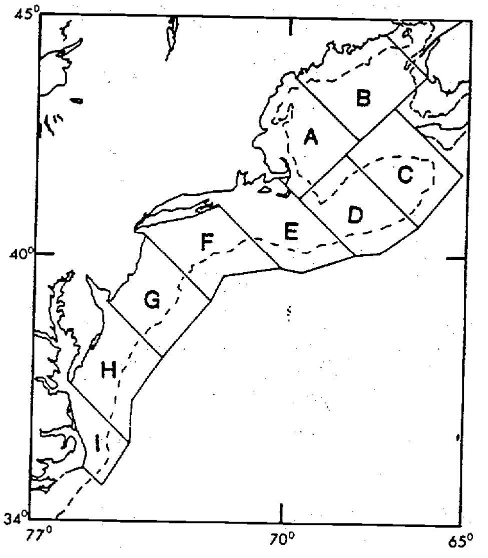

Figure 11-1. Aerial Survey Subunits for CETAP (Winn et al., 1982).

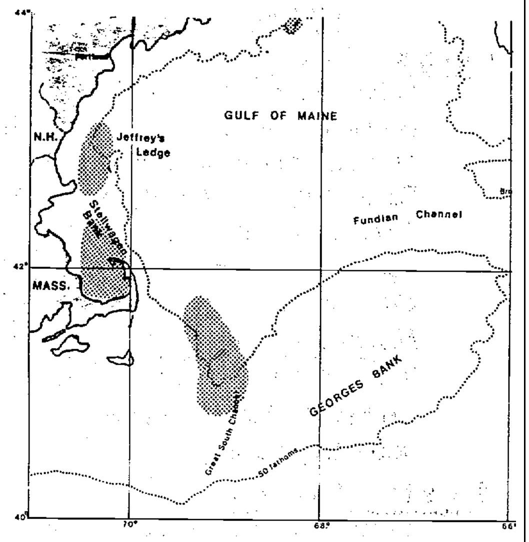

Figure 11-2. The Great South Channel, study area for SCOPEX.

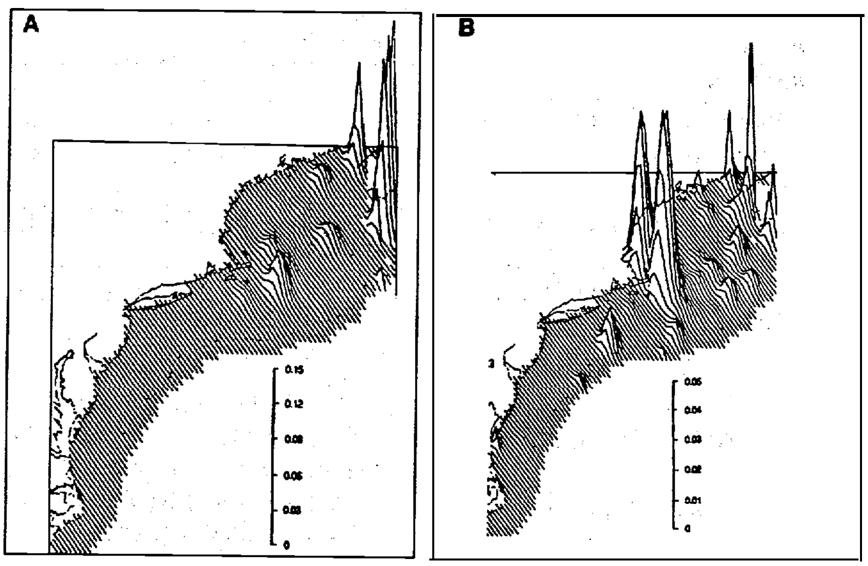

Figure 11-3. Distribution of A. Right Whales and B. Humpback Whales in the North and Mid-Atlantic Planning Areas (from Winn et al. 1987)

Species	Common Name	Number of Sightings	Number of Individuals
Large Whales			
Balaenoptera physalus	Fin whale	437	1,158
Eubalaena glacialis	Right whale	197	558
Megaptera novaeangliae	Humpback whale	163	440
Balaenoptera acutorostrata	Minke whale	89	113
Physeter macrocephalus	Sperm whale	43	71
Balaenoptera borealis	Sei whale	40,100	
Orcinus orca	Killer whale	2	6
Hyperoodon ampullatus	*N.* bottlenose whale	1	1
Total, identified large whales		1,008	2,447
Unidentified large whales		229	402
Total, large whales		1,237	2,849
Small Whales			
Lagenorhynchus acutus	White-sided dolphin	267	12,658
Globicephala melaena	Pilot whale	217	4,407
Phocoena phocoena	Harbor porpoise	165	301
Delphinus delphis	Saddleback dolphin	115	5,790
Tursiops truncatus	Bottlenose dolphin	107	1,856
Grampus griseus	Grampus	45	702
Stenella coeruleoalba	Striped dolphin	6,790	
Mesoplodon spp.	Beaked whales	6	18
Stenella spp. (spotted)	spotted dolphins	2	11
Lagenorhynchus albirostris	White-beaked dolphin	1	9
Total, identified small whales		931	26,542
Unidentified small whales		342	8,171
Total, small whales		1,273	34,713
TOTAL SIGHTINGS		2,510	37,562

Table 11-2. Cetacean Sightings in the Georges Bank Region, November 1978-January 1982 (Winn et al., 1987)

1987). Both spring and fall humpback migrations appear to occur offshore.

The North Atlantic right whale population is the most endangered species in Atlantic OCS planning areas. Less than 500 individuals remain, and although protected since 1937, the population shows little sign of recovery (Brownell et al., 1986). Work conducted by CETAP, Woods Hole Oceanographic Institute, New England Aquarium, the University of Rhode Island, and the Center for Coastal Studies have identified summer distributions of right whales in New England and Canadian waters (Kraus et al., 1986; Mayo et al., 1985; Winn et al., 1987) (Table 11-2). A major concentration of right whales commonly appears in the Great South Channel between late April to mid-July (Kenney and Winn, 1986). Some right whales are observed in Cape Cod Bay during the winter (Mayo, unpublished data) and one or two calves are reported to have been born in the Bay (Watkins and Schevill, 1982). The main winter calving area, however, appears to be located off the northern Florida-Georgia coast. An integrated research program on right whales funded by a congressional appropriation to NMFS, the Right Whale Initiative, is being conducted by the institutions identified above (Scott and Hansen, 1989).

In 1988-89, extensive oceanographic sampling, whale tagging, and aerial surveys were conducted in the Great South Channel (Figure 11-2) to study the relationships among right whales, zooplankton, and the physical and biological environment. This study, the South Channel Ocean Productivity Experiment (SCOPEX), is co-funded by the National Science Foundation and MMS. Analyses of the considerable data collected during the field seasons should provide valuable information on the highly endangered right whale and also new insight into why the study area is unusally high in productivity.

Smaller whales, porpoises, and dolphins occur year-round in mid- and north Atlantic waters. CETAP has plotted on-shelf and shelf-edge populations in detail (Winn, 1982). White-sided dolphins are the most numerous species with saddleback dolphins and pilot whales also common (Table 11-2). The mysterious deaths of large numbers of bottlenose dolphins along the Atlantic seaboard during the summer of 1987 will' probably increase interest in the segregation and movement of affected stocks. Geraci (1989) concluded the proximate cause of the mass mortalities was poisoning by the brevetoxin produced by the red tide dinoflagellate *Ptychodiscus brevis.* The stock of migratory mid-Atlantic bottlenose dolphins may have declined by about 50% (Scott et al., 1988).

Harbor seals occur regularly in Maine waters and move as far south as Long Island Sound during the winter and may stray to New Jersey. This species prefers bays, harbors, and estuaries and appears tolerant, if not curious, of boats and human activity (Katona et al., 1977). The population was reported to be increasing in Maine (Prescott and Gilbert, 1979), and more recent surveys indicate the winter population may have tripled to about 4000 seals in southern New England between 1980 and 1987 (Payne and Seizer, 1987), Most harbor seals south of Maine occur on Cape Cod with a notable concentration at Monomy Island, Massachusetts.

The gray seal is found in eastern Maine waters in small numbers year round and may occur as far south as Long Island during winter months. Winter breeding areas appear to be in Canadian waters with the major population centered in the Gulf of St. Lawrence. A small year-round population also is found on Muskeget Island, 'Massachusetts (Prescott and Gilbert, 1979), though since 1983, this aggregation has shifted to Wasque Shoals, southeast of Martha's Vineyard (Payne and Selzer, 1987). The number of gray seals has increased in New England, with the majority born on Sable Island, Nova Scotia, though some, limited pupping may occur in New England. Hooded and harp seals occasionally stray into New England waters and very rarely a walrus is sighted.

Turtles move northward from the south Atlantic areas in summer months to feed in mid- and north Atlantic waters. Nesting of loggerheads occurs on beaches from Virginia southward. CETAP distributional data reflects a preference of turtles for warmer shelf waters with only scattered sightings in the G ulf of Maine. Loggerheads and leatherbacks occur throughout the area with loggerheads being the more common species. Leatherbacks are most common in the mid-Atlantic during the summer, presumably preying on abundant jellyfish. Kemp's ridley turtles and green turtles are known to also occur in the region through scattered sightings and strandings. Almost all ridley turtles found in this region are immature/juvenile animals. The Gulf Stream is apparently utilized for northward movement, but details of sea turtle migration routes are unknown.

The south Atlantic is relatively less studied than the north Atlantic, particularly in offshore

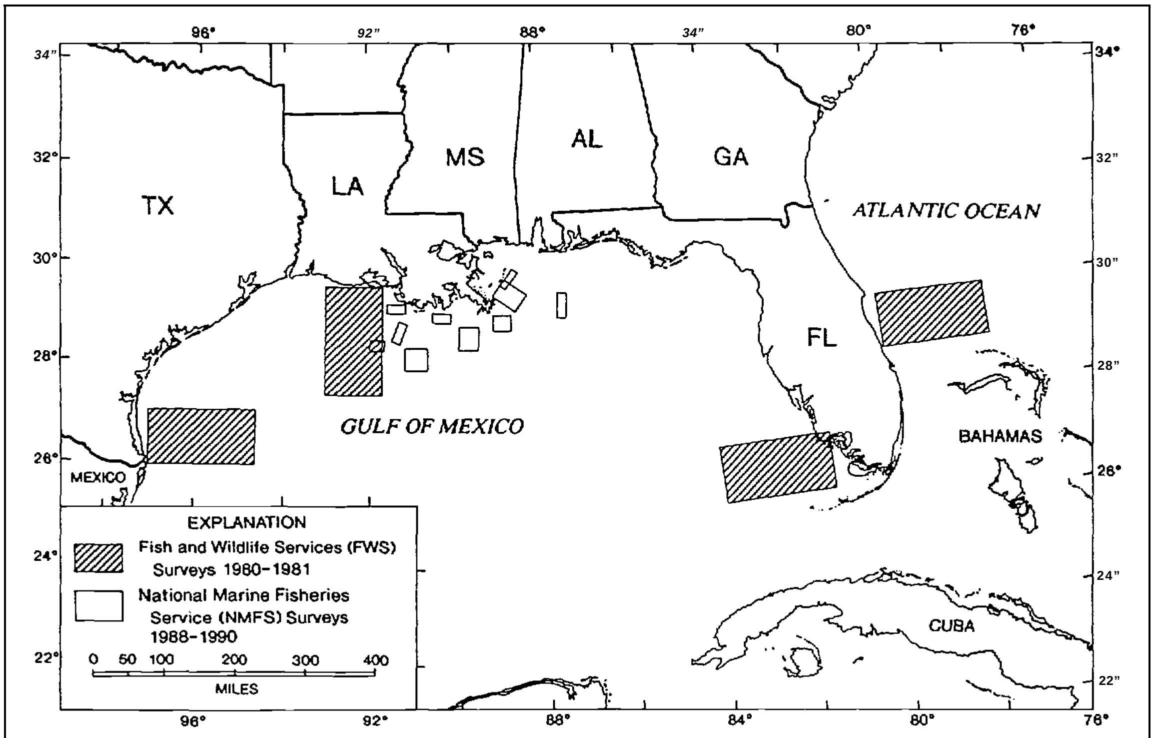

Figure 11-4. Aerial Survey Areas for MMS-Sponsored Studies in the Gulf of Mexico

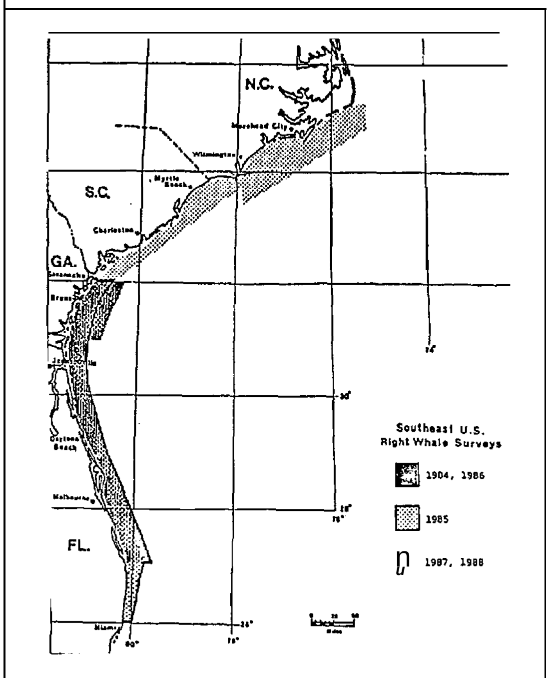

Figure 11-5. Aerial Survey Areas for Winter Studies of Right Whales (Kraus *et al.* 1988)

areas. Thirty-two species of marine mammals have been recorded in the region with 22 species occurring on a regular basis (MMS, 1984). In addition, several species of endangered/threatened birds utilize coastal habitats for nesting or migration routes. Five species of marine turtle have been recorded in the region, three species with nesting sites, Friis et al. (1983a, 1983b) provides concise species accounts for the region of Cape Hatteras south to the Florida Keys, based on a compilation of historic data and limited aerial surveys conducted from 1979-81 (Figure 11-4)

Kraus et al. (1988) conducted 4 years of winter aerial surveys for right whales along the Florida-Georgia coast from 1984 to 1988 (Figure 11-5), and Winn (1982) collected historic and current sighting data on right whales south of Cape Hatteras. Results indicate a major calving ground off the Florida-Georgia border inshore of the 10 meter isobath. Adults identifiable by distinct markings (Kraus et al., 1987; Crone and

Krause, 1990) were recorded in the south Atlantic area in the winter and also in summer surveys in the Gulf of Maine. This study raises questions as to the location of the bulk of the population during the winter, and whether the northern Florida-Georgia area is the only calving site. Not surprisingly, NMFS declared the right whale in jeopardy for the south Atlantic (MMS, 1984).

With the exception of the right whale, larger whales do not congregate in or heavily use the south Atlantic area. Sperm whales are the most common species in deeper water but do not routinely visit shelf areas. Sei whales are normally found north of the area, while fin and humpback whales migrate offshore relatively rapidly through the region. Blue whales may occur in this area but are very rare.

Numerous species of small whales, dolphins, and porpoises occur in the south Atlantic with spotted and bottlenose dolphins, short-finned pilot whales, and pygmy sperm whales being the most numerous (Fritts et al., 1983a). Minke whales occur off the coast of Florida in the winter.

The West Indian manatee is mostly restricted to Florida coastal and inland waters and therefore south of any Atlantic OCS operations to date. Concern was expressed by FWS on increased vessel traffic and measures to reduce collisions with manatees (MMS, 1984). Activity in the Straits of Florida would potentially interact with manatee populations.

Loggerhead sea turtles are the most abundant species in the region with notable nesting sites at Cape Remain, Cumberland Islands, Merritt Island, and Hutchinson Island. Florida accounts for the second largest loggerhead nesting population in the world (Carr et al., 1982). Along the east coast from North Carolina to Key Biscayne, Florida, nearly 21,000 loggerheads nest annually and comprise about 98% of U.S. nests for this species (Thompson, 1989).

Leatherback turtles are essential y a pelagic species often reported in New England waters and perhaps ranging as far north as Baffin Island. Nesting, however, is almost entirely tropical with only small numbers using Florida beaches. The leatherback appears to use the Gulf Stream to migrate northward in the summer (Winn, 1982).

Kemp's ridley sea turtles 'nest almost entirely on one strand of Mexican beach and are extremely threatened. Subadult turtles appear along east coast estuaries as far north as Nova Scotia in summer months. The Gulf Stream appears to provide a northern transport mechanism with nearshore southward migration (Winn, 1982).

Green sea turtles nest annually in Florida and may occur in lease area waters year-round. Almost all U.S. nesting of green turtles occurs along the east coast of Florida. About 300 nests occur annually and the number appears to be slowly increasing (Thompson, 1989).

On rare occasions, hawksbill turtles may occur in southern U.S. waters off the coast of Florida; and an occasional individual nest or two is found in the Keys (Harris et al., 1984).

Although overwintering of turtles is not fully understood, it appears that numerous turtles do overwinter buried in sediments of artificial ship channels along the Florida coast (Carr et al., 1982). Fritts and Reynolds (1981) observed turtles year-round in Florida waters indicating that overwintering is absent in some turtles or involves occasional surfacing. Interestingly, a decrease in sightings occurred before surface water temperatures dropped and increased sightings began before a temperature rise (Keller and Adams, 1983).

NMFS, in biological opinions for Atlantic lease areas, has expressed concern over dead turtles found with tar obstructing their throat and the potential of lighted offshore structures attracting turtles at night. Further research of effects of oil on marine turtles was initiated and is discussed under the effects section.

Endangered species of birds in the Atlantic areas include the bald eagle, American peregrine falcon, Arctic peregrine falcon, brown pelican, and wood stork (see also, Coastal and Marine Bird section). The FWS concluded no jeopardy to these species would occur through proposed (Sale 90) OCS activities (MMS, 1984).

Gulf of Mexico Region

The Gulf of Mexico (GOM) Region has sponsored the fewest studies on protected species. Biological opinions issued by the FWS and NMFS have found no jeopardy situations during past sales or as a result of production operations however, concern has been expressed on the need for better data on the species composition and abundance of cetaceans offshore. Although identified in a 1982 workshop (Keller and Adams, 1983) as a potential threat to protected species, the use of underwater explosives to remove platforms has only recently created an issue of significant concern as dead turtles and cetaceans, possibly a result of this procedure, were discovered on Texas beaches (Klima et al., 1988).

Endangered/threatened species in the GOM region that could be affected by OCS leasing and development include six whale species (humpback, right, sei, blue, fin, and sperm), West Indian manatees, loggerhead sea turtles, Kemp's ridley sea turtles, green sea turtles, leatherback sea turtles, hawksbill sea turtles, bald eagles, wood storks, Arctic peregrine falcons, brown pelican, whooping cranes, American crocodiles, Key Largo wood rats and cottonmice, Alabama and Perdido Key beach mice, and Key deer.

BLM sponsored studies (Fritts et al., 1983b) were the first systematic investigations of the distribution and abundance of offshore cetaceans in the GOM (Keller and Adams, 1983). Bottlenose dolphins have been the subject of nearshore studies by NMFS and are the most common and best understood cetacean species in the GOM (Keller and Adams, 1983).

Nesting of marine turtles is also well studied by Federal and State agencies, though at sea studies of turtles are rare and information is notably lacking (Fritts et al. 1983b).

Loggerhead turtles are common in the central and western GOM and fairly abundant off the western Florida coast but are infrequent off the coast of Texas. Kemp's ridley turtles are the primary species in the western GOM, but are severely depleted. Green and leatherback turtles are far less common, while the hawksbill is the rarest species in the GOM. Until recently virtually no nesting of sea turtles had been observed on U.S. GOM shores west of Florida. The causes for this may be related to physical oceanographic processes, but exact reasons remain uncertain (Carr et al., 1982). However, more recent surveys indicate sporadic nestings of at least loggerhead turtles along GOM shores.

Exploitation of sea turtles for food is common in the Caribbean. In the U. S., alteration of nesting habitat was believed to be the greatest threat to sea turtles, followed by incidental takes by fishing activities (trawling, long-lines, gill nets). Between 10,000 to 23,000 turtles drown annually from commercial shrimp trawling activities in the Gulf of Mexico and South Atlantic (Thompson, 1989). The recent Western Atlantic Turtle Symposium (Ogren, 1989) placed more emphasis on incidental catch – *this massive loss, principally of subadults, is negating the benefits of the numerous beach protection efforts and hatcheries on southeastern US beaches, and is causing a slow but steady decline of the nesting populations.* Possible impacts through rig removals or oiling of nesting sites, in themselves, do not appear to threaten great numbers of turtles, but when added to the overall threats to turtles, any additional source of potential harm is a major issue. The National Research Council has initiated a study on causes of sea turtle declines with results just published but not received at this writing (NRC, 1990).

Common Name	Scientific Name
Balaenopteridae	
Fin whale	*Balaenoptera physalus*
Sei/Bryde's whale	*B. borealis/edeni*
Physeteridae	
Sperm whale	*Physeter macrocephalus*
Pygmy/dwarf sperm whale	*Kogia breviceps/simus*
Ziphiidae	
Cuvier's beaked whale	*Ziphius cavirostris*
"Beaked" whales	*Mesoplodon* sp.
Delphinidae	
Pygmy killer whale	*Feresa attenuata*
False killer whale	*Pseudorca crassidens*
Killer whale	*Orcinus orca*
Short-finned pilot whale	*Globicephala macrorhynchus*
Rough-toothed dolphin	*Steno bredanensis*
Common dolphin	*Delphinus delphis*
Bottlenose dolphin	*Tursiops truncatus*
Risso's dolphin	*Grampus griseus*
Atlantic spotted dolphin	*Stenella frontalis*
Pantropical spotted dolphin	*S. attenuata*
Striped dolphin	*S. coeruleoalba*
Spinner dolphin	*S. longirostris*

'able 11-3. Species of Whales and Dolphins Sighted during Aerial Surveys in, the Gulf of Mexico from July 1989-June 1990.

The Kemp's ridley sea turtle is probably the most endangered species of sea turtle. The turtle has one primary nesting site near Rancho Nuevo, Mexico. Compared to as many as 40,000 nesting turtles counted in one day in 1947, fewer than 600 turtles nested in 1986 (Caillouet et al., 1987). An international program to restore the turtle population was begun in 1978 and includes an attempt to establish nesting on the Padre Island National Seashore near Corpus Christi, Texas. NMFS has a major head-start research program at its Galveston Laboratory to rear and release yearling turtles (Manzella et al., 1988). Under current conditions, Thompson et al., (1986) predict extinction of the species in about 200 years.

Offshore data on small whales, dolphins, and porpoises are summarized by Fritts et al., (1983a). New information obtained during this,, aerial survey study included the documentation of beaked whale and pilot whale populations off the Texas coast and the presence of Risso's dolphin in the western GOM. In contrast to aerial observations, stranding data indicate that *Kogia* species. are relatively common in GOM waters and that the Gulf may represent a population center for these species (Schmidly, 1981). A Southeastern Marine Mammal Stranding Network was formally organized in late 1977 and continues to be a prime source of information for GOM marine mammals.

The abundance and distribution of baleen whales in the GOM shelf region is not well known. Fin whales may occur year-round, and there are indications of a GOM population of Bryde's whales. One stranding of a right whale occurred in Texas in 1972, and similar incidental sightings and strandings for blue, sei, minke, and humpback whales exist. Historical whaling records indicated sperm whales to have been common in the GOM. Somewhat surprising was the rediscovery of sperm whales off the south Texas coast (Fritts et al., 1983a), a location without reports of this species for decades. Mate (personal communication) has received reports of killer whale sightings during recent oceanographic cruises in the GOM. Initial data from deepwater aerial transects conducted by NMFS for MMS in 1989 (Figure 11-3) indicate a relatively rich cetacean fauna offshore (Table 11-3).

Further studies of offshore cetaceans could yield new information on GOM cetaceans, as survey data is sparse. A Sea Turtles and

Marine Mammals Workshop was held August 1-3, 1989 to identify data gaps and determine research that should be conducted on these species. Publication of workshop results is projected for mid-1 990.

Pacific Region

The Pacific Region has funded large field efforts to survey marine mammals and birds in southern California (1975-78) and central-northern California (1980-83) (Dohl et ai. 1981, 1983; Bonnell et al. 1981, 1983), and a similar broad-scale survey was initiated in 1988 along the Washington and Oregon coasts (Figure 11-6). The west coast has about 35 species of pinnipeds and cetaceans that may occur in U.S. waters.

Other endangered species are the southern sea otter (threatened), bald eagle, American peregrine falcon, light-footed clapper rail, California least tern, unarmored three-spined stickelback, salt marsh harvestmouse, and two plants (salt marsh bird's-beak, Menzies' wallflower).

Bald eagles historically bred in the Channel Islands (Figure 11-7) off the southern California coast until the mid-1950's. The islands were given the highest priority for re-establishing bald eagles in California, and in 1980, six immature bald eagles were released on Santa Catalina Island. The project has continued with a flock of 12 birds surviving from a total of 25 translocated. In 1986, an additional nine immature eagles from Vancouver Island were introduced,

Also, in southern California, Morro Bay Rock is a highly publicized peregrine falcon nesting site. Additional nests are believed to exist in the Point Conception area. About 50 known nesting pairs of American peregrine falcons were reported for central and northern California in 1983.

Brown pelicans are recovering from catastrophic nesting failures during the late 1960's and early 1970's. The oniy consistent breeding location on the U.S. west coast is Anacapa Island. Nonbreeding birds range as far north as British Columbia. The California i east tern and light-footed ciapper raii have suffered from loss of coastal habitat for nesting and successful breeding. The rail population may be below 150 pairs making it one of California's most endangered species. A petition to list the marbled murrelet as threatened in the states of Washington, Oregon, and California is presently under review by FWS (FWS, 1988b). The murrelet is rare in these states with nesting restricted to oid growth forests.

Biological opinions issued for California sales by FWS have, to date, conciuded proposed activities are not likely to jeopardize the continued existence of these bird species, sea otters or endangered plants.

Four species of endangered sea turtles (green, leatherback, Pacific Ridley, and loggerhead) are found in southern California waters as intermittent visitors. No turtles nest on California beaches. Leatherbacks range the farthest north and can be sighted in centrai and north California areas.

The southern sea otter, if considered a subspecies, is endemic to California. The taxon *Enhydra lutris nereis* (southern sea otter) is controversial, and its validity is currently unresolved (FWS 1987). As either a subspecies or distinct population, the southern sea otter is listed as threatened with the potential consequences of a major oil spill (from tankering) being cited as a primary factor for listing. The MMS has funded studies that confirm the otter's vulnerability to oil (see effects section) and have investigated the sea otter's behavior, population growth, and possible means to protect otters from spilled oil or mitigate effects. Findings of the latter study have been used at otter recovery centers in Vaidez and Seward, Alaska following the recent Exxon oil spill. An estimated 1,570 animals comprise the entire California population with a range from Anno Nuevo Point south to the Pismo Beach/Santa Maria River area. The population remained

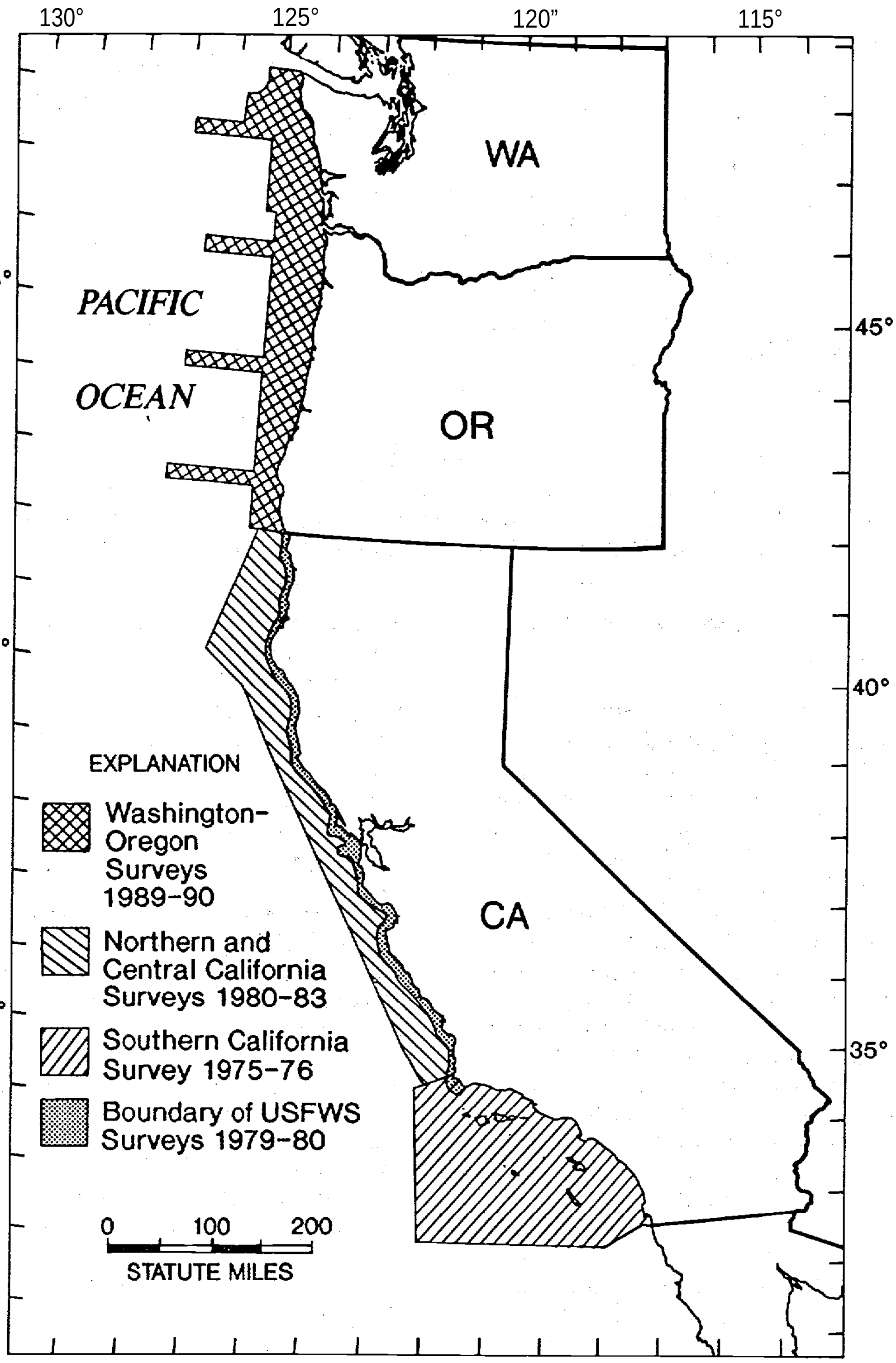

Figure 11-6. Marine Mammal and Seabird Survey Areas Covered by MMS Sponsored Studies

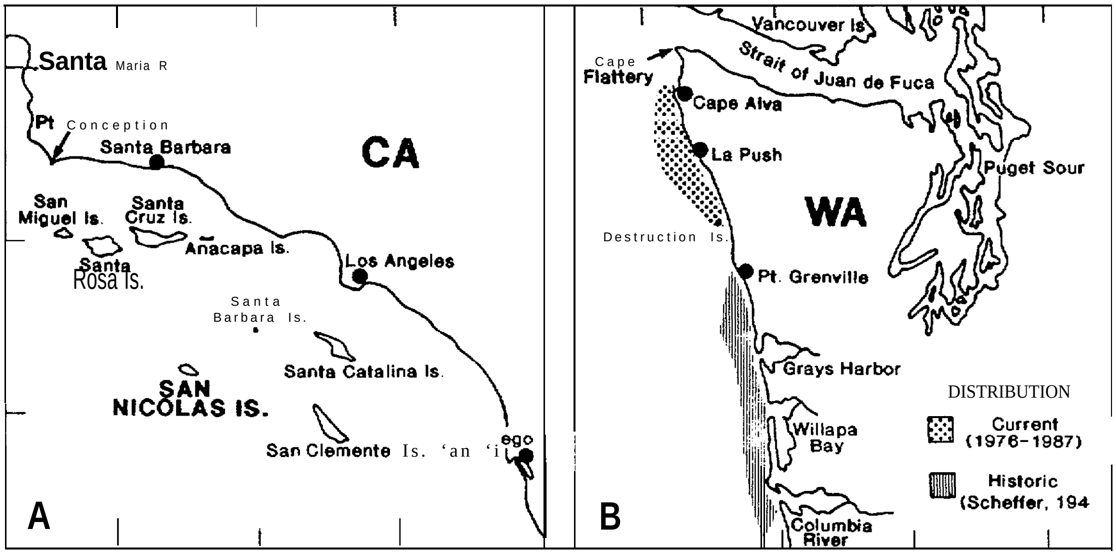

Figure 11-7. West Coast Sea Otter Sites, A. San Nicolas Translocation Site. B. **Distribution of Sea Otters in Washington State (from Bowlby et al, 1988)**

stable or declined slightly between 1982-1987 (FWS, 1987b).

The FWS has begun translocation of a small number of animals to San Nicolas Island (Figure 11-7A) with the goal of establishing a second population center in California. Sea otters are a center of controversy as they can rapidly deplete local shellfish and other marine life. The EIS prepared for Translocation of Southern Sea Otters by FWS provides an excellent review of both the biology and socio-economic impact of otters in California (FWS, 1987a). From August to December, 1987,60 sea otters were shipped to San Nicolas Island (FWS, 1988b). To date, the translocation effort has surprised and perplexed FWS biologists as, contrary to predictions, some otters have successfully crossed deep-water channels and returned to mainland coastline. By late January 1988, only 24 otters were located on the island. Eleven otters were known to have died or been returned to parent populations, leaving 25 otters unaccounted for (Moore, 1988).

In 1969-70,59 sea otters captured in Alaska (Amchitka Island) were released at Point Grenville and La Push on the Washington coast. Additional otters from Alaska were released off Oregon. Surveys conducted by the Washington Department of Wildlife during 1986-87 indicate the population has approximately doubled after 17 years to an estimated population of 136 (Bowl by et al., 1987, 1988). The animals released off Oregon have disappeared either through mortality or (more likely) by movement northward to the group off Washington. The population ranges about 70 km along the Washington coast from Destruction Island north to Point of Arches (Figure 11 -6B). Although not listed as endangered under the ESA, the population is classified as endangered by the State of Washington.

The Guadalupe fur seal is a threatened species breeding on Guadalupe Island off the coast of Baja, California and perhaps San Miguel Island. The population is below 2000 animals. Since 1969, small numbers of seals have hauledout on San Miguel Island and occasionally at San Nicolas, San Clemente and Santa Barabara Islands. Sightings have become more common in recent years (Stewart et al., 1987).

The North Pacific fur seal main breeding population centers around the Pribilof Islands, and the species is most often associated with

Alaska. However, early winter migrations from Alaska bring all but older males to coastal waters off Washington, Oregon, and California where they feed from roughly November to March. A colony of fur seals was discovered in 1968 on San Miguel Island. This population of a few thousand animals remains in southern California waters year-round, with limited breeding on the island.

Steller sea lions also bred on San Miguel Island, but have become *locally extinct* in recent times (Stewart et al., 1987). The number of Steller sea lions in California has declined rapidly, although populations in Oregon appear stable (Brown, 1988). Throughout their ranges both species have shown significant population declines. Decisions on whether to declare these species as depleted under the MMPA are expected during 1989 (NMFS, 1986, 1987a, 1988). [Steller sea lions were given emergency listing as threatened, April, 1990 (FWS, 1990)].

Northern elephant seals breed in winter along the west coast of California, Mexico, and the Baja, usually on coastal islands. Mainland colonies occur at Ano Nuevo and Point San Martin (30 miles south of Monterey). Small numbers now haulout as far north as Shell Island at Cape Arago, Oregon (Brown, 1988). During summer feeding, elephant seals range as far north as southern Alaska. MMS has recently partially funded at sea behavioral studies (Le Boeuf et al., 1987).

California sea lions breed from Mexico as far north as the Farrallon Islands. Non-breeding males range up to British Columbia in a well-documented northern migration (Freel and Aceituno, 1978). The population in California is large and growing, which is causing increasing conflicts with commercial and sport fishing interests (NMFS, 1987b). Habitat utilization and distribution at sea were studied by Bonnell and Ford (1986). The migratory pattern results in peak haulout of sea lions along the Oregon coast in September and March-April, with a progressively later and earlier migratory pulse in Washington and British Columbia waters (Brown, 1988).

The harbor seal is distributed in shallow' coastal waters, generally avoiding other pinnipeds and forming loose aggregations of individuals. Its southern range extreme is San Ignacio Lagoon, Mexico (Lentfer, 1988). Populations are declining for uncertain reasons in the southern-most range but are increasing in Washington and Oregon (NMFS, 1987b). The Columbia River appears important as a winter feeding area for northern populations (Brown, 1988; Jeffries, 1986), The harbor seal is the only pinniped that breeds in Washington State and is the principal species involved in fisheries interactions in Washington and Oregon (NMFS, 1987b).

Seven species of large whales are known to occur in west coast waters. In California, whales are numerically a minor element of the cetacean population but seasonal abundance during migration and sheer biomass may be locally significant (Dohl et al., 1983). The whale populations are usually characterized as migratory in, California with winter breeding/calving grounds to the south and summer feeding grounds to the north. Although this is the normal pattern for gray whales (breeding in Mexican waters, feeding in Arctic seas), other species may have more complex migratory patterns.

Gray whales are seasonally the most abundant species with a range from Chukchi in Alaska south to Baja. Southern migration to calving lagoons in Baja California and Mexico begins in November with pregnant females in the lead and juveniles last (Rice and Wolman, 1981). Some juvenile whales may linger along the coast and around the Channel 1 stands without completing the southern leg of the migration. Spring northward migration begins in February and lasts through May. Dohl et al. (1983) suggest that as the population continues to increase in size, more whales are becoming resident in northern California waters. Small numbers of whales also reside in Washington and British Columbia waters.

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Exceptions to the classical migration pattern exist. The migration in both directions is nearshore along most of the route (Darling, 1984). The entire population migrates directly through several OCS planning areas in the Pacific and Alaska ; thus major concerns exist on possible cumulative effects. Despite this route, the species has exhibited a dramatic recovery in population numbers. Record numbers of calves were observed during the 1986-87 migration (Dohl, 1987).

Humpback whales normally winter off the coast of Mexico and migrate north for summer feeding in Arctic waters. The North Pacific humpback population has a rather complex distribution, and exact migration routes between northern feeding grounds (Bering Sea, Chukchi Sea, Gulf of Alaska, Southeastern Alaska and Farallon Islands) and southern breeding grounds (Mexico, Hawaii, Mariana Islands) are not known (Kaufmann and Forestell, 1986), Dohl et al. (1983) noted an **increasing number of humpbacks in the Farallon Basin that summer-over and may reside in California waters** for at least 8 months annually. This central California feeding herd appears to use Mexican waters as a wintering ground (Urban et al., 1987).

Blue and fin whales are sighted in modest numbers year-round in California (Dohl et al., 1981, 1983) and are also sighted in Oregon and Washington coastal waters (Speich et al., 1987). Sei and sperm whales also occasionally enter coastal waters but generally remain offshore in oceanic waters. Finally, the right whale can occur in California waters as indicated by historical sightings and rare recent reports of individuals. None were sighted on MMS surveys.

Smaller cetaceans are common along the west coast, the most abundant in the Southern California Bight being the common dolphin. Seasonal distributions were studied by Dohl et al. (1986) under an MMS contract. Other common species include the harbor porpoise, Risso's dolphin, and pilot whale. Bottlenose dolphins have recently been observed as far north as Santa Barbara (Wolf et al., 1987). Major species of central/northern California cetacean populations include Pacific white-sided dolphins, northern right whale dolphins, Risso's dolphins, Dall's porpoise, and harbor porpoises (Bonnell et al., 1983). Harbor porpoise populations were surveyed along the California, Oregon, and Washington coasts during 1984-86 by NMFS (Barlow, 1987).

To date, the two species of most concern and at the center of public attention are the gray whale and southern sea otter. MMS has responded to these concerns with additional studies on both species to better define potential threats and mitigating measures (Estes and Jameson, 1983; Davis, 1986; Malme et al., 1984; Woodward-Clyde, 1983). According to FWS, the sea otter translocation project should ultimately lessen a potential jeopardy situation from oil spills. Conversely, failure of the project would have somewhat unpredictable impacts, but concern for safety and recovery of the population could increase. In theory, gray whales are exposed to more human activity along its entire range than any other whale yet the population shows no overt signs of harm. The benthic feeding habit of gray whales is exceptional among large whales and perhaps is a factor in its dramatic recovery, In any event, concern on cumulative effects from human activities, including but not exclusive to OCS oil and gas development, are warranted. Effective means to study or detect cumulative effects in whales remain elusive.

Alaska Region

Because of the vast area of the Alaska OCS (33,904 miles of tidal shoreline) and relative abundance and diversity of marine mammals, the task of obtaining fundamental data on species distributions and population estimates is more difficult than similar efforts in the other OCS Regions. The magnitude of the task is made more difficult by extremes in weather **and limited shore-based research facilities.**

In the Gulf of Alaska Region (Gulf of Alaska, Kodiak, Cook Inlet, and Shumagin Planning Areas, see Figure 11-8), 19 species of non-endangered marine mammals have been observed. Four species occur in substantial numbers: Steller sea lions, fur seals, Pacific harbor seals, and sea otters. Seven species of endangered whales occur in the region: gray, right, blue, fin, sei, sperm, and humpback whales (Table 11-4).

The ESP has contributed significant data on marine mammals. Hall (1979) completed a survey of cetaceans in the Prince William Sound Area. Comprehensive marine mammal surveys of the Gulf of Alaska were conducted for MMS by NMFS between 1976 and 1981 (Fiscus et al., 1976) and included analysis of platforms of opportunity data from 1958 to 1980 (Consiglieri et al., 1982). Rice and Wolman (1981) studied summer distributions of fin, humpback, and gray whales. Hubbs Sea World Marine Research Institute (Leatherwood et al., 1983) also conducted whale surveys for portions of the region while, most recently, Bruggeman et al, (1987a) conducted aerial surveys of marine mammals along the Alaska Peninsula including Shumagin, North Aleutian Basin, and St. George Basin Planning Areas.

Most recent information on pinnipeds has been obtained through MMS-funded OCSEAP studies (Calkins and Pitcher, 1986). Detailed information has been gathered on harbor seals (Pitcher, 1977; Pitcher and Calkins 1979) and Steller seal lions (Calkins and Pitcher, 1982). Schneider (1976a) studied population distribution of sea otters in the Kenai peninsula. NMFS has indicated particular concern for the well-being of North Pacific right whales and migrating gray whales. In addition, Steller sea lions have undergone substantial population declines for unknown reasons. Calkins (1 986) notes a lack of information on small cetaceans and feeding habits of sea otters. Interest also exists to further study a population of beluga whales in Cook Inlet.

On March 24, 1989, the largest oil spill in U.S. history occurred when the *Exxon Valdez* struck Bligh Reef. Over 10 million gallons of crude oil were released into Prince William Sound in less than 5 hours (NRT, 1989). A situation now exists where the Gulf of Alaska, specifically Prince William Sound, projected to be of low interest for OCS development and any additional MMS protected species studies, is now a site of a major oil spill, perhaps the first to affect marine mammals in any number. Since the oil spill was not OCS related, MMS involvement to date has been limited. However, it is clear that substantial new information on the effects of oil on protected species (particularly sea otters and pinnipeds) will result.

The Bering Sea Region (Figure 11-9) can be divided into the northern Bering Sea (Norton Basin and Navarin Basin), an area dominated by sea ice from late December to May, and the southeastern Bering Sea (St. George Basin and North Aleutian Basin). Marine mammals are abundant and diverse in the Bering Sea with 25 species reported to occur in the area, 19 being regular inhabitants (Fay, 1981).

The southeastern Bering Sea includes areas of particular biological importance: the Pribilof Islands, Unimak Pass, and Bristol Bay. Common pinnipeds are the Steller sea lion, Pacific harbor seal, Pacific walrus, and the north Pacific fur seal. Northern sea otters are common along the Aleutian islands. The Pribilof Islands are critical breeding grounds for the fur seal with nearly three-quarters of the world's fur seal population seasonally concentrated around the islands (NMFS, 1986). Numerous breeding sites for sea lions are found in the region in addition to large and relatively predictable haul-out sites for sea lions and walruses (Figure 11-9). During winter months, ice-associated seals (e. g., spotted and ribbon) will often be found in St. George Basin.

Cetaceans are abundant. An estimated 80% of the total gray whale population enters the Bering Sea from April to December (Braham,

	Seasons			
	Winter Jan-Mar	Spring **Apr-Jun**	Summer **Jul-Sep**	Autumn Ott-Dec
Cetaceans				
Blue whale[a]		R	R	R
Fin whale	R	o	+	R
Sei whale	R	+	o	R
Humpback whale	R	o	+	o
Right whale[a]		R	R	R
Gray whale	+	o	R	o
Sperm whale		o	0	0
Minke whale[b]		+	+	
Killer whale[b]	o	0	0	0
White whale[b]	o	0	0	0
Pilot whale		-	R	-
Giant bottlenose whale		R	R	
Goosebeak whale[b]	o	0	0	0
Bering Sea beaked whale[b]				
Dan porpoise[b]	o	0	0	0
Harbor porpoise[b]	o	0	0	0
Pacific white-sided dolphin	R	o	+	R
Risso's dolphin	R	R	R	-
Northern right whale dolphin	-	-	R	-
Carnivores				
Northern fur seal	+	o	0	+
Steller sea lion[b]	o	0	0	0
Northern elephant seal		R	R	-
Harbor seal	o	0	0	0
Sea otter[b]	o	0	0	0
Walrus		R	R	R

[a] Historically abundant seasonally
[b] Resident

Table 11-4. Check list of Marine Mammals by Season in the Gulf of Alaska (Consiglier et al., 1982) R = rare visitor, O= regularl y present, + = greatest frequency, - = unknown

1984b). Unimak Pass is the most important migratory route to enter the Bering Sea, with nearshore migration through the southeastern Bering Sea to feeding grounds in the North Bering and Chukchi Seas (Brueggeman et al., 1987a). Fin and humpback whales are also common during summer months. Humpbacks are found nearshore from April through November, while fins are farther offshore, with some individuals overwintering in the area (Brueggeman et al., 1983). Sperm whales are sighted occasionally. Blue, sei,

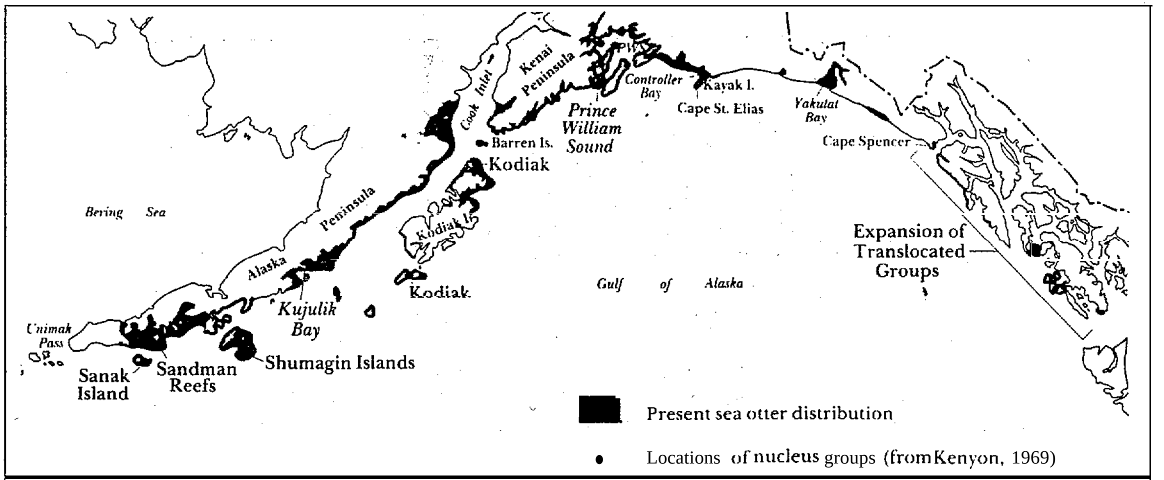

Figure 11-8. Gulf of Alaska Study Area Showing Distribution of Sea Otters (Calkins, 1986)

and right whales are rare. Bowhead whales are infrequent in the southern Bering Sea. Other common non-endangered cetaceans include minke whales, killer whales, beluga whales, Dall's porpoises, and harbor porpoises.

The northern Bering Sea includes major benthic feeding grounds for gray whales and walruses (Nerini et al., 1986; Nelson and Johnson, 1987). The Bering Strait is an important migratory passage into the Chukchi Sea for summer feeding grounds or out of northern waters during winter ice. Although feeding gray whales, with some humpbacks and fins, predominate in summer months, the Navarin Basin in winter may contain the entire western Arctic population of bowhead whales (Fraker 1984). Two right whales were sighted in the area (Brueggeman et al. 1983). In addition to large walrus populations, spotted, ribbon, and bearded seals are common. Less common are ringed seals and polar bears.

The endangered Arctic peregrine falcon and Aleutian Canada goose may be found within the Bering Sea region. FWS notes that proposed OCS oil and gas activities would be unlikely to impact these species.

Numerous MMS sponsored studies have been conducted on cetacean and pinniped distribution and biology within the Bering Sea in addition to some work on sea otters. Fay (1981) noted the significant contribution of these studies to the knowledge of spring-summer distributions of phocid seals and otters. Considerable work has been completed since 1981 to further enhance knowledge of Bering Sea marine mammals.

Ljungblad et al. (1987) andTraecy(1988) have conducted aerial surveys for endangered whales in the northern Bering, Chukchi, and Beaufort Seas since 1979 (Figure 11-1 O). Gray whale data for the Bering sea have provided new information on annual distributions and behavior for this species. Brueggeman et al. (1987b) studied winter distributions of bowhead whales and correlation with types of sea ice. Leatherwood et al. (1983) surveyed whales in the southern Bering Sea and has recently compieted an appraisal of whale habitat utilization in the St. *George* Basin (Leatherwood, 1985). Considerable information on Beluga whales has recently been released by Alaska Department of Fish and Game scientists (Burns and Seaman, 1986; Lowry et ai., 1986; Seaman et al., 1986).

The earlier work of Schneider (1976b) on sea otter distributions in Bristol Bay and Aleutian islands is now being enhanced by an ongoing tagging study centered at False Pass (Unimak Island). initial studies on seals have aiso been

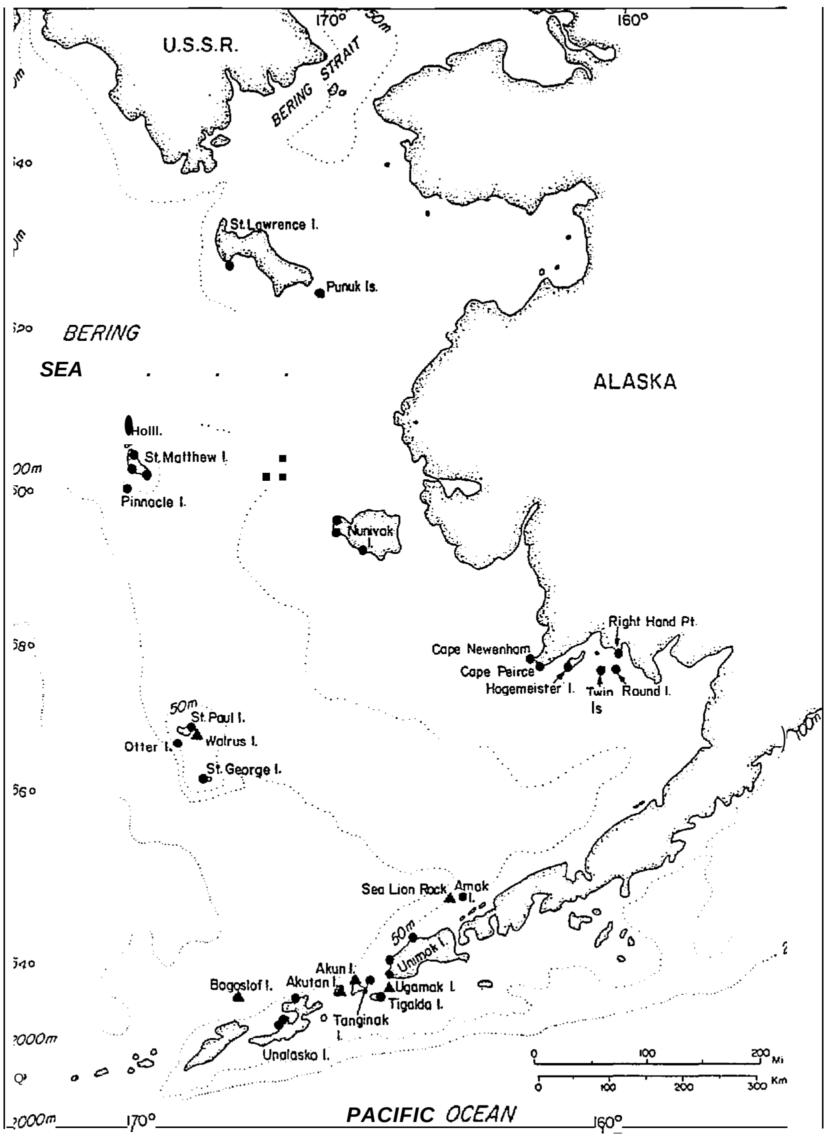

Figure 11-9. Bering Sea Study Area and Locations of Important Haulout Sites used by Northern Sea Lions (triangles indicate rookeries (Johnson et al., 1989)

continued to a limited degree (Lowrey and Foster, 1981; Fay et al., 1984; Brueggeman and Grotefendt, 1986), and additional analysis of walrus population data continued through 1987-88. A more detailed study of the Unimak Pass area was initiated in FY 1987.

When ESP data are coupled with other significant data sources for Bering Sea marine mammals, such as NMFS, State of Alaska, and National Science Foundation sponsored research, a relatively good baseline of information exists. As a result of long-standing international treaties and a controlled harvest, fur seals may have one of the largest databases for any marine mammal (Reed et al., 1986). On a broad scale, the most notable weakness in existing

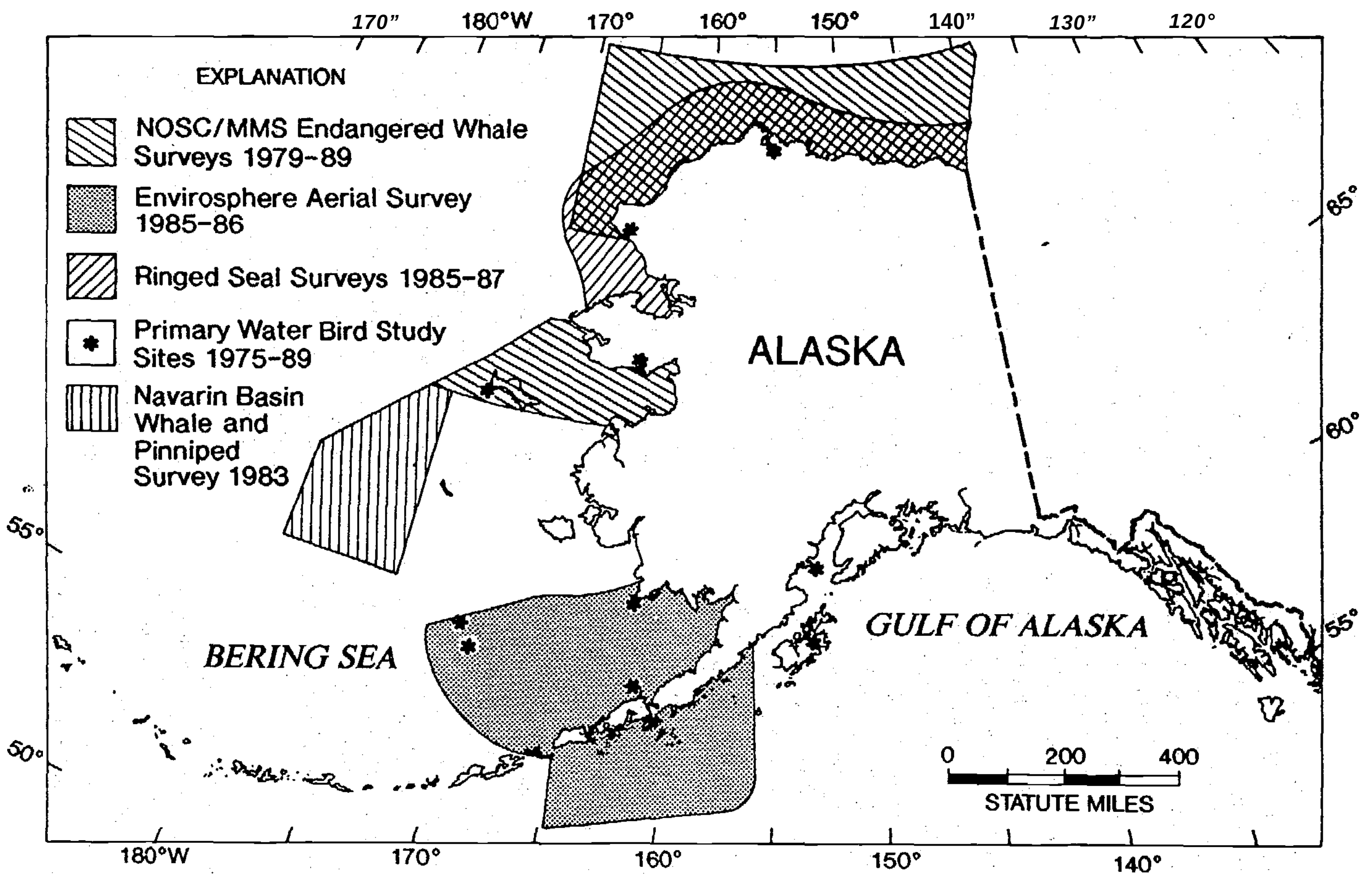

Figure 11-10. Study Area for NOSC Aerial Survey and Other MMS Sponsored Major Survey Efforts in Alaska

information is winter distributions of marine mammals. On a finer scale, particular locations of notable importance to one or more marine mammal species characterize the region. Oil and gas activities that could affect these locations could require additional detailed information required for local risk assessment. Although the gray whale population may have reached or exceeded pre-whaling numbers (Braham, 1984b), the concentration of significant portions of the population at breeding grounds in the south, migratory 'bottlenecks', and relatively restricted benthic feeding grounds in the north Bering Sea, in theory, make the population vulnerable to a local catastrophic event. NMFS, as expressed in biological opinions, feels that oil and gas activities (oil spill) that could harm whales or critical habitat (Chirikov Basin, Unimak Pass, Bering Strait), or cumulative exposure to disturbances along migratory paths could place the population in jeopardy. However, the level of cumulative effects needed to jeopardize the species currently defies identification. Similarly, the existence of the entire stock of bowhead whales in the northern Bering Sea during overwintering and migration through the Bering Straits and concentration of whales in the spring ice leads is of specific concern,

Right whales occur in the Bering Sea, **but** because the population is at such low numbers, little information exists on distributions of remaining individuals. Essentially, contact with a right whale is seen as unlikely and unpredictable (Brownell et al., 1986). NMFS has stated that harassment or harm to a single whale constitutes jeopardy to the population.

For non-endangered species, certain problems are evident. Any large haulout of pinnipeds is of concern for possible adverse effects from disturbance or habitat degradation. Of note are the continued population declines of Steller sea lions and fur seals for unknown reasons (Braham et al., 1977b; NMFS, 1986; 1987a; 1988). Walrus populations have shown marked fluctuations in the past 150 years, perhaps from man-induced overharvest and overprotection (Fay et al., 1984). Populations are presently very high, perhaps at an unstable state and recently show signs of declining (Sease, 1986). Finally, sea otters are indicating a strong recovery and expansion into historical ranges (Lentfer, 1988). Impacts of otters on commercial fishery species are of concern. The potential of otters to alter a coastal habitat in one manner or another appears to be significant. The basic factor for all these species is that detectable and presumably biologically significant shifts in populations are occurring that make biological assessments and predictions more difficult. The need for most recent data is perhaps more important relative to species exhibiting less dynamic changes.

The Arctic region (Hope Basin, Chukchi Sea, Beaufort Sea) is dominated by ice. Sea ice affects or governs the movement and distribution of all marine mammals in the region. Marine mammals play a unique role in the social fabric of Native inhabitants. Legal protection of biological species and environmental impacts become entwined with management of harvestable subsistence resources and the preservation of Native culture.

The Chukchi Sea (Figure 11-11) contains 20 species of marine mammals, of which only the ringed seal, bearded seal, and polar bear are year-round residents. This area is the prime habitat for ringed seals relative to the Bering or Beaufort Seas. The seal is strongly associated with ice and is dependent on sea ice as a substrate for resting, whelping, and molting (Lentfer, 1988). It often is the only species available to hunters in the winter with perhaps over 1000 animals harvested annually in the region. Arctic fox and polar bears also prey on ringed seals, and although not a true marine mammal, the fox is relatively common on winter sea ice.

Bearded seals remain on sea ice year-round, moving to the Bering Sea during heavy winter ice. This seal is a preferred food and source

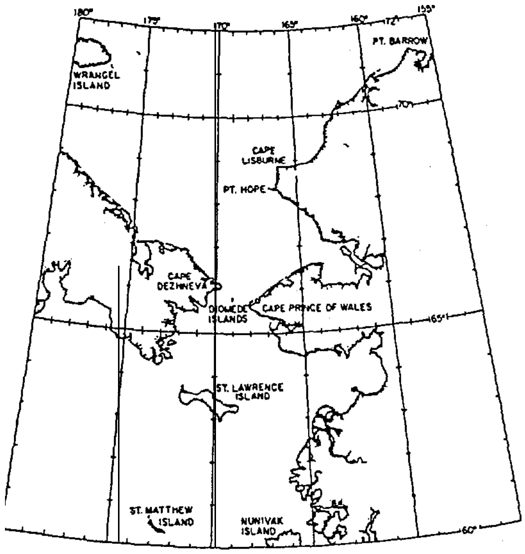

Figure 11-11. Chukchi Sea Study Area

of skins for native hunters. The increased use of motor boats by native hunters has shifted seal hunting preference from ringed to bearded seals (Lentfer, 1988).

The Bering-Chukchi walrus population accounts for about 80% of the world's population (Fay, 1982). Following wintering in the Bering Sea, a large proportion of this population feeds from open pack ice in the northern Chukchi Sea, concentrating toward either the coasts of Siberia or Alaska (Lentfer, 1988). Animals become common in nearshore waters when ice drifts in or ice drifts to deeper water forcing the benthic feeding walrus to utilize haulout sites on land. During southern fall migrations, terrestrial haulouts are used extensively including coasts of the Chukchi Peninsula, islands in the Bering Strait, Punuk Island, and Round Island (Lentier, 1988).

Spotted seals are very common from June to September in bays, estuaries, and riier mouths. Two major haulout areas and numerous minor sites occur along the Chukchi coast (Lentfer, 1988).

Beluga whales mostly winter in the Bering Sea with some possibly remaining in the southern Chukchi Sea. As soon as ice breaks up in the spring, whales move to Bristol Bay, Mackenzie Delta/Eastern Beaufort, or occur in groups in shallow water and lagoons along the western Alaska coast (Seaman et al., 1986). Whales are hunted in lagoons near Point Lay and ice leads off Point Barrow.

Gray whales enter the Chukchi Sea (U.S. waters) after the retreat of pack ice. Details of gray whale feeding and migration routes in the Chukchi are lacking; however, early ESP funded studies through NOAA-OCSEAP contributed to the present understanding of the California - Alaska migratory route (Figure 11-1 2). According to data collected by Ljungblad et al. (1982), an estimated 1,650 whales occurred in U.S. waters.

Bowhead whales overwinter in the Bering Sea and migrate through the Chukchi in spring and fall. Depending on ice conditions, whales usually utilize nearshore ice leads between Cape Lisburne and Barrow for a mid-April to mid-May spring migration, Whaling records indicate the Bering and Chukchi Seas were summer feeding grounds but studies have revealed no modern evidence of this (Fraker, 1984). Most feeding occurs in the Canadian Beaufort although some feeding may occur in Alaskan waters. In general, the fall migration route is less well documented in the Chukchi Sea (Fraker, 1984) although very specific data exist for bowheads entering Beaufort Sea leasing areas during the fall (Figure 11-1 4) (Ljungblad et al., 1987).

Other marine mammal species are not common in the Beaufort area. Fin whales occur occasionally while right, sei, minke, blue, killer, and humpback whales are rare. Also *rare* are sea lions, narwhals, and fur, harbor, and ribbon seals.

Within the proposed lease sale areas of the Beaufort Sea (Figure 11-1 5), few marine mammals occur regularly (Lowry and Frost, 1980). Ringed seals occur year-round and are the most abundant seal, but in lesser

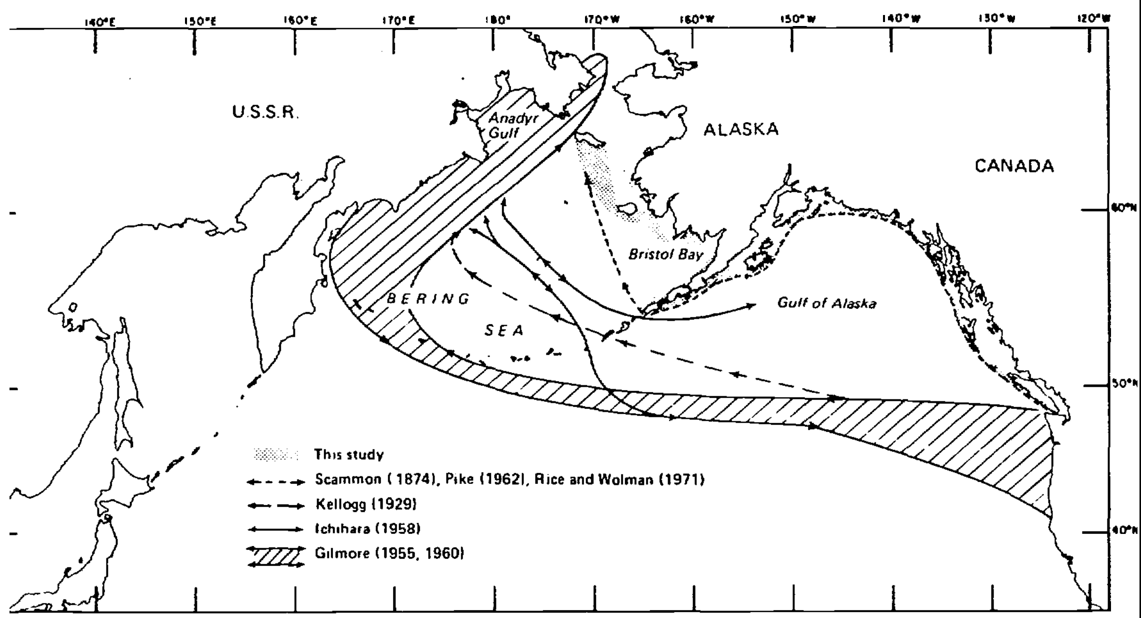

Figure 11-12. Revisions of Hypothetical Grey Whale Migration Routes (Braham, 1984)

numbers than in the Chukchi Sea. Sea ice conditions may further concentrate ringed seals in the Chukchi Sea in some years (Lentfer, 1988). Bearded seals maybe found on moving ice in the summer and spotted seals range into the Beaufort during summer months. Walruses are restricted to portions of the western Beaufort during the summer.

An estimated 3,000-5,000 polar bears are found in Alaska with similar densities in the Chukchi and Beaufort Sea (Amstrup et al., 1986). Polar bears spend the summer on drifting pack ice. Distribution in the Beaufort Sea is strongly influenced by seal distribution, with ringed seals, usually young-of-the-year, being the primary prey. Bears move toward the coast during mating season; females enter maternity dens excavated in snow by late November, and leave dens with cubs during March-April. Bears are quite sensitive to disturbance during denning and will abandon cubs. Cubs may not be self-sufficient until about 2.5 years. Contrary to early accounts, denning on sea ice maybe the rule rather than the exception (Lentfer, 1988), as land dens are sparse along the Alaska coast. [t is not clear if human disturbance has altered distribution of denning in Alaska and if sea-ice denning decreases success relative to land denning (Lentfer, 1988). Native harvest of bears is estimated to be about 150 animals annually. The MMPA does not protect female bears with cubs from native hunters and is an issue of concern.

Virtually all of the western Arctic bowhead population [estimated at about 7,200 (IWC, 1988)] passes Point Barrow in the spring (April-June). The Alaska Beaufort Sea is primarily a migration path to feeding grounds in the Canadian Arctic (Figure 11-13). Some opportunistic feeding, calving, and socialization appear to occur near Point Barrow (Carroll et al., 1987) Once past Point Barrow, bowhead whales normally migrate offshore and north of oil exploration activities, The return fall migration is centered from mid-September through mid-October although whales may spread westward into the Alaska Beaufort Sea during August. Migration is nearshore through leasing areas.

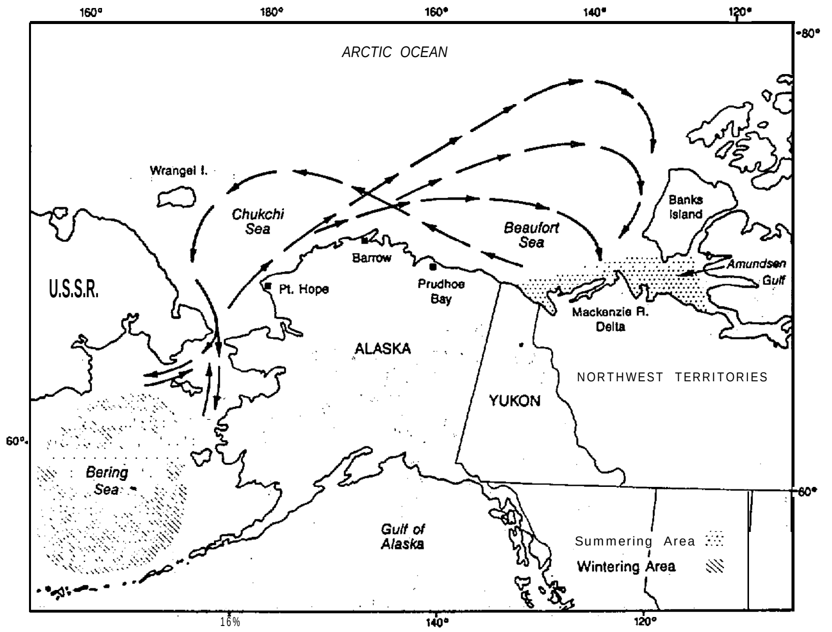

Figure 11-13. The Annual Migration Routes of the Bowhead Whale in the Western Arctic (Fraker, 1984)

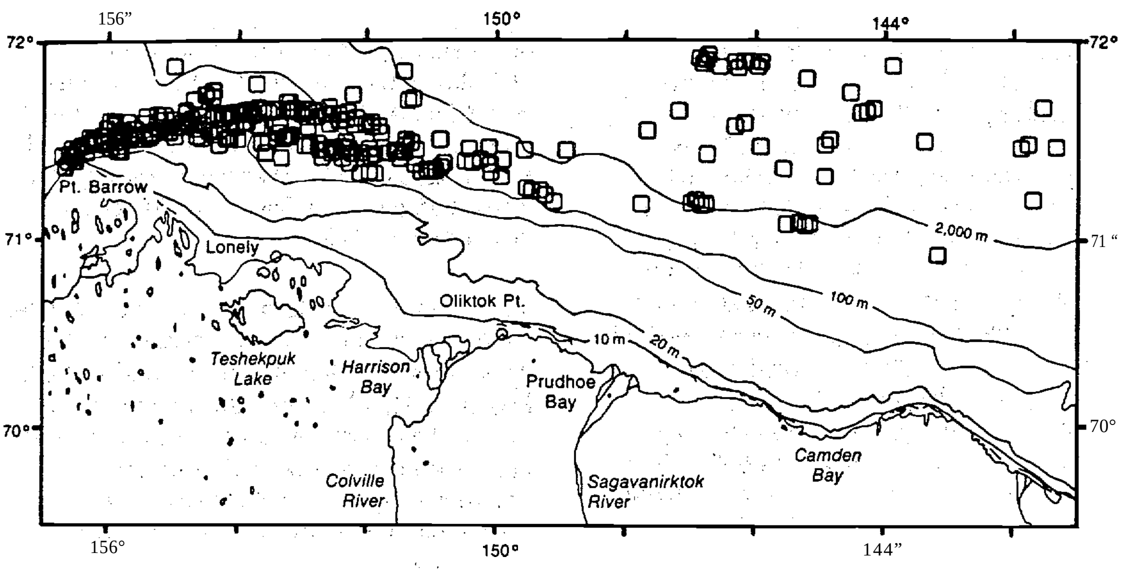

Figure 11-14. Annual Median Water Depth Countours Depicting Bowhead Migration Routes in the Alaskan Beaufort Sea,. September-October, 1975-85 (Ljungblad et al., 1986)

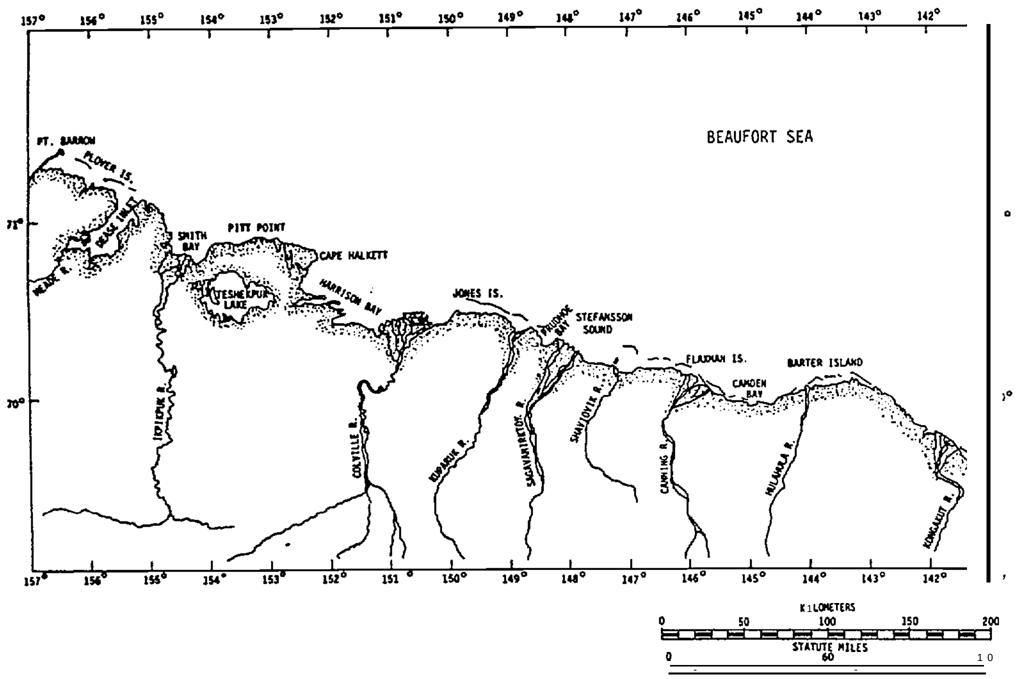

Figure 11-15. Beaufort Sea Study Area

Alaskan Natives conduct hunts during migrations – a spring hunt mainly in the Chukchi Sea and Barrow areas, and a fall hunt involving the villages of Nuiqsut, Kaktovik, and Barrow. From 1970-77, the average native landings rose substantially from 9-12 whales to about 30 (Gusey, 1983). This resulted in the International Whaling Commission (IWC) voting in 1977 to remove the Natives' subsistence hunting exemption. Intense political and legal responses followed (Bockstoce, 1980) ultimately resulting in a quota system being enforced. The presence of offshore oil and gas activities in the region has added another factor in the conflict as a potential for biological harm to the bowhead whale and possible interference with subsistence hunting both exist. These conflicts have resulted in relatively large research efforts to study bowhead population size and dynamics, and the effects of OCS activities. In a May 20, 1987 Biological Opinion, NMFS notes no jeopardy to bowheads by leasing and exploration operations; however, a potential for jeopardy 'should be recognized' for development and production operations. Biological opinions for each phase of OCS oil and gas development have been clearly defined in earlier court cases (Bean, 1983).

MMS contributions to bowhead whale studies have been substantial. Two review articles were issued by oil companies (Gusey, 1983; Fraker, 1984) which include early MMS study results. The most substantial MMS bowhead survey effort has been eight seasons conducted by the Naval Ocean Systems Center (Ljungblad et al., 1988) and two seasons by the MMS (Traecy, 1988) in the Beaufort Sea. Detailed data on fall migrations have resulted including timing, median depth analysis (Figure 11-1 4), and annual variations relative to ice conditions. The importance of the eastern Beaufort Seato bowheads during fall migration has been recently studied (Richardson, 1987). Late feeding in fall may be the last feeding period for several months and may involve the Alaskan Beaufort Sea. Although many whales do briefly feed in the study area, results for 1985-86 indicate a low percentage of energy needs (1 -2%) was acquired there, though individual exceptions may exist. It was thought that bowheads delayed or slowed migration with feeding in the Alaska Beaufort during light ice years. Most recent results (Ljungblad et al., 1987) indicate little feeding in this area despite light ice in 1986. Carbon isotope ratios in zooplankton and bowhead tissue suggest that bowheads "apparently grow slower than previously believed (Richardson, 1987)".

In 1988, MMS initiated a cooperative effort with numerous groups including industry, State, Federal, and Canadian representation to write and publish a Bowhead Whale Book.

Tagging Studies

Although standard observational methods using aircraft and ships have provided much new information on whales, the tracking of whales is limited to relatively small portions of total ranges during times of clear weather. Aerial observations, particularly in Arctic regions, are not without risks to investigators. Tagging whales with radio transmitter or recording devices is one means to approach these problems. An MMS-sponsored workshop (Montgomery, 1987) has reviewed means to remotely track large whales and identified possible methods to initiate development of a satellite-linked whale tag for use in MMS studies on bowhead and right whales. The development of a consistently successful tag remains a goal in itself. As such, tagging studies are perceived as efforts to develop a methodology applicable to goals of survey and behavior studies in all regions and reviewed as a topic separate from other regional studies.

The ESP has conducted several studies using tags on marine mammals. Surgically implanted radio transmitters have been used successfully for sea otter population studies (Garshelis and Siniff, 1983), and depth recording devices have been attached and recovered for studies on elephant seals (LeBoeuf et al., 1987). Satellite tags are routinely employed (non-MMS studies) to track manatees and large mammals such as polar bears (Montgomery, 1987).

Tagging of whales has been less successful with only sporadic positive events. Hobbs and Goebel (1981) first investigated whale tagging for the ESP. Frost et al. (1984) used radio tags attached to captured belukha whales to successfully track whales in Bristol Bay. Watkins (1981) successfully radio tagged a limited number of-fin whales, but not in OCS waters. Mate and Harvey (1981, 1982) have tested several satellite tag designs with limited success although considerable progress in engineering and improved design are noted (Montgomery, 1987). A major obstacle to success has been the inability to deliver and obtain a lasting attachment of a satellite tag to a free-swimming whale. A surgically attached tag used on a pilot whale released by the New England Aquarium provided good dive time and position data for over 90 days (Mate,. 1989; Mate et al., 1987). Jeff. Goodyear, using radio 'dart' tags, implanted tags in several bowhead whales; however, tracking of signals by aircraft provided few data (Richardson, 1987).

Radio tags have been used quite effectively" for many studies but not for large whales (in any consistent manner). Progress in basic ," designs and experience gained in past testing indicate a reasonable probability of future success. The potential value of a reliable satellite-linked tag to obtain data on endangered whales is considerable. MMS is sponsoring efforts to test new satellite tag designs beginning in 1988-89. Field studies were initiated in 1989 on right whales and will continue in the summer of 1990.

Effects of OCS Oil & Gas Activities

Potential effects of OCS activities on protected species involve the same basic concerns involved for all living resources with perhaps a special emphasis on behavioral effects resulting from disturbances. Biologically, mammals and birds have complex behavioral patterns, and legally, a take includes considerations of effects beyond overt physical harm and contact. This section will consider only marine mammals and sea turtles. Potential effects on endangered bird species are covered in the section reviewing bird studies.

Geraci and St.Aubin(1980) present a discussion of potential effects of OCS development on marine mammals and possible means to conduct research. Their schematic of proximate factors is reproduced in Figure 11-16. One update of this scheme would be the inclusion of shockwaves from underwater explosions associated with platform removals.

Section 7 Consultation-Biological Opinions (e.g., MMS, 1984) usually simplify this array into four fundamental concerns:

- effects of spilled oil
- effects of disturbances
- vessel collision hazards
- cumulative effects

Any event is both a function of what happens (e.g., seismic discharge, 25,000 gallon spill of crude oil) and the time/location of the event. Even if events conspire to produce what is theoretical y a jeopardy situation (e.g., oil spreads across Nantucket Shoals during the spring concentration of right whales), no one knows exactly what would happen. An unlikely event with uncertain outcomes is the essence of many potential effects.

Hansen (1985) has reviewed potential effects of oil spills on marine mammals in Alaskan waters. MMS has directly funded numerous effects studies that represent a substantial contribution to existing information on marine mammals and sea turtles. A comprehensive report of the effects of oil on marine mammals using worldwide references has recently been completed under a MMS contract to Battelle (Geraci and St. Aubin, 1988). An updated and condensed version of this effort will be published by Academic Press in 1990. With these references in mind, very brief comments follow.

Although oil can kill marine mammals in field and laboratory situations (Geraci and St. Aubin, 1982 1985a; Baker, 1983), the documented harm incurred by marine mammals through 1988 appears to be markedly slight. Marine mammals are a diverse group and the effects of oil vary with the type of marine mammal. It is clear that surficial contact with oil has significant and potentially lethal effects on marine mammals that depend on fur for insulation (sea otters, polar bears, fur seals, and possibly newborn seal pups). Grooming behavior to clean a soiled pelt increases the likelihood of ingesting oil, further jeopardizing the animal. In contrast, the skin of cetaceans appears to bean effective barrier to oil and, unless prolonged exposure occurs, which (unlikely in most natural conditions), no lasting effects are likel y (Geraci and St. Aubin, 1985a).

Sea turtles appear to be vulnerable to direct oiling both as a function of limited behavioral response to avoid oil and adverse physiological effects once exposed (Vargo et al., 1986). Oiling from tanker discharges and mortality of turtles has been reported along the Florida Atlantic coast and Gulf of Mexico (Geraci and St. Aubin, 1985a), but never has the oil involved been demonstrably derived from OCS activities.

As reviewed by Geraci and St.Aubin(1988), both physiological and ecological aspects of a marine mammal are significant in evaluating potential effects of oil. Sea otters are among the most vulnerable marine mammal, "... whose thick coat, compulsive grooming behavior, and precarious metabolic balance ensure that even casual encounters with oil can have deleterious effects. " Similar problems exist for polar bears, although their broader distribution on pack ice would appear to reduce the impact on the population from a local oil spill.

The ability of mammals to avoid oil slicks will have a significant bearing on the potential of actual exposure to oil in field conditions. A near-shore species with innate behavior to remain in a“ given territory and inability to detect oil, versus an open water species that can readily detect oil, are extremes that appear to exist. Geraci et al. (1983) clearly demonstrate the ability of trained dolphins to ‘ detect and avoid oil slicks (but not sheens). Whales in proximity to slicks mayor may not avoid oil based on limited field observations, though precise information is lacking. Sea otters, with territorial behavior and near coast habitat are both ecologically and physiologically vulnerable to oil. Means to protect habitat from spilled oil, removal of otters from a threatened area, and methods to rehabilitate oiled animals have been studied as mitigating methods (Davis, 1986; Tetra Tech, 1986). Many of the initial rehabilitation methods were put into practice by Davis and others during the *Exxon Valdez* oil spill.

In marked contrast to the potential plight of sea otters, cetaceans appear to beat risk only in cases of confinement or, perhaps fouling in feeding baleen plates. “The documented cases of oil-associated mortality of cetaceans are so rare and equivocal as to suggest that concerns regarding their vulnerability may be more conjecture than real (Geraci and St. Aubin, 1988). ”

Pinnipeds appear to be intermediate between the risks to otters and cetaceans. The effects on the *Exxon Valdez* oil spill on marine **mammals remain unpublished at this date. Initial accounts at briefings and unpublished update** reports more than 1,000 of sea otters and an unknown number of harbor seals and Steller sea lions were killed. Some pinnipeds appear to exhibit neurological disorders and

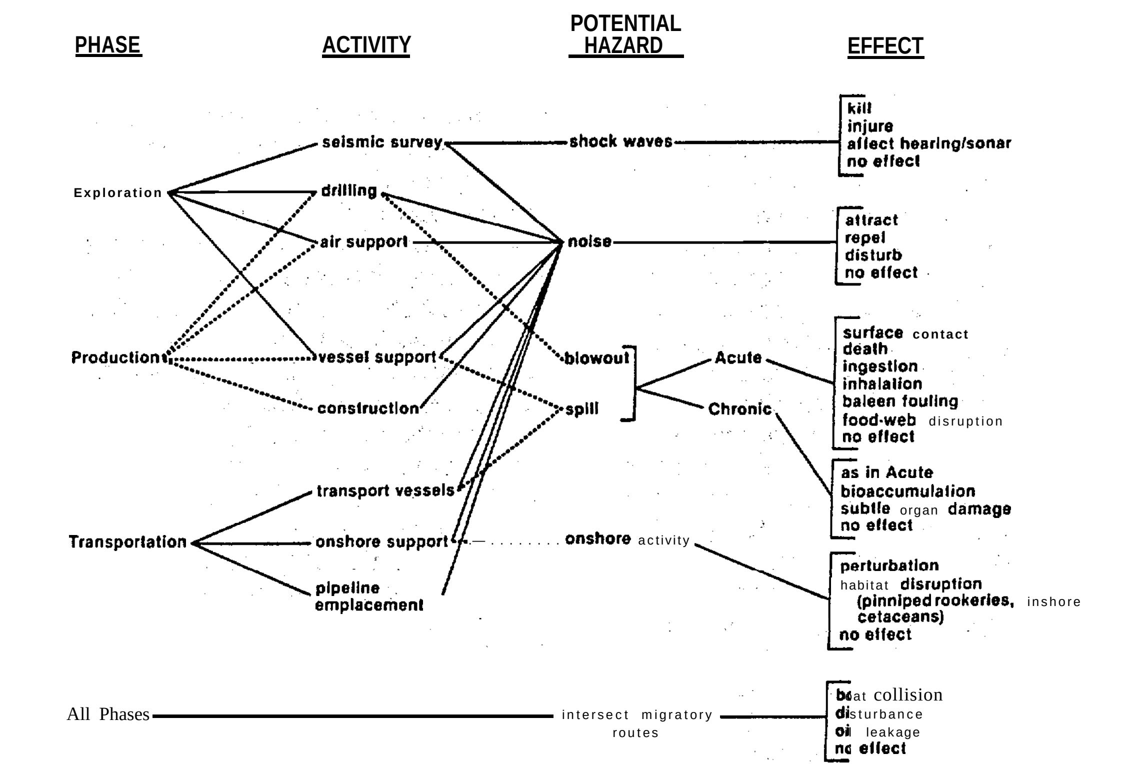

Figure 11-16. Potential Hazards and Effects from OCS Operations (Geraci and St. Aubin, 1985)

oiled but alive seals are reported. Portions of the extensive review of Geraci and St. Aubin (1988) on effects of oil on marine mammals will, without doubt, need updating and re-evaluation when data from this spill are available.

The indirect effects of oil and long-term chronic effects of oil on marine mammals are less clearly understood and inherently difficult to study. Biochemical analysis of tissue samples for marine mammals is complex (Reijnders, 1986). Effective sampling of marine mammals presents obvious problems, and laboratory studies are not a practical alternative. Not surprisingly, data are limited. Benthic feeding marine mammals appear to have a longer-term risk for ingestion of oil-contaminated food; however, it appears marine mammals can metabolize and excrete hydrocarbons, and potentially minimize the probability of a residual effect following a spill event (Geraci and St. Aubin, 1988). Harbor seals and harbor porpoises have been suggested as potential species for studies of chronic exposure to industrial pollution (Hansen, 1985).

Noise at a level of auditory response (not shock waves such as a result of seismic airguns or underwater demolitions) is produced by vessels, aircraft, and drilling operations. Concern has been expressed in biological opinions and by marine mammal investigators that noise disturbance in some situations will adversely affect protected species. The potential effects include stampedes and mortality at major haulout sites for pinnipeds; abandonment of breeding sites, dens, or other key habitat; disruption of breeding or feeding; disruption of migratory routes; interference with communications; and interference with native hunting. For species with good terrestrial vision, visual disturbance, and smell also become factors in ascertaining disturbance. MMS has conducted a series of studies on the effects of noise on selected marine mammals beginning with Gales (1982). Most studies have been on bowhead whales (Richardson et al., 1985, 1987; Miles et al., 1987), with additional studies on gray, beluga, and humpback whales; sea otters; and pinnipeds (Cummings et al., 1984; Malme et al., 1984, 1985, 1986; Riedman, 1983; Stewart et al., 1986). A major effort to compile and summarize effects of noise from these results and other similar non-MMS work is being accomplished during 1987-88. The broader aspects of disturbance (noise and other factors) on pinnipeds is also being reviewed by a second study effort conducted during the same time interval.

The most detailed work on disturbances and reactions involves bowhead whales. Although industrial disturbance is the concern, mechanisms to determine effects have included extensive basic research in underwater acoustics and whale behavior. Research has included behavioral response of individual whales to vessels, aircraft, and recorded playbacks of industry activity. Closely related are studies on observed distribution of whales relative to industry sites (Richardson et al., 1987) and possible changes in migratory paths (Ljungblad et al., 1987).

Richardson et al. (1985) summarized early work on bowhead behavioral reactions to industry activities and noted that "... in general, bowheads showed considerable tolerance of ongoing noise from seismic exploration, dredging or drilling, but tended to react more strongly to rapidly changing situations such as an approaching boat or aircraft or a brief playback experiment. " Further work (Richardson et al., 1987) indicates that industry activity in the Canadian Beaufort may have affected whale distribution;,though variations in zooplankton prey may also be a factor. More recent studies (funded by industry) have found some indication that bowheads may be more sensitive to noise than previously observed, but the low sample number and variables of field observations make conclusive results impossible (LGL, 1987). Responses generally involved changes in swimming direction. In some cases, whales moved rapidly away from ship traffic but returned to the initial feeding area soon after the vessel had passed.

Although some disturbance reactions occurred at greater ranges than expected, the drilling site did not block or delay migration. No interference with the Kaktovik native hunt was evident, as the 1986 season was highly successful.

The question of whale behavioral responses to human activity is complex and goes beyond oil and gas operations. Richardson et al. (1987) list examples where human activity is suspected of displacing whales and also where whales persist in the face of heavy vessel traffic or hunting. Humpback whales appear to be abandoning past preferred shallow-water areas in Hawaii as human activities Increase (Tinney, 1988). Ironically, scientific research was suspected to be "... one of the most significant forms of' humpback whale harassment in Hawaii." Jones and Swartz (1986), conversely found no evidence of adverse effects of whale watchers or other vessel traffic on the demography of gray whales in Laguna San Iguacio, Baja California. The number of friendly whales (deliberate approach to boats) has increased dramatically for gray whales, much to the delight of whale watchers. The behavior is well documented' in the Mexican lagoons and has also been reported in British Columbia and the Bering Sea. The behavior appears to be a recent phenomenon, and in marked contrast to past times of whaling, when the gray whale was named the *devil fish* because of violent behavior and attacks on small boats. Watkins (1986) reports on changes in behavior of four New England whale species over a 25-year span. Humpbacks, similar to gray whales have appeared to develop a previously absent positive attraction to whale watching vessels while fin whales no longer flee approaching vessels.

Whale responses appear to vary considerably with the species and furthermore with individuals. Both previous experience and current activity affect responses. Playback tests suggest that many bowhead whales would react to drillship or dredge noise in a 3-11 km range yet some whales were seen within 0.8 km of an actual dredge (Richardson et al., 1990). The authors cite at least two factors, variable responsiveness and habituation that cause such varied results. Watkins (1986) observations led him to conclude that whales generally appear to habituate rapidly. If true, the first experience of whales with industry activities may not reflect the longer-term behavior.

Shock waves from underwater explosions during platform removal may pose a threat to sea turtles and small cetaceans in the GOM. Determination of the association of turtles around platforms and means to repel or remove protected species within a danger zone are presently being studied.

Data on effects, animal behavior, physical parameters, and other factors now exist through ESP studies and other sources. Efforts to evaluate multiple factors that culminate in effects on protected species have been attempted, in several cases through use of predictive models, reflecting an evolution of effect studies as more information is collected. Attempts to model possible results of oil spills and relative risks for fur seals and bowhead whales have been completed by Reed et al. (1986) and Reed et al. (1987) respectively. A risk analysis model has been completed for use on selected Pacific marine: mammals and seabirds. Efforts to model ranges for probable acoustic disturbance to bowhead and gray whales has recently been completed by Miles et al. (1987). The use of predictive models is highly useful to better. define problems and organize available data and facilitate the work of EIS analysts. Results, however, rarely, if ever, give a precise quantitative answer and the probabilities and relative outcomes often prove difficult to convey to a general audience.

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12. Archaeological Resources

General Description

The National Environmental Policy Act (NEPA) assessment process examines the human environment. While the proceeding sections of this report have addressed physical and biological aspects of the environment, this section, as well as those entitled Sociology and Community Planning, Economics, and Visual and Recreational Resources, address the social aspects of the environment. Since, as in the case of physiology or biology, each OCS region faces different social issues, the goals and methods of the social science research sponsored by each region also sometimes varies.

The Archaeological Resources Program within the ESP began in FY 1974. Compared to other components, such as biology or physical oceanography, this program is quite small; spending for all four regions totals about $2.5 million. Because the program's goal is to identify and protect specific resources that might otherwise be disturbed by planned OCS activities, the Archaeological Resource Program has been most germane in the Gulf of Mexico Region, which has a long history of OCS development and production.

Numerous laws and orders pertain to the MMS program to inventory and protect archaeological resources. The National Historic Preservation Act (PL 894365) requires that all archaeological resources listed or eligible for listing in the National Register of Historic Places be considered in a federal agency's planning process before it issues a permit. Additionally, the Advisory Council on Historic Preservation must be given an opportunity to review the project if archaeological resources are involved. The National Environmental Policy Act (PL 91-190) declares as national policy the preservation of important archaeological resources. The Outer Continental Shelf (OCS) Lands Act (PL 95-372) mandates that activities must not disturb any significant archaeological resources. This Act restricts MMS's responsibility for the protection of archaeological resources to the area affected by mineral development activities.

Friedman and Mosher (1987) summarize the history of MMS's role in archaeology:

The archaeology program began under the auspices of the Bureau of Land Management and the U.S. Geological Survey. At first, the approach to archaeological resource protection was to require archaeological surveys on all leased blocks. This approach was necessary because so little was known about archaeology on the OCS. Later, in an effort to coordinate and streamline data collection procedures, information from various disciplines (geology, geophysics, geomorphology, history and archaeology) was combined to develop comprehensive regions/ baseline studies . . . .

The MMS program includes both prehistoric and historic resources. The goal for both is to preserve cultural remains in place. The ESP'S scientific approach reflects a multi-phase approach to archaeological resource protection. The program focuses on regional baseline studies. Although baselines may involve ground-truthing, they stress the development of models that predict where archaeological resource sites are most likely to exist. These studies support the first phase of resource protection. Should a baseline indicate probable conflicts, industry may be required to conduct remote-sensing surveys to locate sites or potential sites. Finally, using information that has been gathered, the MMS, in consultation with the State Historic Preservation Officer, develops a plan to mitigate effects to potential archaeological sites. The MMS program identifies sites to avoid potential conflicts. Thus, although a site may never be scientifically evaluated, documenting its location leads to its protection.

About 18,000 years ago, at the height of the last major glacial advance, worldwide sea levels averaged 120 meters lower than present ones. As a result, large expanses of the present continental shelf were exposed as dry land; processes of erosion, such as rivers cutting valleys to the sea, gave the exposed areas a new topography. Over time, these areas were populated by plants and animals including humans. Later, as the Earth's climate warmed again and the ice began a slow melting process, the sea again began to rise, gradually covering the continental shelf, flooding the recently cut river channels. Any archaeological sites present in these areas were submerged and perhaps preserved under sea sediments. Approximately 5,000 to 6,000 years ago sea level reached its present stand. Archaeological sites from this earlier period of lowered sea levels may provide clues about man's first entrance into North America and about how he adopted to the changing climate and environment of the late glacial period (Pierson eta/., 1987).

Because of limited archaeological data from the OCS, predictive models of prehistoric site locations are built on analogies with onshore areas. Using data from adjacent onshore areas, both a study area's prehistoric culture sequences and the history of its late Pleistocene and Holocene environments are synthesized. Based on this synthesis, probable adaptive strategies and settlement patterns for the submerged continental shelf can be delineated (SAI, 1981). Thus, although archaeological sites might occur anywhere along this former land surface, site distribution on dry land suggests that they concentrate in the vicinity of particular topographic features such as river channels, lakes, bays, and lagoons. Remote-sensing equipment can be used to locate these types of ancient landforms, even though they are often buried beneath sea floor sediments. Archaeological sites associated with these landforms can be identified by analyzing core-sized sediment samples taken from them. More detailed information on the size of an archaeological site, its age, the length of time and season it was occupied, the major food resources used by the former inhabitants, and the former climate and site environment can be gathered from the site using a high-density grid of sediment cores and basic soils analyses.

In 1986, the MMS completed a study designed to predict the locations and confirm the presence of buried prehistoric sites on the Gulf of Mexico OCS. Five types of ancient landforms, including valley margins/floodplains, terraces, natural levee ridges, point bars, and bay/estuary margins, were identified in association with the buried Sabine River Valley off the shore of Texas and Louisiana. These landforms were further evaluated for potential archaeological deposits through the collection of subbottom profiler data. Based on these data, cores were collected to evaluate areas of potential archaeological deposits. The final phase of this study attempted site identification through laboratory analysis of the core material. These soil analyses suggest the presence of at least two archaeological sites at the locations tested. Other remote-sensing surveys from various lease blocks have recorded numerous examples of ancient landforms exhibiting a high probability for the occurrence of prehistoric sites; however, few of these landforms have been subjected to further testing because the MMS archaeology program stresses avoidance of resources rather than identification.

Stright (1 989) inventoried 35 submerged prehistoric sites in the Atlantic, Gulf, and Pacific sections of the continental shelf, most in nearshore estuarine environments although some in deeper water. The *in situ* survival of shipwrecks suggests that many prehistoric sites will have survived (Aten, 1989). Nevertheless, these cultural resources are illusive; they *may be deeply buried and inaccessible in some regions of the continental shelf and shallow but difficult to identify in others* (Dunbar *et a/.,* 1989).

Historic Resources

On the OCS, historic resources include wrecks of aircraft; whaling, fishing, and military vessels; and the cultural objects found in association with them. While, like prehistoric sites, these wrecks can be found almost anywhere, several factors determine their likely presence. First, unlike prehistoric sites, historical records exist for many shipwrecks. For example, even before the *Monitor* was discovered, its approximate location off Cape Hatteras was known. The MMS maintains files of known shipwrecks which it continually updates with new information received from archaeologists, researchers, sport divers, and others who discover shipwrecks. Second, the presence of wrecks can be predicted from known transportation routes and hazards. Shipwrecks tend to concentrate in highly traveled areas that have some type of natural or manmade hazard to vessels. Consequently, most wrecks are found in less than 20 meters of water and are clustered around major ports and capes with associated shoals.

Factors affecting shipwreck preservation include water temperature, bottom-sediment type, sea floor topography, and ocean currents. Warm water is a healthy environment for organisms which destroy the organic material in shipwrecks. Cold water provides a better preservation environment but this is lessened in some areas by the destructive force of ice. Cold water also makes shipwrecks more inaccessible and expensive to investigate. Fine-grained sediments, like silts and clays, help to preserve ships while gravels and bedrock have lower preservation potentials. Also, areas characterized by steep slopes or strong bottom currents have lower shipwreck preservation potentials than areas with gradual bottoms or little current activity.

The search for shipwrecks requires an understanding of the type of resource sought. The history of shipping is different in each OCS region. Alaska's historic period began in 1728 with the arrival of Russian vessels in Alaska. In this early period, one-third of all Russian ships were lost. American whalers entered the area in 1835 and moved north into the Arctic in 1848. The whaling industry lost many ships; for example, in 1871 most of the whaling fleet was caught in the ice and destroyed offshore Wainwright and Pt. Belcher. Ship losses increased significantly during the late 1890's and early *1900's* first with the Gold Rush and then with increased fishing activities. The Alaska OCS Region's shipwreck files contain listings of over 1,000 wrecks.

The maritime history of the Atlantic coast began around 1500. Between 1500 and 1700, exploration and settlement involved the Spanish flotilla system. From 1700 until about 1820, English overseas commerce and privateering flourished. The War of 1812 encouraged the development of the American shipbuilding industry. Oceangoing steamboats and ironclads were introduced during the Civil War. After that war, a modern American Navy and maritime mercantile expansion were primary factors in American maritime history. Throughout this history, an estimated 15,000 to 20,000 shipwrecks have occurred of the Atlantic coast. The densest clusters are located off the North Carol ina and Florida coast.

Marine history in the Gulf of Mexico begins with Spanish ships of exploration and plunder. During the 16th and 17th centuries, French, Dutch, and British ships challenged Spanish maritime dominance and by the end of the 18th century only British and Spanish ships were left. From then until the present day, the United States has been the major maritime force in the area. The MMS database for the area contains approximately 4,000 shipwrecks.

The historic period on the Pacific coast began in 1542. During the Spanish colonial period (1769-1 822) and the Mexican period (1822-1 846), Spanish and Mexican dominance was successfully challenged by ships from England, France, Italy, Russia, and the United States. Shipping increased during the American period from the 1849 California Gold Rush, the 1870's development of agriculture and fisheries, and the turn-of-the-century discovery of oil. The Pacific OCS Region files contain listings of more than 2,000 reported shipwrecks.

Regional Data Availability

Atlantic Region

Baseline cultural resource studies have been conducted in the North Atlantic (Moir et al., 1979) and South Atlantic (SAI, 1981). Data from these studies have been utilized in Environmental Impact Statements (EIS's) for Atlantic lease sales. The limited amount of offshore activity has precluded any conflicts to date.

Gulf of Mexico Region

A baseline cultural resource study was conducted for the Gulf of Mexico (CEI, 1977). Research designed to test the validity of the predictive models contained in the baseline studies has also been sponsored by MMS (CEI, 1986). In 1982, the National Park Service sponsored a project to identify Gulf coast prehistoric sites using sediment analysis. This involved taking a series of core-sized samples from selected onshore prehistoric sites and offsite locations and subjecting them to a series of standard sedimentological and geochemical analyses designed to identify and define the composition of cultural deposits versus natural sedimentary deposits (Pearson eta/., 1986).

Other research efforts have been made to further our ability to predict the location of, and identify historic sites on the OCS, and to enable investigators to distinguish, based on geophysical records, between historic shipwrecks and modern ferrous debris (Friedman and Mosher, 1987). The identification of shipwrecks has proceeded rapidly over the last decade; in 1989, Garrison reports data on over 4,000 shipwrecks in the Gulf of Mexico, twice as many as were identified ten years previously (CEI, 1977; Garrison, 1987).

Pacific Region

Similar to other Regions, the Pacific sponsored early in the ESP a basic literature review and mapping of archaeological resources for the Southern California Bight (SAI, 1978). A broader geographic area (Morro Bay to the Mexican border) was studied by Pierson *et al.* (1987). Research entitled, "California, Oregon, and Washington Archaeological Resource Study," is currently underway. The objectives of this study are: (a) to develop an archaeological data base for the Pacific Coast identifying areas of prehistoric site potential and to determine the locations or likely locations of shipwrecks that exist in the region: and, (b) to map central and northern California, Oregon, and Washington showing Holocene deposit isopach maps with appropriate contour intervals and locations, known prehistoric site locations onshore, zones of potential prehistoric site locations offshore, and known and potential shipwreck locations.

Alaska Region

At the height of the Wisconsin glaciation, about 18,000 years ago, the Bering Land bridge was a vast landscape with low topographic relief and a few widely spaced mountains (now islands in the Bering Sea). This region is divided into two provinces, the North American or "eastern Beringia" and the Asian or "western Beringia." Rising sea levels separated the two continents about 14,000 years ago; rising sea levels continued to inundate the continental shelf until approximately 4,000 years ago.

Presumably, humans expanded across the Bering Land Bridge into the Americas, hunting large Pleistocene mammals as they had done in the Old World. If this is the case, the oldest sites in the New World should be located in eastern Beringia and along the inundated continental shelf between Alaska and Siberia. However, as Dixon (1989) notes, research findings of the last decade have lowered expectations that firm archaeological evidence for this hypothesis will be found, particularly on the Alaskan OCS. Three separate issues have led to these lowered expectations. First, earlier reports of eastern Beringian sites and artifacts have been reevaluated; although, in the 1970's some sites were dated as early as 27,000 B.P. (Before Present) (see Irving and Harington, 1973), currently the earliest recognized date is no older than 12,000 B.P. Questions concerning the earlier dates have arisen because (1) assemblages of fractured and modified bone that were purportedly manufactured by humans are now postulated to have had non-cultural origins such as rodent gnawing and ice fracturing (Binford, 1981; Morlan, 1984), (2) radio carbon dating procedures have improved, demonstrating that earlier dates are unreliable due to postmortem carbonate substitution (Hassan and Ortner, 1977), and the lack of clear stratigraphic evidence.

Second, with the reevaluation of site dates, currently the oldest firmly dated assemblage for eastern Beringia is the interior Alaskan Nenana complex, approximately 11,300 years old (Powers and Hoffecker, in press). Since this postdates the Land Bridge by more than 2,ooO years, it undercuts the ability to draw analogies between the submerged continental shelf and adjacent onshore areas. Finally, substantial ice-gouging of the Land Bridge have probably destroyed Beringian sites on a massive scale. However, ice-gouging reworks sea sediments to a depth of 1 to 2 meters; onshore archaeological sites have been buried as much as 3-4 meters. Therefore, conceivably submerged sites may be found in areas capped by 2 or more meters of sediment. To date, Pleistocene proboscidean remains recovered from the Bering Continental Shelf exhibit evidence of non-cultural processes of reworking although they also suggest the possibility of prehistoric site survival as well (Dixon, 1983). Dixon (1989) summarizes the potential for such sites as follows:

(1) it is improbable that archaeological sites exist which document the so-called first movement of humans from the O/d to the New World via the Bering Land Bridge ca. 14,000 B./? or older, (2) most prehistoric sites on the Beringian Continental Shelf not capped by ca. 2 m of *sediment may have been destroyed by ice-gouging and coastal erosion, (3) there is potential for sites dating between ca. 12,000 and 4,000 to occur on the continental shelf in certain protected settings, (4) those sites which do exist probably exhibit exceptional preservation of organic remains, and (5) there is nothing in this analysis to preclude the presence of shipwrecks, a/though those located in shallow areas may be subject to severe disturbance as a result of ice-keel gouging.*

The following list represents the Archaeological Resource baseline studies for the Alaska Region:

- Bering Land Bridge Cultural Resource Study
- Literature Survey to Determine Probabilitiesof Locating Drowned Habitational Sites
- Lower Cook Inlet Cultural Resources
- Compendium of Alaskan OCS Cultural Resources Studies

Dixon *eta/.* (1986) provides an overview of these efforts.

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13. Sociology and Community Planning

General Description

To date, most socioeconomic studies have focused more on economics than sociology. Alaska is the one exception, first, because of unique issues concerning Alaska Natives and their traditional practices and, second, because of Native legal rights as defined by Federal laws such as the Alaska Native Claims Settlement Act (ANCSA) and the Alaska National Interest Lands Conservation Act (ANILCA). However, over the last 5 years, the Scientific Committee of the OCS Advisory Board has encouraged MMS to more fully consider the noneconomic social effects of offshore oil development in all OCS regions. The Scientific Committee persuasively argued that greater emphasis in this area would support MMS decisionmaking and improve local community planning for required services. Such information also addresses the requirement in Section 20(b) of the OCS Lands Act that includes monitoring of the human environment.

The NEPA mandate for interdisciplinary analysis recognizes the difficulty of separating social and economic research. Such separation is often artificial. For example, whereas issues about commercial fisheries are primarily economic, they often exhibit social facets. In some areas, families pass traditions concerning commercial fishing from generation to generation. Space use conflicts or the lure of high paying jobs in the oil industry may threaten this tradition. Such social ramifications of economic change should be analyzed because of the boom-bust potential of the oil and gas industry. Possible mitigations also need to be examined. Similarly, Alaskan subsistence is a multifaceted issue. Although subsistence is analyzed as a sociocultural issue, it has ramifications for economics, fisheries, and endangered and protected species. Subsistence reflects cultural continuity; for example, the sharing of the harvest reinforces traditional values, family organization, and leadership roles in Native communities. Subsistence is a way to participate in a noncash economy. However, since current harvest methods require the purchase of equipment and supplies, subsistence pursuits also entail market-determined activities such as commercial fishing or wage work. For this reason, adverse effects on commercial resources can indirectly affect subsistence.

The need for State and local governments to plan for the possible consequences of OCS activity has been addressed through a variety of studies, only some of which are funded through the ESF! Many local planning studies were conducted using Coastal Energy Impact Program funds. Local governments are concerned because an influx of population could increase the demand for services such as schools, health care, police protection, and fire protection. For example, an OCS facility may be sited in one community, but its workforce may choose to reside in another. Thus, whereas one community may reap tax benefits from an industrial facility, other communities could be required to provide additional services for new residents. In Alaska, concern also exists about the disruption of traditional lifestyles and the increased incidence of social pathologies among the Natives following the influx of new residents.

During the exploration stage, most offshore workers do not relocate closer to the transit point to their offshore platform. Because of the multiday offshore shifts (such as 2 weeks on, 2 weeks off), most workers in frontier areas return to their homes during their time off. Not until the development and production stage is reached are offshore workers I ikely to reestablish their families in a new area. Even then, predicting the community where an offshore worker will relocate is impossible since proximity to work is less of a determinant when multiday shifts are normal.

Through the OCS Oil and Gas Information Program (OCSIP), MMS provides to States, local governments, and other interested parties, up-to-date information on activities resulting from lease sales, such as the location and characteristics of onshore facilities. The OCSIP was established in 1978, as required under Section 26 of the OCS Lands Act, and is intended to assist State and local government planning for possible onshore impacts of oil and gas activities. The Summary Reports and Indexes prepared under OCSIP are prepared by MMS. Other important sources of information for this topic include Census data and Coastal Zone Management plans.

Within the last decade, a scientific inquiry into the question of risk perception, or how people understand and evaluate risk, has developed. In general, professionals who assess risk exhibit more faith in their formal findings than do average members of the American public. Risk assessors tend to view public opposition as uninformed and irrational (Lave, cd., 1987), or even as exhibiting a neurotic reflex to over regulate industry based on obsessive risk avoidance (e. g., Wildavsky, 1988). However, attempts to "educate" the public concerning particular risks usually feed public opposition and mistrust (Hance, et al., 1988). Research into risk perception would indicate that the public is not ill-informed, neurotic, or intransigent but, rather, is simply worried about different things than the average risk assessor (Freud enburg, 1988). Slovic, Fischhoff, and Liechtenstein (1980, 1981, 1982) conducted much of the preliminary research into variables that affect individual risk perceptions. These, and later findings, are summarized as "the key variables that underlie community perception of risk" (Hance, et al., 1988):

- Voluntary risks are accepted more readily than those that are imposed.
- Risks under individual control are accepted more readily than those that are not.
- Risks that seem fair are more acceptable than those that seem unfair.
- Risk information that comes from trustworthy sources is more readily believed than information from untrustworthy sources.
- Risks that seem ethically objectionable seem more risky than those that do not.
- Natural risks seem more acceptable than artificial ones.
- Exotic risks seem more risky than familiar ones.
- Risks that are associated with other, memorable events are considered more risky.
- Risks that are "dreaded" seem less acceptable than those that carry less dread.
- Risks that are undetectable create more fear than detectable risks.
- Risks that are well understood by science are more acceptable than those that are not.

To date, findings in the field of risk perception have tended to be general and difficult to apply to specific risk-management situations. For example, what makes particular risks ethically objectionable e or dreaded? Do ways to address ethical objectionability differ from ways to address public dread? Nevertheless, as the agency charged by Congress with administering OCS oil and gas development, the MMS is interested in this field of research. Findings may improve the program in two ways. First, a risk perception study may help identify underlying concerns relating to OCS development and, thereby, facilitate responses to public concerns that are relevant. 'Second, a risk perception study may provide useful suggestions for improvements to the scoping process and, thereby, encourage more constructive public involvement in the leasing process.

Regional Data Availability

At/ant/c Region

In the Atlantic, socioeconomic baseline literature searches were conducted in the early years of the ESP. A baseline for the North Atlantic was prepared by The Research Institute of the Gulf of Maine (TRIGOM) in

1974. [n 1975, the University of Delaware completed Socioeconomic Factors Relating to the OCS of the Mid-Atlantic Coast from Sandy Hook, New Jersey, to Cape Hatteras, North Carolina. The Virginia Institute of Marine Sciences prepared a report on the South Atlantic in 1974. Other sources of information for the Atlantic include census data and Coastal Zone Management plans. Together, these information sources have proved adequate for prelease environmental analysis.

The Atlantic Region managed the study, "Assessment of Space and Use Conflicts between the Fishing and Oil Industries" (Centaur Associates, 1981). This study provided information on, and assessed potential impacts to, commercial fishing activities in the North, Mid-, and South Atlantic, Gulf of Mexico, and California planning areas. This study developed a predictive catch loss model from space loss due to OCS oil structures.

Gulf of Mexico Region

In 1973-74, a baseline socioeconomic literature survey for the Gulf of Mexico was conducted by Environmental Consultants, Inc. The Fish and Wildlife Coastal Characterization series also includes socioeconomic information. More recently, the Gulf of Mexico has funded a series of socioeconomic studies to document the direct and indirect economic effects of OCS activity in the Gulf of Mexico Region. Although these have been providing a wealth of information, the studies have been focused more toward gathering economic than social data. Other information sources include census data, Coastal Zone Management plans and studies, and National Park Service sociocultural studies.

Commercial fishing issues were examined in Centaur Associates (1981) and in Ditton and Auyong (1984). This last study analyzed the use of platforms in the central Gulf of Mexico by commercial fishermen.

Pacific Region

All "Summary of Knowledge" literature surveys for the southern California, central and northern California, and Oregon and Washington areas that were completed in the early years of the ESP include volumes on socioeconomic considerations. The **1984** report "Cumulative Socioeconomic Impacts of Oil and Gas Development in the Santa Barbara Channel Region: A Case Study" examines the effects of offshore oil and gas development on the socioeconomic environment of Santa Barbara and Ventura Counties from 1960 to 1983. The report "Facilities Related to OCS Oil and Gas Development Offshore California: A Factbook" (Centaur Associates, 1985) is similar to the New England River Basins Commission Factbook (NERBC, 1976). These factbooks serve as reference sources for information concerning offshore facilities and industries that support OCS operations. The California Factbook focuses on the socioeconomic characteristics of California OCS activities and facilities.

More recently, the Pacific Region has sponsored a series of compilations of baseline socioeconomic data for the coastal counties. The reports "Economic and Demographic Profile of San Luis Obispo County" and the Phase I "Baseline Socioeconomic Profiles of California" will be followed by similar reports for Washington and Oregon. These contain information on employment characteristics, economic structure, land use, community infrastructure, **including demographic characteristics,** energy use, and public finance. Other sources of information include local coastal plans and several technical papers that concern previous southern California lease sales. The Pacific Region also funded a study of the possible socioeconomic effects of OCS development on Washington and Oregon Indian tribes.

Responding to increased demand for onshore treatment, storage, and transportation facilities due to oil and gas development in the **Santa Barbara Channel and Santa Maria Basin, the Counties of Ventura, Santa Barbara, and San Luis Obispo** in California **established the Tri-county** Socioeconomic Monitoring and Mitigation Program (SEMP). The purpose of SEMP is to document the ongoing socioeconomic impacts of each project and to provide an equitable means for mitigating them.

California's commercial fishing issues are examined in Centaur Associates (1981). In addition, the Pacific Region sponsored Centaur Associates (1983), which identifies sea floor conflicts between oil and gas pipeline activities and California commercial trawl fishing and evaluates measures to mitigate them.

Alaska Region

The Alaskan Social and Economic Studies Program (SESP) has been extensive. This program, mandated by Section 20 of the OCSLAA, was initiated in 1976 at the urging of the State of Alaska. The Alaska Region faced a unique situation. In general, the coastal areas bordering Alaska's OCS were undeveloped and only loosely integrated into the national economy and polity. The majority of Alaska's coastal communities were small (500 inhabitants or less) and lacked infrastructure. These towns were geographically isolated; they lacked roads and connected tied to the outside only by limited air and barge service. Most towns had no experience with industrial development. In fact, west and north of the Bristol Bay fisheries, most towns were poorly linked to the market economy in general. Their inhabitants lived on a mix of wild resource harvests for domestic use, transfer payments, and sporadic employment in the public sector. Most towns were predominantly Native American; the dominant language was often I nupiaq or Yupik rather than English. Cultural values, religious views, the manner in which traditional sharing joined together households, and leadership patterns differed markedly from those found in other OCS regions. Moreover, as recognized by Federal laws like ANILCA and the Marine Mammal Protection Act, these differences were strongly linked to traditional Native uses of wild resources.

This situation raised unique problems for assessing social and economic effects. First, Alaska's social issues differed from those in other regions. Not only the strength, but the nature of a community's dependency on coastal resources had to be defined. For example, to assess the economic impact of the loss of a year's whaling, the average dietary contribution and a replacement value would have to be determined. Although both gathering such data and making such estimates proved difficult, the basic approach to assessing dietary loss parallels the econometrics-based analyses used in all OCS regions. However, many Alaskan issues – such as wild resource harvests, infrastructure development, or labor-market growth –raise issues of "culture change, "industrialization, or modernization that are not amenable to such econometric analysis. Returning to the whaling example, in many Native communities the traditional organization of the whale hunt entails other community leadership roles whereas the sharing of the whale reinforces traditional religious beliefs and household organization. Much of the Alaskan social science effort has aimed at documenting such "noneconomic" problems and developing methods for adequately assessing impacts to them.

Second, the Alaska Region lacked some information required for impact assessments. Data problems arose from several sources. Although some academic work addressed noneconomic problems facing Alaskan impact analysis, most dated from the early 1960's or before. For example Hunters *of the Northern Ice* (Nelson, 1965) describes North Slope subsistence harvest methods prior to the introduction of the snowmachine (which profoundly changed hunting patterns). Since ANILCA brought massive demographic, social, and economic change to rural Alaska after **1976,** the problem of dated literature was acute. Coverage of noneconomic issues in the existing literature was uneven and addressed academic concerns rather than the needs of impact assessment. For example, Nelson's book virtually ignores caribou and bowhead whales, both critical to MMS impact assessments. Since recent laws define many of the assessment issues, the problem of unevenness was exacerbated. For example, the Arctic environment's role in shaping Eskimo society is a traditional academic question. The relative importance of subsistence and commercial harvests of wild resources is a recent legal one that departs from the academic debate. Consequently, most subsistence research has been funded through nonacademic government sources such as MMS.

Because rural Alaskan communities were small, isolated, and historically and ethnically varied, serious difficulties also arose with the kinds of time-series data on which environmental assessments normally rely. For example, confidentiality requirements of the U.S. Census Bureau require household-level data from across Alaska to be joined with data from Hawaii and Guam. For this reason, the census cannot be used to compare rural Alaskan households in areas that experienced industrial development with households in areas that have not. Similarly, detailed community-level employment data are often suppressed by the State of Alaska because few employers exist in rural towns. The lack of reliable time-series data became a particular problem as MMS began to design a sociocultural monitoring methodology.

As in other OCS regions, the Alaska social and economics program provides technology assessments and economic and demographic modeling as basic support for the assessment process. Because of the problems described above, the Alaska program also includes an extensive social science component. At first, this component's focus was on broad baseline descriptions for all coastal regions bordering on OCS planning areas. Such large-scale baselines are now essentially complete. For the Gulf of Alaska subregion, social and economic studies have been completed in support of lease sales in the northern and western Gulf of Alaska. These include socioeconomic baselines, local effects studies, petroleum development scenarios, economic and demographic analyses, commercial fishing industry effects, and transportation effects studies.

Recent study reports for this subregion include Cultural Dynamics (1986a, b). The first presents descriptive information on sociocultural systems for 11 villages located in southcentral Alaska. The social, political, and economic organization of each village is described along with analysis of linkages between villages. Cultural Dynamics (1986b) includes information on seven socioeconomic topics for the Kodiak-Shumagin region. These are commercial fishing, subsistence, economic change, public sector expenditures, outdoor recreation and tourism, infrastructure investment, and the sociocultural systems. The sociocultural system of Kodiak is tied to the fishing economy.

For the Bering Sea subregion, the social and economic studies completed since 1977 in support of lease sales include baselines, forecasts, and updates in the areas of socioeconomic and sociocultural studies, economic and demographic analyses, petroleum technology assessments, and transportation effects studies. Recent studies have also included harvest disruption. The current focus is on monitoring OCS activity in the Bering Sea with studies of cumulative changes, assessment of OCS effects to date, and preparation for potential development. Some of the best information on the cultural importance of subsistence pursuits exists in the Bering Sea literature. References include Fienup-Riordan (1 982), Jorgensen (1984 and n.d.), and Robbins and Little (1984), all sponsored by MMS. The interdependence of commercial and subsistence fishing is shown in the harvest disruption studies.

For the Arctic subregion, the social and economic studies completed since 1977 in support of lease sales in the Beaufort Sea area include baselines, forecasts, and updates in the areas of socioeconomic and sociocultural studies, economic and demographic analyses, petroleum-technology assessments, and transportation effects studies. Studies include the Social Indicators study and subsistence mapping.

A sociocultural monitoring methodology was developed for the North Slope area. Results are reported in Smythe and Worl (1985). This study examined institutional response and change for the period 1979-1983 in three communities on the North Slope: Kaktovik, Wainwright, and Barrow. Another study identified risk perceptions in the Arctic as found in scoping testimony (ISER, 1983).

Overall, site-specific information is increasing for the Beaufort Sea and Chukchi Sea Planning Areas. One example is Worl and Smythe (1986), a case study of Barrow in the Beaufort Sea Planning Area. This study described the sociocultural and socioeconomic conditions and trends in the community of Barrow, so that the effects of OCS development can be understood in the context of other trends. The Point Lay case study provides (1 mpact Assessment, 1990a, b) similar information for Point Lay and Point Hope in the Chukchi Sea Planning Area.

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14. Economics

General Description

The exploration, development, and production of oil and gas on the Outer Continental Shelf (OCS) continue to have **important economic consequences** for the Nation as a whole, for industry, and for individual communities. From FY 1973 to FY 1988, 163 socioeconomic studies totaling over $20 million have been awarded (approximate y 80 percent in Alaska). These studies exist to help MMS decisionmakers understand the complex interactions between the processes and structures associated with OCS oil and gas activities and the economic, social, and cultural systems of the onshore populations. Because of the complex nature of the problems addressed, many of these studies are not strictly economic, social, or cultural but, rather, include elements of several disciplines.

The economic component of the socioeconomic studies can be divided into three broad categories. First are those studies whose sole or main purpose is to compile, in a single document, existing economic and demographic data that is obtainable only from many diverse published and unpublished sources. Many of the early socioeconomic studies conducted by the MMS were of this type. These studies were intended to create a *baseline* of socioeconomic data from which changes could be measured.

The second category of socioeconomic studies attempts to understand and forecast future impacts of OCS oil and gas activities on local communities. Methodologies for accomplishing this task have included simple multiplier models to forecast total employment and population; input/output models that illustrate the inter-industry relationships of a complex regional economy; and econometric models that attempt to forecast a range of socioeconomic variables.

The last category is socioeconomic studies that examine the effects or costs of OCS oil and gas activities on other users of OCS resources. Studies in this category have included the subsistence studies in Alaska, tourism and aesthetics studies in the Pacific, and commercial fishing studies in all regions. Most attention has been given to potential conflicts between offshore oil and gas operations and commercial fishing. In an attempt to quantify such impacts on the commercial fishing industry, the ESP has funded the development of a regional-level computer model to estimate preemption losses (costs from excluding commercial fishing from certain areas) and gear loss (costs from fishing gear destroyed by OCS oil and gas equipment or activities). In addition, the model estimates, by region, potential direct and indirect costs of oil spills from platforms, pipelines, and tankers.

Regional Data Availability

Atlantic Region

Initial ESP socioeconomic studies (1975-1978) used economic and demographic models to predict impacts on local populations. Later studies focused on two specific problems, the impacts of pipeline siting processes and alternative modes of transporting oil to market (Policy Planning and Evaluation [PPE], 1983), as well as on conflicts between OCS oil and gas activities and commercial and recreational fishing (Centaur Associates, 1981).

Many non-ESP studies provide information on the potential direct employment and population impacts of OCS development. Examples include *Factbook: Onshore Facilities Related to Offshore Oil and Gas Development* (New England River Basins Commission, 1976a); *Methodology for Assessing Onshore impacts for Outer Continental Shelf Oil and Gas Development* (Weston Environmental Consultants

Designers, 1978); and *Coastal Energy Impact Study for Northeast Florida* (Northeast Florida Regional Planning Council, 1983). A variety of non-ESP studies also provide information on indirect employment and population potential impacts including Onshore Support Bases *for OCS Oil and Gas Development: Implications for New Jersey* (Rutgers University, 1980); and *Tech Update 10: Onshore Facilities Related to Offshore Oil Gas Development (New* England River Basins Commission, 1976b). In general, these studies use a multiplier methodology to determine both indirect and induced employment, as well as population changes associated with the changes in employment.

As noted above, the Atlantic Region has been concerned about conflicts between OCS oil and gas operations and commercial and recreational fishing. To assess the magnitude of this conflict; the MMS supported a comprehensive survey of ongoing and potential conflicts between these two alternate uses of the OCS resources. An MMS study conducted by Centaur Associates (1981) had four objectives: (1) to review historical conflicts between OCS oil and fishing industries; (2) to identify potential and ongoing fishing gear type/oil structure conflicts; (3) to develop a predictive catch loss model for space loss from OCS structures; and (4) to assess the ability of particular harbors to accommodate oil support vessels and staging areas. The two most useful products from the study were a detailed narrative on the kinds of potential conflicts between various fishing gear types and different OCS oil and gas activities and structures and a catch loss simulation model for forecasting dollar losses caused by OCS oil and gas activities.

The second focus of Atlantic Region economic studies involved methods of transporting oil and natural gas to shore. A study by PPE (1983) identified alternative modes of transporting oil and gas produced on the Atlantic OCS to market and identified the onshore facilities needed for each mode. It determined the technological feasibility and regulatory and environmental constraints associated with each alternate, determined the required capital and operating costs of facilities and unit cost of produced and transported products for each alternate, and conducted an economic analysis of each. The economic analysis consisted of a net present value (NPV) model to calculate value (net loss or gain) from operating each alternate mode over a range of assumptions dealing with parameters such as operating cost, water depth, and field size.

Gulf of Mexico Region

The greatest economic impact from OCS oil and gas activities occurs in the Gulf of Mexico Region. Because of the size and importance of the oil and gas industry in this region, the simple multiplier methodology for estimating economic impacts used in the Atlantic is not suitable. To understand how the oil and gas industry in general and OCS oil and gas activities in particular affect the regional and local economies, the ESP has supported the development of a detailed economic input/output (I/O) model of the Gulf of Mexico's coastal areas.

The development of the 1/0 model was a 3-year project completed in 1988. Year one (Centaur Associates, 1986) gathered data on the direct economic impact of OCS oil and gas activities. Data collected included employment, wages, geographic distribution of employment, and the relationship of place of work to place of residence. Virtually none of the data listed above was available from published or unpublished sources. The volume of data required, the detail, a'nd the confidential nature (i.e., employment records) entailed a major commitment from the firms involved in OCS oil and gas activities in the Gulf of Mexico. In 1984, at the request of MMS, the Offshore Operators Committee (OOC) formed a special socioeconomic subcommittee to provide the needed data. This subcommittee included representatives from Amoco, Chevron, Conoco, Exxon, Gulf, Mobil, Odeco, Shell, and Texaco. Three datasets were assembled by the OOC subcommittee for the exclusive use of this study including:

- **Producer employment records.**

Approximate y 12,500 employment records were obtained from the nine firms represented on the subcommittee. Data elements extracted from employee records include 1984 wages/salary, job description, residence zip code, work site (onshore or offshore), staging area, and work schedule.

- **Producer expenditure records.**

Each firm represented on the subcommittee provided detailed expenditure records for 1984. These data itemized all expenditures for goods and services broken down by type of activities (air transport, geophysical exploration, platform fabrication, etc.)

- **Budget documents for specific projects or activities undertaken in 1984.**

Physical characteristics of these activities were also provided to enable expenditures to be calibrated with the physical measures used in the environmental impact statements.

Using these three data sets, data from year 1 of the study and the national I/O tables, a 116-sector I/O model was constructed (Lamphear et al., 1986). In addition to the direct and total requirement tables found in all I/O models, the study also produced a demographic profile table that contained data on workers place of origin, local hiring, commuting habitats of non-local workers, type of worker, staging areas for offshore workers, age, number of children, etc. These demographic data are essential to assess potential impacts of OCS oil and gas activities.

The third year of the study evaluated the impacts of a price-related decline to resource depletion. This phase also investigated other coastal development opportunities that could be developed to moderate the economic impact of declining oil and gas development. Emphasis was placed on using existing OCS-related infrastructure and work force for other development opportunities.

A major concern of the Gulf of Mexico and other regions is understanding the economic effect of major (worse case) oil spills. On June 3,1979, the blowout of the exploratory well IXTOC I in the Gulf of Mexico Bay of Campeche provided an opportunity to study this concern. At the time, the IXTOC I spill was the world's largest. The spilled oil was carried into American waters by August. In addition to IXTOC I oil, the Texas coast was also affected by fresh unweathered oil from the sinking tanker *Burmah Agate.* In 1980 the ESP supported a 3 year study (Restrepo et al., 1981) to determine the economic impact on the coastal Texas economy of these two major oil spills. Nineteen Texas coastal counties, grouped by five subregions, were selected. Within these subregions, the study concentrated on economic impacts to three industries: tourism, recreation, and commercial fishing. Separate analytical models were developed for assessing the direct and indirect economic effects. Relative density gradient models, supplemented with on-site interviews of owners and managers of impacted businesses, were used to estimate the relative levels of direct economic impacts to the three industries in each of the subregions. An existing 1972 Texas State I/O model was modified and updated to assess the indirect and induced economic impacts. The study's conclusions were specific to the Texas coast but may also have implications for oil spills in the Atlantic and Pacific Regions.

Pacific Region

Socioeconomic studies in the Pacific have concentrated on baseline data collection, tourism and recreation, and commercial and sport fishing. The latter two categories are discussed in their appropriate sections of this report. Examples of socioeconomic baseline data collection studies are: *Baseline Socioeconomic Profiles of Coastal Counties in the* Southern *California Planning Area* (Centaur Associates, 1988), *Cumulative Socioeconomic Impacts of Oil and Gas Development in the Santa Barbara Channel* Region: A *Case Study* (Centaur Associates, 1984), and A *Summary of Knowledge of the*

Central and Northern California Coastal Zone and Offshore Areas - Socioeconomic Conditions (Winzler and Ken y Consulting Engineers, 1977). In addition, the ESP supported the development of the *Facilities Related To Outer Continental Shelf Oil and Gas Development Offshore California: A Factbook* (Wallace, 1985). The factbook is a regionalized (data based only on activities that have occurred in the Pacific OCS) version of the Factbook developed by the New England River Basins Commission back in the late 1970's *(New* England River Basins Commission, 1976a). The factbook contains data on the labor, capital, and material needs of each phase of OCS oil and gas development.

The ESP conducted a case history of OCS development in the Santa Barbara Channel to better understand the impact of OCS oil economies (Wallace, 1985). The geographic area covered by this study was Santa Barbara and Ventura Counties, California. Both multivariate regression analysis and regional 1/0 models were used. The I/O model was developed in 1972 by the Bureau of Economic Development and updated in 1977. Data used in the multivariate regression anal ysis covered the period 1965-1980.

Alaska Region

Due to the unique cultural conditions found in Alaska, the differentiation of studies into individual disciplines (economic, sociological, cultural, etc.) is almost impossible. In order to study this unique and complex human system, the Alaskan Region established the Social and Economic Studies Program (SESP). The goal of the SESP is to provide timely social, cultural, and economic information about the consequences of specific" OCS leasing and management decisions.

The SESP was originally organized around several core studies associated with each lease sale. These core studies included:

- Petroleum Technology Assessments (PTA),
- Statewide/Local Economic and Demographic Effects,
- Transportation System Effects,
- Commercial Fishing Effects Regional Socioeconomic and Sociocultural Studies, and
- Sociocultural Systems Studies.

The PTA studies detail cost and engineering assessments of applicable technology concepts and project their use in given sale areas. These studies are used to construct exploration, development, and production scenarios for a lease sale, scenarios which form the basis for the analysis of social and economic effects. The economic and demographic studies use formal economic models to forecast local and State employment, migration, and population growth. Transportation studies focus on terminal and route capacity characteristics for each of the principal modes of travel: air, water, rail, and trucking. Space use conflicts and the growth of commercial fishing harvest and consequent employment have been the subject of commercial fishing studies. The , socioeconomic descriptions and effects studies include analysis of land use patterns, housing composition, land status and development constraints, availability of land, and community infrastructure and social services. The sociocultural system studies describe past and existing conditions and trends in cultural systems within individual communities and regions. The sociocultural issues that have been addressed include the traditional use of terrestrial and marine resources, subsistence, cultural values, politics, inter-ethnic conflicts, social health, and family relationships.

These earlier studies were often regional in scope and demonstrated that significant individual characteristics exist among the scattered settlements of rural Alaska. Recent SESP studies have focused on social trends in communities near where onshore OCS development is likely to occur. Recent studies have focused on harvest disruption, subsistence activities, social effects of new sources of cash, changes induced in the structure of local economies by OCS activities, conflicts between commercial fishing and OCS activities, transportation systems, and social infrastructure. Earlier economic models have been refined to be simpler to use and more sensitive to the unique conditions found in each community. The SESP is also developing systematic measures (social indicators), which will provide MMS with tools to monitor change in communities impacted by OCS oil and gas activities.

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15. Visual and Recreational Resources

General Description

The MMS uses information on coastal and offshore recreational activities as part of the environmental analyses required for offshore oil and gas activities. Such analyses include projections of potential impacts on recreational activities that may be caused by accidental oil spills, facility construction at or near recreation areas, and trash and debris accumulation.

Estimating the economic impact of a possible oil spill on recreation areas is very difficult due to data limitations and the high degree of uncertainty attached to the many variables involved. Excellent reports that detail the problems and present methodologies to compensate for some of the uncertainty have been published. For example, NOAA has funded studies that explain the utility of the various techniques for determining economic **impacts.** These include: *The Use of Economic Analysis in Valuing Natural Resource Damages* (Yang et al., 1984) and Assessing *the Social Costs* of *Oil* Spills: *the Amoco Cadiz Case Study* (U. S. Dept. of Commerce NOAA, 1983). To comply with a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirement, the Department of the Interior (DOI) sponsored the study, Measuring Damages to Coastal and Marine Natural Resources: Concepts and Data Relevant for CERCLA Type A Damage Assessments (Economic Analysis, 1987).

Generally, each State has departments of tourism or of economic development that compile statistics on the contributions of recreational activities to the State economy. States document recreational areas on their highway maps and in Statewide Comprehensive Outdoor Recreation Plans. Information and statistics on recreational fishing activity are available from the States and from the National Marine Fisheries Service. Much information on recreational **resources is** found in travel guidebooks such as those prepared by the American Automobile Association. The **problem with using this information** for analyzing multi-State planning areas is that the information is not comparable between States.

Visual resource management issues are also analyzed. For example, they were considered in an Alaska (Harmon, 1979) and California study (Granville, 1981), both of which applied a variation of the Bureau of Land Management's Visual Resource Management system to coastal areas. These were efforts by landscape architects which did not consider the aesthetic preferences of the users. These studies also failed to consider whether users of an area would alter their behavior if aesthetic degradation occurred.

An interest in compatible siting of onshore industrial facilities and coastal recreation areas is more appropriately a land use issue than an aesthetic issue. Local governments regulating land use have control over siting. In developing programs under the Coastal Zone Management Act, States are required to identify coastally dependent uses and to establish a regulatory framework to ensure that coastal land is not used inappropriately. Thus, State and local governments can consider the aesthetics of industrial development when granting permits. They can apply conditions for screening industrial facilities from recreation areas and for timing construction so as not to interfere with peak recreation use.

Another problem that can interfere with the enjoyment of an onshore **recreational experience is the presence of trash and** debris. This is a particular problem on the Texas **coast where ocean circulation tends to** concentrate trash, generated at sea, on the beaches.

The closely related activities of general recreation, recreational fishing, and commercial fishing are strongly bound by their common reliance on undisrupted and productive natural ecosystems. Whether use is measured in terms of pounds of fish or sunbathers per mile of beach, activity levels are directly responsive to connected environmental factors such as air, beach, and water quality, availability of productive habitat, balanced food chains and primary productivity, and pristine conditions. All three activities respond similarly to subtle shifts in environmental quality; a study focusing on any single element will likely yield results which may, with appropriate reservations, result in generalizations for the group.

Regional Data Availability

Atlantic Region

The Atlantic Region managed the study *Assessment of Space and Use Conflicts between the Fishing and Oil industries* (Centaur Associates, 1981), This study covered the North, Mid-, and South Atlantic, Gulf of Mexico, and California planning areas and provided information on recreational fishing activities.

Information on recreational activities is aiso available from the Atlantic coastal States, although not necessarily in a comparable form. Generally, States collect information on tourist revenues and on attendance at State parks,

In a 1977 study, the economic consequences of a hypothetical oil spill impacting Long Island were analyzed (Long Island State Park and Recreation Commission, 1977). Wilman attempted a similar study for Cape Cod and Martha's Vineyard (Wilman, 1984). Bell and Leeworthy (1986) prepared a report on the economic importance of saltwater beaches in Florida. The Atlantic Region has conducted a study modeling the possible effects of OCS development on recreation and tourism in Florida.

Gulf of Mexico Region

The Gulf of Mexico Region sponsored the IXTOC 10il Spill Economic Impact Study in 1980 (Restrepo and Associates, 1982). This study measured the economic effects of the IXTOC 1 blowout and the sinking of the Burmah Agate upon the tourism, recreation, and commercial fishing industries in the Texas" coastal region. Economic losses to recreational businesses were concentrated within a small number of businesses close to the water's edge and in the recreation-oriented subregions. The IXTOC I oil spill reached the most affected regions during the height of the summer tourist season; estimated economic loss to recreational sectors was "approximately three million dollars. Oil from the Burmah Agate reached the study area during the off season and had no measurable economic impacts. The estimates of indirect economic effects to the recreation industry from the spills were judged insignificant, particularly when examined at the regional level. Reports by Ditton and Graefe (1978), Ditton and Auyong (1984), and Roberts and Thompson (1983) demonstrate the popularity and importance of production platforms to offshore recreational activity and the implications for coastal economies. Another recreational issue is the possible use of retired OCS platforms as artificial reefs. Platforms on the OCS have important incidental functions as artificial reefs, particularly for recreational fishing activities. These aspects of platforms have been considered by Federal Agencies and Gulf coastal States (Ditton and Auyong, 1984). Changes in MMS regulations have been proposed that would permit operators to leave abandoned platforms in place.

Many Federal and State agencies including the National Park Service, the Texas General Land Office, and the Louisiana Office of State Parks, are concerned about trash accumulation on recreational beaches. This problem is most serious along the Western Gulf of Mexico and to a lesser extent, along the Central Gulf of Mexico shoreline. Along the GOM, trash accumulations tend to follow ocean currents and drift patterns. The MMS has organized sessions at the last three GOM ITM's on the debris issue, designed to share new information on the sources and nature of the debris on beaches of the Central and Western GOM Planning Areas and to review the progress of institutions, individuals, and organizations active in litter removal and educational campaigns.

Pacific Region

Tourism is a major issue that involves coastal aesthetics, recreational facilities, and tourist spending. The Pacific Region has sponsored two studies related to this issue. The first, *Inventory and Evaluation of California Coastal Recreation and Aesthetic Resources* (Granville, 1981), was designed to identify and describe existing recreation and aesthetic resources along the California coast. The second study, *Impacts of Outer Continental Shelf Development on Recreation and Tourism* (Dornbusch, 1987), developed an econometric computer model. The emphasis was to quantify the current value of tourism to coastal economies and to predict the potential impacts of OCS development on recreation use, tourism-related industries, and the multiplier effect on local economies.

Mead and Sorenson (1970) conducted a study of the effects on recreation of the 1969 Santa Barbara oil spill. The spill resulted in a short-run trade diversion, depressing the motel and restaurant business near the affected oceanfront in favor of neighboring areas, However, the spill did not significantly affect overall tourist activity in the county.

Access sites to beaches were mapped and described in the *California Coastal Access Guide* by the California Coastal Commission (1981). Public access sites to the Washington beaches have been described in the *"Washington Pub/it Shore Guide" (Scott* and Reulling, 1986).

Alaska Region

For the Alaska Region the ESP has funded the "OCS Visual Resources Management Methodology Study" (Harmon, 1979) published as Technical Report (TR-27). Many of the studies sponsored by the Alaska Social and Economic Studies Program on economics or fisheries topics include information on recreational issues such as the contributions of tourism or of sport fishing to the local economy.

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16. Information Synthesis, Management, and Dissemination

General Description

In **evaluating the history of the ESP, it appears that over the first 15 years of the program** most effort has been devoted to the design of studies and the means to conduct them. As is probably true of many large research programs, information synthesis and dissemination received less attention during this period. Currently, one of the greatest concerns of the MMS is the apparent lack of effectiveness to communicate the results of the ESP (as well as other relevant research) to concerned citizens and non-MMS decisionmakers. The MMS is working to improve this process by including information dissemination and management as a priority within the ESP. Although having welldesigned, focused studies with testable hypotheses is critical for the scientific community, it is equally important that mechanisms are developed to ensure that the information is used effectively.

Current Data Availability

This chapter contains an overview of the current status of ESP/MMS information synthesis and dissemination efforts. Because information management initiatives are often generic to the entire ESP, the discussion of data availability begins with generic issues (or Headquarters) and then discusses items specific to the Regions.

Headquarters

The MMS Headquarters is responsible for proposing overall policy for information management and dissemination, maintaining the programmatic databases, and sponsoring initiatives that are not regionally specific. To date, the specific activities that Headquarters has focused on include:

- Database management,
- Project summarization, and
- Data and report archiving.

In the period of 1973-1988, the ESP sponsored more than 600 contracts including 2,ooO reports, publications, and other products prepared as documentation. As this volume of material has grown, so have the problems of providing access to individuals and organizations with a need for the information. In the early years of the program, before the number of documents available became too large, the staff of the ESP, as well as the users of our information, had access to reference collections arranged and indexed manually. These files were maintained in both the Regional Offices and Headquarters.

In 1981, Headquarters prepared a master index of contract information for internal use. This document, entitled *Outer Continents/ Shelf Environmental Studies* Program *Contract Projects Summary – Fiscal Year 7973 Through Fiscal* Year 7980 contained basic contract data on all completed and ongoing studies, arranged by seven program subject categories and MMS planning areas. This volume was updated annually until 1985, when an on-line data retrieval system was activated.

The on-line system, referred to as the Environmental Studies Data System (ESDS), is a series of *dBase IV* files running on an MS-DOS configured personal computer. This system was available for data query 24 hours a day, using *F/emote* as a communications **package** and dedicated telephone access line. During spring 1989, MMS relocated most offices to Herndon, Virginia. A new communications system is now under development. Once operational, users will need to register with the Branch of Environmental Studies (BES) to obtain a password. Copies of the database are provided to each Regional Office for their use and are periodically updated. (At this writing, a new Local Area Network System is being installed that will replace Remote)

The ESDS has two basic components: (1) **archive data** of basic information that record

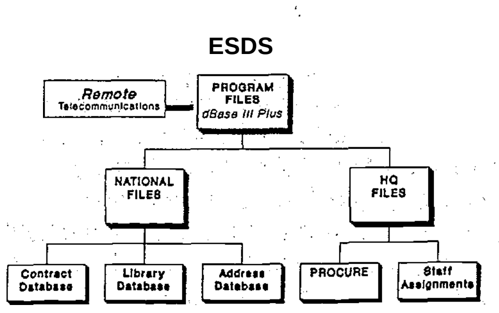

Figure 16-1. Components of the Environmental Studies Database System

completed actions and 2) operational information used to track and accomplish tasks on a daily basis. The former are available for public review, whereas the latter are for internal use only. Figure 4-1 provides a diagram of the ESDS components.

The two database files (DBF) of interest to most users are CONTRACT.DBF and LIBRARY.DBF. The first contains procurement and "management information on all active and completed contracts, whereas the second contains bibliographic information on publications, reports, journal articles, etc. that have been prepared as a result of studies sponsored by the ESP. The LIBRARY.DBF also contains records of other reference material found in the ESP library. During 1989- "1990, " the University of Rhode"Island developed an improved version of ESDS for use within MMS. In addition to the ESDS, the BES is currently preparing, with the help of a contractor, technical summaries of past ESP reports. Each technical summary consists of two to three pages of text and a location map showing the area involved in the study. In addition to basic contractual information, each summary contains a keyword listing, the background and objectives of the project, a summary of significant conclusions and results, and a list of study products. **For studies completed since FY 1987,** the contractor is required to prepare a technical summary following the standard format developed for this project. An electronic file (Word Perfect 5.1) of all summaries and a master file of camera-ready hard copies is maintained at Headquarters, Collections of summaries will be periodically released as MMS OCS Study technical volumes. To date, two volumes (CSA, 1989 and 1990) have been released.

The MMS has also established guidelines for the submission of all ESP reports to the National Technical Information Service (NTIS). Although Regional Offices are required to submit reports to NTIS, this was not always done in the past. Headquarters is currently working with the Regional Offices to identify volumes not submitted to NTIS and correct this deficiency. The NTIS accession numbers are available in the ESDS databases. Since 1985, studies reports have also been required to have MMS technical report numbers, they and are listed in the quarterly publications lists and annual reports prepared by the MMS Office of Offshore Information and Publications (e.g. Bajusz, 1988).

A limited number of final reports are normally delivered directly to Regional Offices at contract completion. The availability of these reports varies according to the anticipated demand and is handled through the Regional Offices. Each Region has a distribution list including State offices, libraries, and Regional Technical Working Group members. Remaining copies are available on request until the supply is exhausted.

Headquarters receives at least one copy of each report or deliverable product produced through the ESP. These are added to the Headquarters reference library maintained by the Branch of Environmental Studies. At present this collection is being inventoried to determine its status and to replace any missing volumes. Appointments to use the Headquarters and regional libraries can be arranged by calling the appropriate ESP group (see Appendix A).

As discussed in several of the technical sections, enough data have been collected on some topics to allow or, perhaps require, a secondary evaluation and synthesis. For example, a book on bowhead whales has just been published (Geraci and St. Aubin, 1990) and a volume on the effects of oil on marine mammals is nearing completion. Past efforts include books on the Bering Sea (Hood and Calder, 1981), Gulf of Alaska (Hood and Zimmerman, 1987), and U.S. Atlantic Continental Rise (Millimann and Wright, 1987).

In general, the final reports submitted to MMS are completed with relatively tight time constraints and attempt to make all data available to MMS. These constraints often result in long reports accompanied by volumes of data and tables. The MMS has always encouraged further reduction of data into published articles. Benefits include a more concise account of significant findings, additional peer review of data, and broader distribution of results. Many recent contracts include preparation of manuscripts and submission for possible publication as requirements following submission of the final report. When appropriate, MMS will sponsor special sessions at professional meetings, including the publication of results (e.g., Lee, 1983; Darnell and Defenbaugh, 1990). The MMS also has provided additional funds to support publication efforts in older studies and most recently has supported production of video tapes (e.g. AVP, 1988).

Finally, MMS has co-sponsored national meetings on topics of interest and funded the National Research Council to conduct technical assessments on specific topics (NRC, 1983) as well as an assessment of the entire ESP (currently in progress). Headquarters also will sponsor workshops (e.g. Montgomery, 1987), although these are usually conducted by the Regional Offices.

Regional Offices

Regional Offices play a key role in providing data for the national databases and Headquarters initiatives. They are also involved in many information management activities specific to the Region. Information Transfer Meetings (all regions), Ternary Meetings (Gulf of Mexico Region) and Synthesis Meetings (Alaska Region) are held to aid in the dissemination and evaluation of information on current research.

Information Transfer Meetings, or ITM's, have been held annually in the Gulf of Mexico Region since 1980. Normally held in the fall in New Orleans, these 2 or 3 day meetings include special sessions on high-interest topics, as well as summaries of ongoing research. Proceedings are prepared and published as MMS Technical Reports (MMS, 1980; 1982a,b; 1984a; 1985a; 1986a; 1987a; 1988a; 1989d). In the other Regions there have been three to four ITM's. The Pacific Region (MMS, 1984b, 1986c, 1987b, 1989e) and Atlantic Region (MMS, 1986b, 1987c) ITM's have been similar in content to those held in the Gulf, but smaller and of shorter duration. In Alaska, the approach has been somewhat different, with each ITM focusing on a different geographic area (MMS, 1985b, 1988b)(the most recent Alaska ITM, January 1990, was focused on protected species, bird, and social studies).

Ternary Meetings are held by the Gulf of Mexico Regional Office as a mechanism to ensure the rapid dissemination of results from ongoing projects. Ternary Meetings are usually held in March, July, and October, with the fall meeting being included into the annual ITM. Normally, all ongoing contracts are discussed by the principal investigators, unless there are no new results to present. Open to the public and held in various locations along the Gulf coast, these meetings provide the Regional Office with frequent public input, Proceedings are issued as technical reports (see MMS 1989b for listing).

in the Alaska Region, Synthesis Meetings, supported jointly by the MMS Regional Office and NOAA OCSEAP, provide a mechanism to address specific issues in areas scheduled for oil and gas activities. These meetings are held as needed, based on the oil and gas leasing schedule, projected industry activities, and environmental concerns. These "meetings stress the interdisciplinary evaluation of environmental issues and resource use conflicts. The OCSEAP and MMS personnel, representatives of the State of Alaska, the petroleum industry, and local and other interest groups attend these meetings. Synthesis reports, issued by NOAA OCSEAP, are based on these meetings and include discussions of data presented during the meetings (e.g., Becker, 1988; Hale,' 1987; Jarvela and Thorsteinson, 1989). To date about 20 reports have been released (see OCSEAP, 1988).

Numerous workshops have been conducted by all regions on a wide range of topics, usually directly related to oil and gas issues but also broader scientific topics that may include MMS concerns. Recent examples include workshops directly related to oil and gas; environmental impacts of causeways in the Beaufort Sea (MMS, 1989a), oil and dispersant toxicity testing (Duke and Petrazzuolo, 1989); and a more general workshop on the state of information on protected marine species in the Gulf of Mexico (report in preparation).

Each office' maintains a reference collection of products from Regional studies and responds to requests for information. Regional offices have considerable flexibility in how they manage their own ESP products and are responsible for establishing their own distribution scheme for ESP products.The Regions also have the option of establishing an appropriate network of repository libraries. Prior to the development of the ESDS by the BES, each Region prepared and distributed listings of the reports completed under contracts conducted for the Region. They still have the option of preparing such listings (Golden, 1988; MMS, 1989b,c; Wilson, 1989); however, a national bibliography is now available for distribution (Johnson et al., 1989).

The NOAA OCSEAP component of the Alaska ESP incorporated a unique final report management system within its program. The MMS receives final reports from individual studies (Research Units or RU's) as soon as they are complete. The OCSEAP will later issue collections of these reports in a series of bound volumes. Periodically, a master bibliography is released (OCSEAP, 1988). Rather than repeat information in these volumes, the MMS national listing being printed (Johnson et al., 1989) is restricted to non-OCSEAP reports.

Each Region and Headquarters also issue an annual Regional Study Plan (RSP); OCSEAP issues a Technical Development Plan. Beginning in FY 1990, RSP's will be prepared to cover 2-year intervals. These documents provide background on regional activities and describe proposed studies and are available by request through the Regional OCS Offices and Headquarters.

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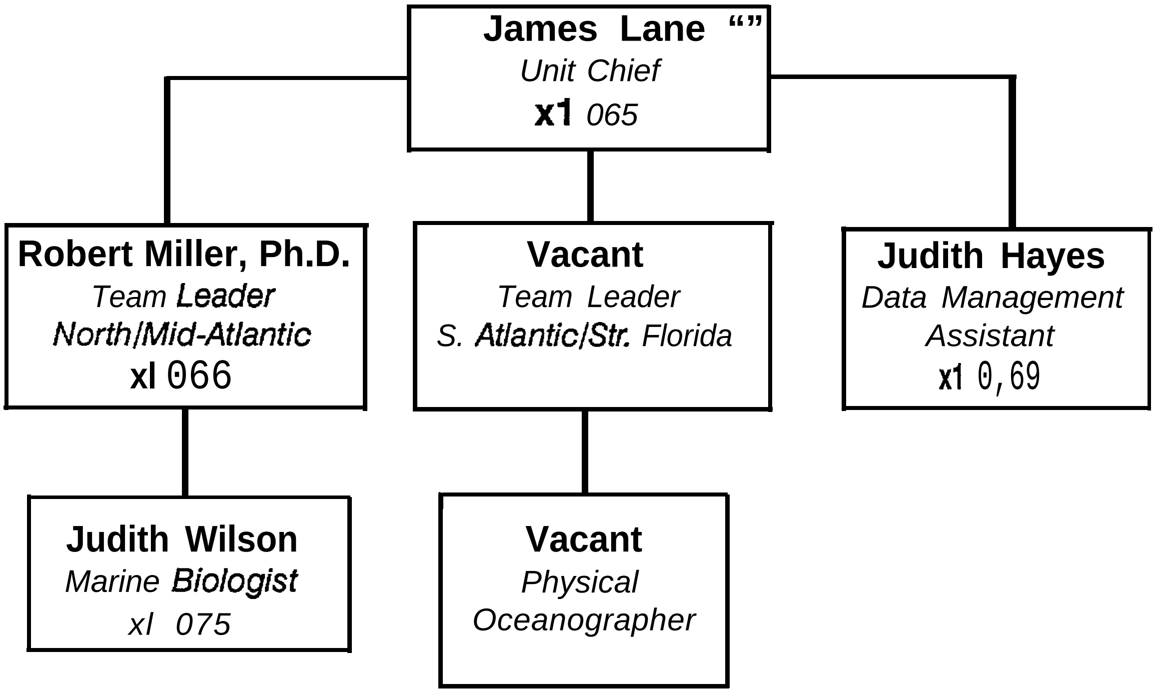

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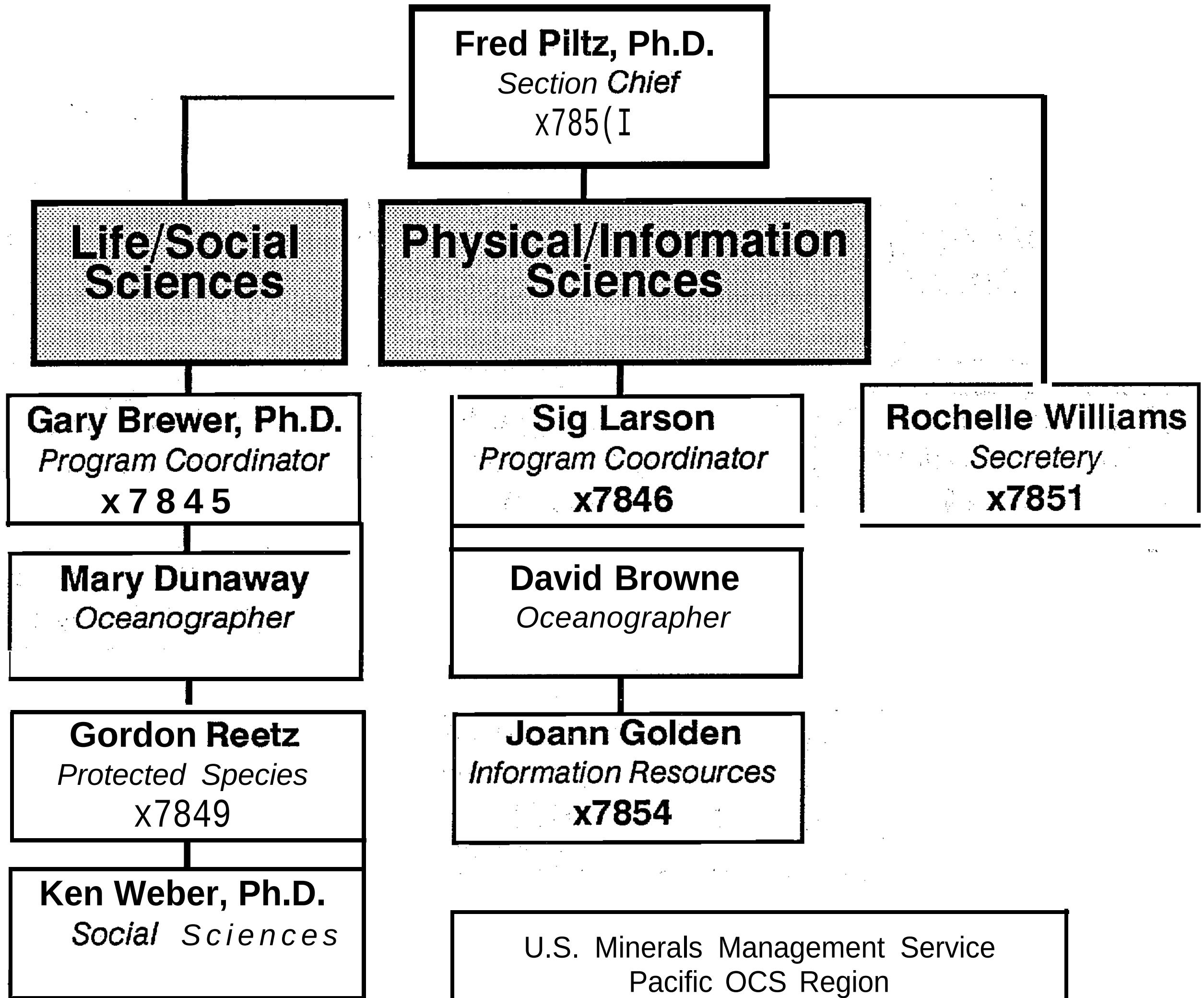

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As the **Nation's principal conservation agency, the Department of the Interior has responsibility** for most of our nationally owned public lands and natural resources. **This includes** fostering **the** wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.