FINAL ENVIRONMENTAL IMPACT STATEMENT FOR THE OCEAN DRILLING PROGRAM

NOVEMBER, 1985

NATIONAL SCIENCE FOUNDATION
OCEAN DRILLING PROGRAM

Final Environmental Impact Statement
for the
Ocean Drilling Program

Errata Sheet

Page ii: Change action addressee to:

Mr. Alexander L. Sutherland
Associate Program Director
Ocean Drilling Program, Room 613
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Page X: Last paragraph, last sentence should read:

"The Environmental Protection Agency rated the DEIS "LO", Lack of Objection."

Page 39 and E-7:

After subparagraph (D) insert the following sentence:

"ODP operations will, insofar as practicable, be conducted in accordance with the Convention or such regulations as may be promulgated by the U.S. Government."

EXECUTIVE SUMMARY

STATEMENT TYPE: Final Environmental Impact Statement

PREPARED BY: Division of Ocean Sciences, National Science Foundation

ATTENTION: Mr. Thomas N. Cooley
Division of Ocean Sciences, Room 613
National Science Foundation
1800 G Street, N.W.
Washington, DC 20550

1. Type of Action: Expansion of a Program

2. Brief Description of Proposed Action:

The National Science Foundation (NSF) is authorized by the National Science Foundation Act of 1950, as amended, to initiate and support basic and applied scientific research, and to initiate and support programs to strengthen scientific research potential. The Ocean Drilling Program (ODP) was established by the National Science Board in March, 1982. Through this program, the NSF is supporting a new scientific ocean drilling program as a successor to the Deep Sea Drilling Project (DSDP). The NSF views the ODP as a major long-term scientific program likely to continue for a decade or more.

Through the ODP, scientists and governments from many countries have joined together to explore the structure and history of the earth beneath the ocean basins. The central purpose of the ODP is to provide core samples from the ocean floors and the facilities to study those samples. Data generated will lead to a better understanding of seafloor spreading, plate tectonics, the structure of the earth's interior, evolution of life in the oceans, climatic changes through time, and, in turn, to a fuller comprehension of the structure of our planet. The United States, United Kingdom, Federal Republic of Germany, France, Japan, Canada, and the European Science Foundation Consortium (composed of Belgium, Denmark, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and Switzerland) are cooperating to organize and undertake the project.

Drilling operations are carried out on board the drillship JOIDES RESOLUTION (SEDCO/BP 471). Scientific operations and logistics are developed through Texas A&M Research Foundation. Program management is provided by Joint Oceanographic Institutions, Inc. (JOI). Program oversight and funding are provided by the NSF. Scientific plans are developed through the international scientific consortium, Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). JOI and JOIDES were key components of the DSDP management and planning structure, also.

FINAL ENVIRONMENTAL IMPACT STATEMENT FOR THE OCEAN DRILLING PROGRAM

Ocean Drilling Program
Division of Ocean Sciences
National Science Foundation
1800 G Street, NW
Washington, DC 20550

November, 1985

3. Purpose of the EIS:

The National Environmental Policy Act of 1969 as amended (NEPA, PL 91-190) requires Federal agencies to evaluate environmental impacts in the United States of all proposed actions and their alternatives, and, when appropriate and necessary, document this evaluation in an Environmental Impact Statement (EIS). Executive Order 12114, January 4, 1979, supplements NEPA by setting forth the obligations of agencies to carry out appropriate environmental reviews of actions which may have impacts outside U.S. jurisdiction. By complying with the environmental review process, Federal agencies ensure that environmentally responsible decisions are made, based upon analysis of the best available information and with full participation of the public.

The ODP differs from most activities for which EISs are prepared. The ODP is primarily a scientific endeavor of significant benefit. It is the continuation of scientific activity that has been ongoing for two decades, and it is the product of extensive planning and preparation.

The NSF prepared an EIS (NSF 1975) on the International Phase of Ocean Drilling (IPOD) of the Deep Sea Drilling Project (DSDP). The 1975 EIS addresses scientific ocean drilling carried out globally in major and minor ocean basins. Initial drilling operations of the ODP do not differ significantly from those carried out during IPOD and addressed in the DSDP/IPOD EIS (NSF 1975).

The decade-long program will expand efforts in scientific deep-ocean drilling and research. The program is global in scope and builds on the successes of DSDP/IPOD. Plans call for drilling in high latitudes, including antarctic seas, and drilling on continental margins in addition to carrying out the more typical drilling operations characteristic of the previous DSDP/IPOD.

The ODP differs from DSDP/IPOD in two important aspects. First, the research vessel, JOIDES RESOLUTION (SEDCO/BP 471), is more modern and more capable than its predecessor, GLOMAR CHALLENGER, which was used for the DSDP/IPOD, but does not differ significantly from CHALLENGER in the type or amount of materials/wastes discharged under a riserless mode of drilling. Second, in the future the ODP will be able to use a marine riser and subsea well control system to safely drill riser holes deeper into sedimentary sequences on continental margins than was possible with CHALLENGER. This will allow coring in areas of significant scientific interest that were bypassed by the DSDP/IPOD because of safety concerns.

The purpose of this EIS is to address the more complicated aspects of riser drilling and of drilling in high latitudes and antarctic seas not previously addressed in the DSDP/IPOD EIS (NSF 1975). Drilling modes that were adequately analyzed in the DSDP/IPOD EIS (NSF 1975) are reviewed in this EIS. Additionally, aspects of drilling in deep-ocean trenches, on active spreading centers, and in or near environmentally-sensitive regions are considered. Potential environmental impacts are identified and discussed. Drilling in the Weddell Sea is currently scheduled during January and February, 1987. No riser drilling on continental margins is planned for the immediate future.

4. Rationale in Selecting Sites for Discussion:

This document has been developed as a programmatic EIS, addressing the scope of the ODP while taking into account the technical capabilities of the drillship, the competence of the vessel operator, as well as the worldwide locations in which the program will be carried out. To facilitate consideration of potential impacts associated with drilling sites, this EIS evaluation focuses on four representative drilling sites: Georges Bank, East Pacific Rise, Mid-American Trench, and the Weddell Sea. The sites encompass the range of scientific goals, and geographic and ecologic conditions expected over the course of the ODP to ensure coverage of all foreseeable impacts.

Sites were chosen by considering the major scientific goals. Then three sets of criteria were evaluated to determine which sites would cover the range of subjects to be addressed in the EIS:

- Environmental factors
- Risk elements
- Data availability.

The four sites selected are shown in Figure A. The four sites and the areas of major discussion presented under each site are listed in Table A.

All four sites are addressed within the same subject category in Chapter 3 (Affected Environment) and Chapter 4 (Environmental Consequences). This approach results in a complete discussion of all potential impacts by the end of the four site assessments.

5. Summary of Environmental Impacts and Adverse Environmental Effects:

The continuation of scientific ocean drilling throughout the global oceans will have negligible impacts on major oceanic ecosystems. Environmental effects of normal drilling operations will be temporary and will be detectable only in the immediate vicinity of the drillship (surface waters) or drill hole (seafloor). Significant effects are identified only for the localized impacts of drill cuttings on the benthic community (smothering) in the immediate vicinity of the drill hole. Only about 100 m^2 (1,076 ft^2) of seafloor around the drill hole are expected to be impacted, however, and recruitment/repopulation in the area of the drill hole is expected to take place.

The expansion of scientific ocean drilling into high latitudes (i.e., antarctic seas) and onto continental margins will have only localized, temporary impacts. Riserless drilling in antarctic waters will release surface seawater (used as the drilling fluid), drilling muds, and cuttings at the seafloor. Riser drilling on continental shelves will release drilling muds and cuttings at the sea surface which may cause minor accumulation of some trace metals by organisms. Negligible effects are expected on the ecosystem and on humans eating marine organisms.

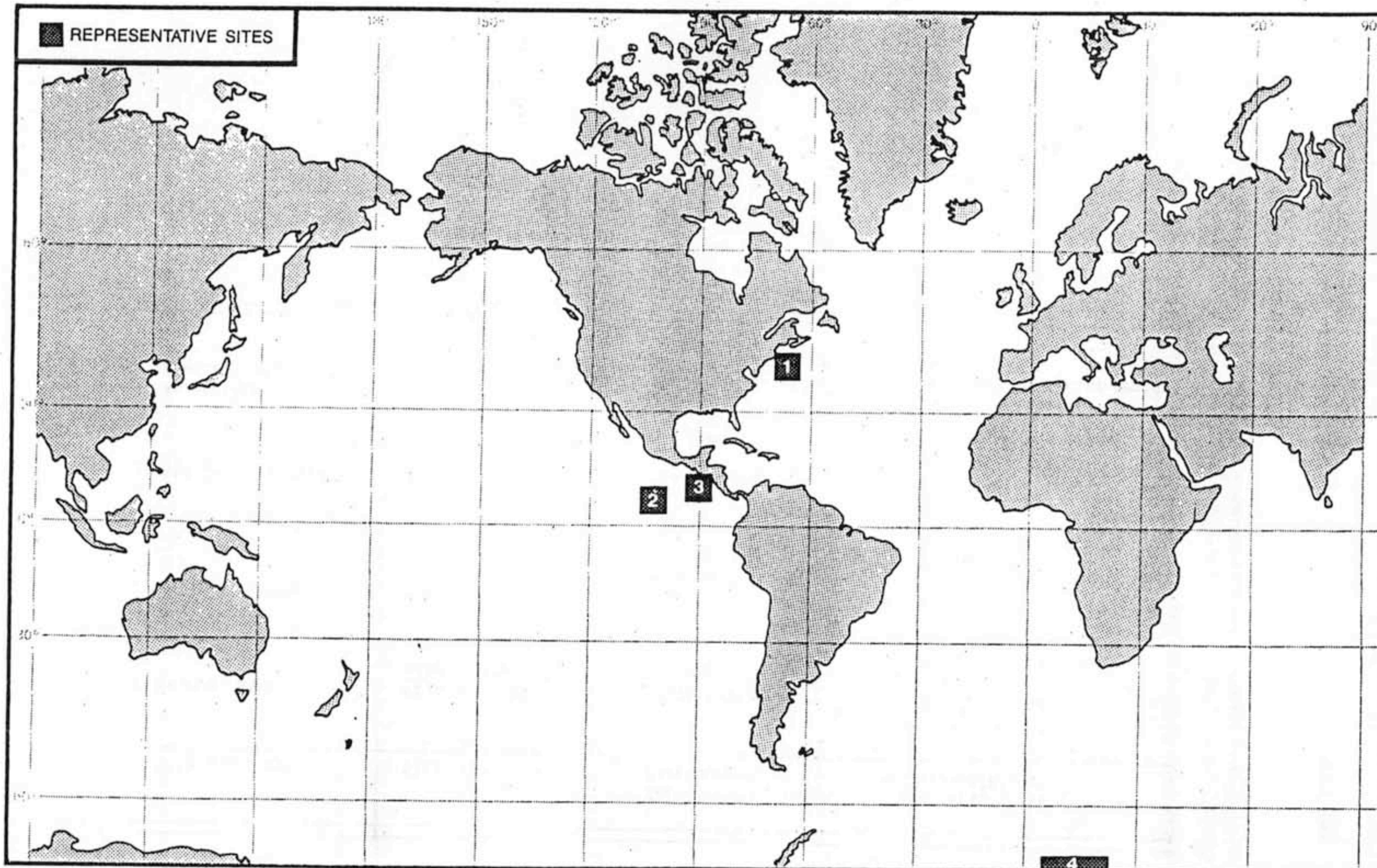


Figure A. Representative drilling sites.

TABLE A. REPRESENTATIVE SITES FOR THE EIS EVALUATION

Site Locations	Site Type	Technical Problems/ Development	Major Impact/Risk Assessment Focus
1. Georges Bank	Passive margin (thick sediments)	Riser system	Oil & gas blowout Fisheries Landfall/shore impacts Drilling muds
2. Eastern Pacific Rise	Spreading center Hydrothermal system	Bare rock spud-in High temp drilling	Magmas Hydrothermal tap-in Upwelling Challenger-type drilling discharges
3. Mid American Trench	Active margin	Gas hydrates	Acoustic environment Small coastal fisheries International boundaries
4. Antarctica (Weddell Sea)	High latitude	Ice Heave compensation	Antarctic treaties Biologically sensitive regions Marine mammals

Of the many potential impacts (outside the normal range of operations) investigated, the following would have the greatest significance:

- Blowout of gas or brine could occur when drilling into sedimentary deposits, though the probability of this occurrence is very small
- Severe short-term impacts from sound sources used during seismic surveying could affect sonar/hearing of marine mammals, or even lead to mortality, if individuals were in immediate proximity to the drillship
- Blowout and subsequent uncontrolled release of oil in an environmentally-sensitive region (worst-case analysis, $P<0.01$) might cause the loss of the drillship and all personnel.

A summary of the relative magnitude, persistence, and probability of impacts resulting from various ODP operations is listed in Table B.

6. Summary of Major Alternatives Considered and Proposed Mitigating Measures:

Alternatives to the proposed expansion of drilling activities by the Ocean Drilling Program are to: 1) delay or exclude implementation of drilling plans pertaining to selected sites; 2) exclude drilling in sensitive areas; and 3) delay or exclude implementation of riser drilling.

Mitigating measures are: 1) exclusion of drilling "on structure"; 2) observance of applicable U.S. Coast Guard laws/regulations; 3) observance of IMO requirements for the Control of Pollution from Drilling Vessels; 4) adherence to Federal Water Pollution Control Act and Marine Protection, Research, and Sanctuaries Act; 5) compliance with Minerals Management Service rules governing drilling activities; 6) compliance with the Antarctic Treaty and relevant Antarctic Treaty recommendations, and the Antarctic Conservation Act; 7) site review by JOIDES Pollution Prevention and Safety Panel; 8) site review by Texas A&M Research Foundation Safety Panel; 9) site-specific well planning procedures; 10) on-site monitoring for hydrocarbons, H_2S, methane gas, etc.; 11) contingency planning; and 12) ship's personnel training.

7. Agencies and Parties from which Comments are Requested:

Federal Agencies and Offices

Council on Environmental Quality
Department of Commerce
    National Marine Fisheries Service
    National Oceanic and Atmospheric Administration
Department of Defense
Department of Energy
Department of Health and Human Services
Department of the Interior
    Fish and Wildlife Service
    U.S. Geological Survey
    Minerals Management Service
Department of State

TABLE B. SUMMARY IMPACT MATRIX

ODP Activity	Impacted Environment	Magnitude	Persistence	Probability	Detailed Impact Discussion
Conversion of ship	Physical				
	Land	L	L	H	Section 4.4
	Air quality	L	L	H	Section 4.4
	Social, economic, legal				
	Economy	M	M	H	Section 4.6
	Technology dev./transfer	M	H	H	Section 4.6
Presence of ship and drill string	Physical				
	Air quality	L	L	H	Section 4.4
	Water quality	L	L	H	Section 4.4
	Sea bottom	L	H	H	Section 4.4
	Acoustical	M	L	H	Section 4.4
	Biological				
	Phytoplankton/zooplankton	L	L	H	Section 4.5
	Nekton	L	L	L	Section 4.5
	Benthos	L	L	H	Section 4.5
	Marine mammals/birds	L	L	M	Section 4.5
	Endangered species	L	L	L	Section 4.5
	Sensitive areas	L	L	L	Section 4.5
	Social, economic, legal				
	Other uses	L	L	H	Section 4.6
	Legal/regulatory	L	L	H	Section 4.6
	Technology dev./transfer	M	H	H	Section 4.6
Release of cuttings and drilling fluids	Physical				
	Water quality	L	L	H	Section 4.4
	Sea bottom	L	M	H	Section 4.4
	Biological				
	Phytoplankton/zooplankton	L	L	M	Section 4.5
	Nekton	L	L	M	Section 4.5
	Benthos	L	L	H	Section 4.5
	Marine mammals/birds	L	L	H	Section 4.5
	Endangered species	M	L	L	Section 4.5
	Sensitive areas	M	L	L	Section 4.5
	Social, economic, legal				
	Other uses	L	L	H	Section 4.6
	Legal/regulatory	L	L	H	Section 4.6
Potential oil and gas spills and blowouts	Physical				
	Water quality	H	M	L	Section 4.7
	Sea bottom	H	M	L	Section 4.7
	Biological				
	Phytoplankton/zooplankton	H	L	L	Section 4.7
	Nekton	H	M	L	Section 4.7
	Benthos	H	M	L	Section 4.7
	Marine mammals/birds	H	M	L	Section 4.7
	Endangered species	H	M	L	Section 4.7
	Sensitivie areas	M	L	L	Section 4.7
	Social, economic, legal				
	Economy	H	M	L	Section 4.7
	Other uses	H	M	L	Section 4.7
	Legal/regulatory	H	M	L	Section 4.7
Transportation of supplies and personnel	Physical				
	Air quality	L	L	H	Section 4.4
	Acoustical	L	L	H	Section 4.4
	Biological				
	Marine mammals/birds	L	L	H	Section 4.5
	Endangered species	L	L	L	Section 4.5
	Sensitive areas	L	L	L	Section 4.5

H = High (large, high, or long-term).
M = Medium (moderate or intermediate).
L = Low (small, low, or short-term).

Department of Transportation
- Maritime Administration
- U.S. Coast Guard

Environmental Protection Agency
Federal Maritime Commission
Marine Mammal Commission
National Academy of Sciences
National Aeronautics and Space Administration

Private Organizations

American Cetacean Society
American Environmental Safety Council
American Fisheries Society
American Society of International Law
Antarctic and Southern Ocean Coalition
Center for Environmental Education
Center for Law and Social Policy
Conservation Foundation
Defenders of Wildlife
Environmental Defense Fund
Friends of the Earth
Greenpeace
International Association of Fish and Wildlife Agencies
International Audubon Society
National Parks and Conservation Association
National Wildlife Federation
Natural Resource Defense Council
Nature Conservancy
Oceanic Society
Resources for the Future
Sierra Club
Union of Concerned Scientists
Wilderness Society

Unsolicited Requests

L.G. Bowles, GSI
C.V. Chapman
Colorado State University Library
S. Dixon, Sea Technology Magazine
M. Finey, McClelland Engineering
W.F. Guy, Union Oil of California
JOIDES Executive Committee
F. Jones, IMCO Services
J. Lindstedt - Siva, Atlantic Richfield Co.
W. Lovess, Office of Naval Research
P. Paske, American Petroleum Institute
R.L. Riouix, U.S. Geological Survey
R.M. Robinson, Conoco, Inc.
J. Sanchez
J. Splettstoesser, Minnesota Geological Survey
R.T. Stone, Minerals Management Service
C.C. Thompson, California Department of Justice

8. Date Draft Statement Made Available: June 21, 1981

9. Date Final Statement Made Available:

10. Preparation:

Under the direction of the Division of Ocean Sciences, National Science Foundation (Mr. Thomas N. Cooley, Project Officer for Environmental Impact Assessment, ODP), TETRA TECH, INC. prepared the EIS in accordance with Contract OCE-84-18886, awarded August 29, 1984, after evaluation of responses to RFP SP84-102 (issued March 15, 1984). TETRA TECH program managers were: Mr. Gary N. Bigham, Project Manager; Mr. Victor M. Yamada, Assistant Project Manager; Dr. Thomas C. Ginn, Marine Ecologist; and Mr. Jeffrey H. Stern, Report Coordinator.

11. Summary of Comments and Responses:

An integral part of the environmental review process is review and comment of the EIS by the public. Comments received are reproduced in Appendix D. Commentors are listed below:

James Callahan
Department of the Interior
Department of State
Environmental Protection Agency
Marine Mammal Commission
National Marine Fisheries Service
National Oceanic and Atmospheric Administration

Specific comments and the NSF's responses are presented in Appendix E. Many of the comments suggested editorial changes to clarify, expand, or correct specific points raised in the EIS. The appropriate revisions were made to the text. Key issues that were brought up (in many cases by more than one party) included the need for:

- Input of biological considerations into the site selection process
- Defining as biologically sensitive areas both hydrothermal vent communities and regions of seasonal high-use by endangered whale species
- Implementation of specific mitigating measures to reduce potential impacts to sensitive areas and endangered species.

The NSF recognizes that these issues are valid concerns. Methods to incorporate biological considerations into the site selection process are under discussion with JOIDES (which provides the scientific planning for the ODP). The definition of biological considerations at each drill site can serve as the basis for site-specific procedural measures to minimize the potential for impacts, especially to sensitive areas and endangered species. Each issue is discussed in Appendix E. The Environmental Protection Agency rated the DEIS "LO", Lack of Objective.

CONTENTS

	Page
EXECUTIVE SUMMARY	ii
LIST OF FIGURES	xvii
LIST OF TABLES	xxi
CHAPTER ONE -- Purpose of and Need for Action	1
1.1 INTRODUCTION	2
THE PROPOSED ACTION	2
PURPOSE OF THE EIS	3
1.2 BACKGROUND ON SCIENTIFIC DEEP OCEAN DRILLING	4
PROJECT MOHOLE AND POST-MOHOLE STUDIES	4
DEEP SEA DRILLING PROJECT	4
INTERNATIONAL PHASE OF OCEAN DRILLING	5
OCEAN MARGIN DRILLING PROGRAM	10
ADVANCED OCEAN DRILLING PROGRAM	10
OCEAN DRILLING PROGRAM	10
1.3 PROGRAM OBJECTIVES	12
OCEAN CRUSTAL STUDIES	12
ACTIVE MARGIN STUDIES	13
PASSIVE MARGIN STUDIES	13
OCEAN PALEOENVIRONMENT STUDIES	15
1.4 OVERALL SIGNIFICANCE OF THE PROGRAM	16
CHAPTER TWO -- Proposed Action and the Alternatives	17
2.1 INTRODUCTION	18
2.2 PROPOSED ACTION	19
PROGRAM COMPONENTS	19
Planning	19
Management	19
Fabrication and Construction	21
Testing	21
Field Operations	21

Sample Handling 21
Data Handling 22
PROGRAM DEVELOPMENT 22
FUSOD Report 22
HUSOD Report 22
COSOD Report 23
Crustal Studies Report 23
PROGRAM PARTICIPANTS 23
Role of the NSF 23
Role of the Management Contractor 25
Role of the Science Operator 25
Role of the Vessel Operator 27
Role of the Academic Community 27
Role of the International Participants 27
Liaison Between Program Participants 29
SPECIFIC DETAILS OF THE PROGRAM 29
Proposed Drilling Locations 29
Drilling Platform 29
Drilling Procedures 34
Applicable Laws and Regulations 37

2.3 ALTERNATIVES TO THE PROPOSED ACTION 40

EXTERNAL PROGRAM ALTERNATIVES 40
No Action 40
Program Deferral 40
Geophysical Surveys 40
INTERNAL PROGRAM ALTERNATIVES 41
OPERATIONAL ALTERNATIVES 41

2.4 SUMMARY OF IMPACTS FOR PROPOSED ACTION AND ALTERNATIVES 42

IMPACT SUMMARY 42
COMPARISON OF IMPACTS 47
CUMULATIVE IMPACTS 48

CHAPTER THREE -- Affected Environment 49

3.1 INTRODUCTION 50

3.2 FEATURES OF THE ENVIRONMENT THAT MAY AFFECT THE ODP 53

WEATHER 53
SEA CONDITIONS 53
GEOLOGICAL CONDITIONS 53

3.3 FEATURES OF THE OCEAN ENVIRONMENT THAT MAY BE IMPACTED BY THE ODP 54

PHYSICAL CONDITIONS OF THE REPRESENTATIVE DRILLING AREAS 54
WEDDELL SEA 54
Meteorology 54
General Circulation 54
Antarctic Bottom Water 59

Ice 59
Geological and Geophysical Conditions 61
Acoustical Environment 61
GEORGES BANK 64
Meteorology 64
General Circulation 67
Tidal Currents 69
Geological and Geophysical Conditions 69
Acoustical Environment 70
EASTERN TROPICAL PACIFIC 70
Meteorology 73
General Circulation 73
Bottom Water Circulation 78
Oxygen Minimum Zone 78
Geological and Geophysical Conditions 78
Acoustical Environment 84

BIOLOGICAL CONDITIONS OF THE REPRESENTATIVE DRILLING AREAS 84
WEDDELL SEA 84
Phytoplankton 84
Zooplankton 86
Nekton 88
Benthos 91
Marine Mammals and Birds 92
Endangered Species 100
Biologically Sensitive Areas 105
GEORGES BANK 105
Phytoplankton 105
Zooplankton 106
Nekton 108
Benthos 108
Marine Mammals and Birds 111
Endangered Species 121
Biologically Sensitive Areas 123
EASTERN TROPICAL PACIFIC 123
Phytoplankton 123
Zooplankton 124
Nekton 125
Benthos 126
Marine Mammals and Birds 128
Endangered Species 141
Biologically Sensitive Areas 142

OTHER USES OF REPRESENTATIVE DRILLING AREAS 142
WEDDELL SEA 142
Commercial Fisheries 142
Military Uses 142
Resource Development 143
Other Scientific Research 143
GEORGES BANK 143
Commercial Fisheries 143
Military Uses 143
Transportation 144

Resource Development 144
Other Scientific Research 144
EASTERN TROPICAL PACIFIC 144
Eastern Pacific Rise 144
Commercial Fisheries 144
Other Uses 145
Mid-American Trench 145
Commercial Fisheries 145
Other Uses 145

3.4 FEATURES OF THE TERRESTRIAL ENVIRONMENT THAT MAY BE IMPACTED BY THE ODP 146

CHAPTER FOUR -- Environmental Consequences 147

4.1 INTRODUCTION 148

TREATMENT OF DRILLING LOCATIONS 148
TREATMENT OF ALTERNATIVES 148

4.2 BASIC ASSUMPTIONS USED IN THE ANALYSIS OF ENVIRONMENTAL IMPACTS 150

ASPECTS OF THE ODP PRIMARILY AFFECTING THE TERRESTRIAL ENVIRONMENT 150

ASPECTS OF THE ODP PRIMARILY AFFECTING THE OCEAN ENVIRONMENT 150
Presence of the Ship and Drill String 150
Release of Cuttings and Drilling Fluids 151
Potential Oil and Gas Spills and Blowouts 159
Transportation of Supplies and Personnel 159
Noise from Drillship and Drilling Operations 159

4.3 IMPACT OF THE ENVIRONMENT ON THE ODP 160

WEATHER 160
ICE 162
SEA CONDITIONS 162
GEOLOGICAL CONDITIONS 163

4.4 IMPACT OF THE ODP ON THE PHYSICAL ENVIRONMENT 165

IMPACT ON LAND 165
IMPACT ON AIR QUALITY 165
IMPACT ON WATER QUALITY 165
IMPACT ON THE SEA BOTTOM 166
IMPACT ON THE ACOUSTICAL ENVIRONMENT 168

4.5 IMPACT OF THE ODP ON THE BIOLOGICAL ENVIRONMENT 169

IMPACT ON PHYTOPLANKTON AND ZOOPLANKTON 169
IMPACT ON NEKTON 171
IMPACT ON BENTHOS 174

5.3 CONSULTATION INITIATED BY THE ODP 226

CHAPTER SIX -- Bibliography 228

CHAPTER SEVEN -- Glossary 256

CHAPTER EIGHT -- List of Preparers 267

APPENDICES

APPENDIX A Global Distribution of Marine Mammals and the Potential Impacts of Offshore Scientific Drilling as it Relates to Life History Requirements A-1

APPENDIX B Processes Affecting Weathering and Chemical Fate of Oil in the Marine Environment B-1

APPENDIX C List of Agencies, Organizations, and Individuals Who Requested or Received the Draft Environmental Impact Statement C-1

APPENDIX D Comments Received on the Draft Environmental Impact Statement D-1

APPENDIX E National Science Foundation Responses to Comments on the Draft Environmental Impact Statement E-1

IMPACT ON MARINE MAMMALS AND BIRDS 179
IMPACT ON ENDANGERED SPECIES 183
IMPACT ON BIOLOGICALLY SENSITIVE AREAS 184

4.6 IMPACT OF THE ODP ON THE SOCIAL, ECONOMIC, AND LEGAL ENVIRONMENT 185

IMPACT ON THE ECONOMY 185
IMPACT ON OTHER USES OF THE ENVIRONMENT 185
IMPACT ON LEGAL AND REGULATORY ISSUES 187
IMPACT ON TECHNOLOGY DEVELOPMENT AND TRANSFER 188

4.7 MISHAPS AND ACCIDENTS 190

OCCUPATIONAL HAZARDS 190
LOSS OF RISER AND DRILL STRING 190
AQUEOUS SOLUTIONS 191
MAGMAS 191
BLOWOUT OF GAS AND BRINE 192
BLOWOUT OF PETROLEUM 193
Worst-Case Analysis 194
Oil Spill Risk Analysis 194
Fate of Crude Oil in the Marine Environment 195
Biological Effects of Crude Oil 199
Organism Impacts 200
Impacts to Habitats 202
Spill Prevention and Cleanup Techniques 207

4.8 MITIGATING MEASURES INCLUDED IN THE ODP 213

LAWS AND REGULATIONS 213
INSPECTION PROGRAMS 213
OPERATIONAL PLANNING AND PROCEDURES 213
CONTINGENCY PLANNING 217

4.9 RELATIONSHIP BETWEEN SHORT-TERM USE AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY 219

4.10 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES 221

HUMAN RESOURCES 221
ECONOMIC RESOURCES 221
ENERGY AND MINERAL RESOURCES 221
BIOLOGICAL RESOURCES 221

CHAPTER FIVE -- Consultation and Coordination with Others 222

5.1 PREPARATION OF THE ODP PROPOSAL 223

5.2 PREPARATION OF THE EIS 224

PARTICIPANTS IN PRE-EIS SCOPING 224
PARTICIPANTS IN EIS PREPARATION AND REVIEW 224

FIGURES

Number		Page
A	Representative drilling sites	v
1	Cross section illustrating basic idea of plate tectonics	6
2	The major plates of the earth's crust	7
3	Locations of the 624 sites at which 1,105 holes were cored during the Deep Sea Drilling Project	9
4	Classification of continental margins	14
5	Ocean Drilling Program management plan	20
6	Ocean Drilling Program organizational chart	26
7	JOIDES organization	28
8	Candidate drill site areas for the first 2 years of the drilling program	30
9	Areas of specific scientific interest that are under consideration as potential future drill sites	32
10	Drillship JOIDES RESOLUTION (SEDCO/BP 471)	33
11	Representative drilling sites	51
12	The Weddell Sea region	55
13	Mean monthly climatological geostrophic winds about Antarctica, January and February	56
14	Water masses and circulation in the Southern Ocean	57
15	Surface circulation in the Weddell Sea and Southern Islands	58
16	Bottom circulation in the Weddell Sea and Southern Islands	60
17	Mean monthly ice concentration contours around Antarctica, January and February	62
18	Sources, mechanisms, and the spectrum of ambient noise in the ocean	63
19	The Georges Bank region	65

20	Circulation in the Gulf of Maine and on Georges Bank	68
21	Schematic cross section of Georges Bank geologic structure	71
22	Tectonic map of the Baltimore Trough and Georges Bank Basin	72
23	The eastern tropical Pacific region	74
24	Surface winds in the eastern tropical Pacific Ocean	75
25	Surface circulation in the eastern tropical Pacific Ocean	76
26	Bottom circulation in the eastern tropical Pacific Ocean	79
27	Seismic lines through DSDP Leg 66 drill sites showing major seismic structures	81
28	The East Pacific Rise Spreading Center in the representative drill site region	83
29	The Antarctic food web	87
30	Oceanic zones occupied by selected species of krill (<u>Euphausia</u>, <u>Thysanoessa</u>)	89
31	Distributions of major krill concentrations	90
32	Distributions and food sources of marine mammals in the Weddell Sea	94
33	General distributions and nesting areas of seabird species in the vicinity of the Weddell Sea	99
34	General distributions of penguin species that breed north of the Weddell Sea	101
35	General distributions of large procellarid species that nest north of the Weddell Sea	102
36	General distributions of small procellarid species that nest north of the Weddell Sea	103
37	Other seabird species in the vicinity of the Weddell Sea	104
38	Simplified food web for Georges Bank	107
39	Generalized foraging areas of nesting species in the Georges Bank region	119
40	Generalized foraging range of species spending summer and fall in pelagic and offshore habitats	120

4a General distribution of the pelagic toothed whales (Category 4). A-18

4b General distribution of the pelagic toothed whales (Category 4). A-19

4c General distribution of the pelagic toothed whales (Category 4). A-20

4d General distribution of the pelagic toothed whales (Category 4). A-21

Appendix B

1 Weathering and dispersion effects on oil in the marine environment B-3

41	Preferred areas for endangered cetacean species in the Georges Bank region	122
42	General distributions of seabird species groups in the eastern tropical Pacific Ocean	132
43	General distributions of petrels and shearwaters in the eastern tropical Pacific Ocean	135
44	General distributions of storm-petrels in the eastern tropical Pacific Ocean	136
45	General distributions of several large seabird species in the eastern tropical Pacific Ocean	137
46	General distributions of boobies in the eastern tropical Pacific Ocean	138
47	General distributions of skuas, gulls, and terns in the eastern tropical Pacific Ocean	139
48	General distributions of migrant boreal seabird species in the eastern tropical Pacific Ocean	140
49	Factors associated with scientific drilling effects on marine mammals	180
50	Slick radius versus time	197
51	Fate of oil on water	198
52	National Marine Fisheries Service formal consultation response pursuant to Section 7 of the Endangered Species Act	227

Appendix A

1	General distribution of marine mammals that rely on fur or hair for insultion and are site tenacious (Category 1).	A-10
2a	General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).	A-12
2b	General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).	A-13
2c	General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).	A-14
2d	General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).	A-15
3	General distribution of the baleen whales (Category 3).	A-17

TABLES

Number		Page
A	Representative sites for the EIS evaluation	vi
B	Summary impact matrix	viii
1	Deep Sea Drilling Project technical achievements after 96 cruises, August 11, 1968 - November 20, 1983	8
2	Major goals of scientific ocean drilling	24
3	Ocean Drilling Program ship schedule for the first 2 years of the program	31
4	Comparison of the specifications of JOIDES RESOLUTION with the program's previous drillship GLOMAR CHALLENGER	35
5	Summary impact matrix	43
6	Representative sites for the EIS evaluation	52
7	Occurrence of storm wind speeds greater than 34 kn at Georges Shoals	66
8	Seal species in the Weddell Sea region	93
9	Cetacean species in the Weddell Sea region	96
10	Seabird species in the Weddell Sea region	98
11	Principal commercial and sport fisheries species on Georges Bank	109
12	Seal species in the Georges Bank region	112
13	Cetacean species in the Georges Bank region	113
14	Seabirds that nest in coastal areas of the Gulf of Maine and Cape Cod	115
15	Seabird species that occur seasonally in offshore habitats in the Georges Bank region	116
16	Seabird species that winter in the Georges Bank region	118
17	Cetacean species in the eastern tropical Pacific region	129

18 Seabird species of regular or common occurrence in the representative sites, eastern tropical Pacific region 133

19 Seabird species of periodic or possible occurrence in the representative sites, eastern tropical Pacific region 134

20 Approved drilling mud types 156

21 Maximum trace metal concentrations measured in drilling mud discharges 157

22 Soluble and solids metal concentrations in dredged materials dumped at sea, 1978 and 1979 158

23 Impacts of the environment on the ODP 161

24 Trace metal concentrations of the whole mud and dissolved fraction compared to water quality standards 167

25 Cleanup guidelines for open or rough sea (>1 km from shore) by European Petroleum Organization 210

26 Cleanup guidelines for nearshore waters (<1 km from shore) by European Petroleum Organization 211

27 Applicable laws and regulations 227

Appendix A

1 Categories of vulnerability A-6

2 Population estimates of marine mammal species vulnerable to population-level impacts A-7

CHAPTER 1

PURPOSE OF AND NEED FOR ACTION

Section 1.1
INTRODUCTION

This chapter reviews the background of the proposed action, describes the goals and objectives of the program, and documents its inception. A more complete description of the ODP is presented in Chapter 2.

THE PROPOSED ACTION

The National Science Foundation (NSF) is authorized by the National Science Foundation Act of 1950, as amended, to initiate and support basic and applied scientific research, and to initiate and support programs to strengthen scientific research potential. The Ocean Drilling Program (ODP) was established by the National Science Board in March, 1982. Through this program, the NSF is supporting a new scientific ocean drilling program as a successor to the Deep Sea Drilling Project (DSDP). This program is funded by the NSF and managed through a contract with the Joint Oceanographic Institutions, Inc. (JOI), which subcontracts scientific shipboard and shore-based operations to Texas A & M Research Foundation at Texas A & M University (TAMU) and logging operations to Lamont-Doherty Geological Observatory (L-DGO). The NSF views the ODP as a major long-term scientific program likely to continue for a decade or more.

Through the ODP, scientists and governments from many countries have joined together to explore the structure and history of the earth beneath the ocean basins. The central purpose of the ODP is to provide core samples from the ocean floors and the facilities to study those samples. The United States, United Kingdom, Federal Republic of Germany, France, Japan, Canada, and the European Science Foundation (composed of a consortium of Belgium, Denmark, Greece, Italy, The Netherlands, Norway, Spain, Sweden, and Switzerland) are cooperating to organize and undertake the project. An international scientific organization, the Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES), formally provides long-term scientific planning and goals for the program. Data generated will lead to a better understanding of seafloor spreading, continental drift, the structure of the earth's interior, evolution of life in the oceans, climatic changes through time, and, in turn, to a fuller comprehension of the structure of our planet and the dynamic processes which have shaped it.

The ODP differs from the DSDP in two important aspects. First, the research vessel, SEDCO/BP 471, informally renamed JOIDES RESOLUTION for the ODP, is superior to its predecessor. It offers advantages (detailed in Section 2.2) over GLOMAR CHALLENGER, which was used for the DSDP. Second, in the future the ODP will be able to use a marine riser and subsea well control system to safely drill holes deeper into sedimentary sequences on continental margins at some later date. This will allow coring in areas of significant scientific interest that were bypassed by the DSDP because of safety concerns.

PURPOSE OF THE EIS

The National Environmental Policy Act of 1969 as amended (NEPA, PL 91-190) requires Federal agencies to evaluate environmental impacts in the United States of all proposed actions and their alternatives, and, when appropriate and necessary, document this evaluation in an environmental impact statement (EIS). Executive Order 12114, January 4, 1979, supplements NEPA by setting forth the obligation of agencies to carry out appropriate environmental reviews of actions which may have impacts outside U.S. jurisdiction. By complying with the environmental review process, Federal agencies ensure that environmentally responsible decisions are made, based upon analysis of the best available information and with full participation of the public.

In its initial stage, the ODP will continue scientific drilling operations similar to those carried out on board GLOMAR CHALLENGER since 1968. For such operations, the EIS prepared in 1975 for the International Phase of Ocean Drilling of the DSDP still applies. However, in view of the expanded activities under the ODP, the NSF has decided to prepare this programmatic EIS. It addresses the large number of potential sites and all possible types of drilling which could be undertaken over the expected life of the ODP. This EIS specifically addresses the environmental considerations and consequences of drilling in high latitudes, drilling with a riser and blowout prevention system, drilling on continental margins, and drilling in or near environmentally-sensitive regions.

Section 1.2
BACKGROUND ON SCIENTIFIC DEEP OCEAN DRILLING

The ODP continues an activity that began over 25 years ago with Project Mohole, the first attempt to drill through the earth's crust to the mantle. Since 1957, the NSF has supported scientific deep-sea drilling through several projects. This section describes the history of these deep-sea drilling activities, and thus the background of the present program.

PROJECT MOHOLE AND POST-MOHOLE STUDIES

Project Mohole was developed to test theories of earth science by coring and measurement of the characteristics of sediments and rocks from the earth's crust to the mantle. The name "Mohole" came from the Mohorovicic Discontinuity (MOHO), the seismic boundary between the crust and mantle, and the project's ultimate drilling target. The earth's crust is thinnest in deep ocean basins below the seafloor. Consequently, plans were developed to drill in water depths far exceeding the contemporary limits of offshore operations, and the NSF agreed to fund the project.

The drilling vessel CUSS I (a trial platform to test theories and practices) began drilling in 948 m (3,109 ft) of water in March, 1961. Holes drilled by CUSS I during the program produced cores representing the first deep, continuous sampling of sediments and rocks below the ocean surface. Although drilling depths did not come close to the MOHO, the project produced valuable data from the recovered cores. New engineering and operational features, including the first rudimentary dynamic positioning system, were also developed and field tested. The full project did not receive funding and the Mohole platform was not completed.

Following Mohole, the NSF discussed the need for an ocean sediment coring program with oceanographers, geophysicists, and geologists. In the spring of 1964, four major oceanographic institutions formed JOIDES, a consortium that provided scientific advisory planning and guidance. The original group consisted of Lamont-Doherty Geological Observatory, Columbia University; the Rosenstiel School of Marine and Atmospheric Science, University of Miami; the Scripps Institution of Oceanography, University of California at San Diego; and the Woods Hole Oceanographic Institution. The University of Washington joined the consortium in 1968. The NSF sponsored a drilling program in the summer of 1965 on the Blake Plateau using the dynamically positioned drilling vessel CALDRILL I. The success of this work led to establishment of the DSDP.

DEEP SEA DRILLING PROJECT

The DSDP proposed to gather core samples and information from the ocean floor. The project was launched in 1968 using the dynamically positioned drillship GLOMAR CHALLENGER, which enabled scientists to drill holes at ocean depths up to 7,000 m (22,960 ft) and with penetration of 1,700 m (5,576 ft) beneath the seafloor. DSDP drilling operations made noteworthy contributions to deep-sea drilling technology. Among the technical innovations used first by the project and now by the offshore drilling industry are computerized dynamic positioning, sonar borehole reentry techniques, improved core bits and equipment, and improved coring techniques. The program made major contributions to better understanding of the chronology of tectonic and environmental events and the evolution of ocean circulation and marine life. In particular, the DSDP provided some of the strongest evidence supporting the model of plate tectonics.

The plate tectonics model was initially developed by Hess (1962) from geophysical and geological observations in the oceans and from earthquake seismology. Present-day models propose the generation of crust at oceanic ridges, followed by lateral transport of the oceanic crust and sediments, and ultimate addition of some of this material to existing continental crust (Figure 1). A second aspect of the plate tectonics model implies that 200 million years ago a supercontinent was fragmented by a process termed rifting. With the continuous generation of new crust, the rifted continental fragments moved apart by the process of seafloor spreading (Dietz 1961) toward the present configuration of continents. This movement apparently continues today (Figure 2). Movement of the continents has changed ocean circulation, weather, and climate. It is the record of these changes, preserved in the sedimentary column beneath the seafloor, that the DSDP recovered by coring.

INTERNATIONAL PHASE OF OCEAN DRILLING

The early phases of the DSDP completed a major reconnaissance over most of the world's oceans, except the ice-covered oceans and the thick sedimentary sequences on the continental shelves. The International Phase of Ocean Drilling (IPOD) was initiated in 1975 as the scope of the program changed to address specific problems on an international scale. The composition of JOIDES changed with the addition of the following oceanographic institutions: Bundesanstalt fur Geowissenschaften und Rohstoffe, Federal Republic of Germany; Centre National pour l'Exploitation des Oceans, France (now part of Institut Francais de Recherche pour l'Exploitation de la Mer); Hawaii Institute of Geophysics, University of Hawaii; Natural Environment Research Council, United Kingdom; School of Oceanography, Oregon State University; Graduate School of Oceanography, University of Rhode Island; Department of Oceanography, Texas A & M University; Ocean Research Institute, University of Tokyo, Japan; and U.S.S.R. Academy of Sciences.

DSDP/IPOD drilling activities came to an end when CHALLENGER was decommissioned in Mobile, Alabama on November 20, 1983 at the end of Leg 96. Table 1 lists some of the technical achievements accomplished during the DSDP. One thousand one hundred five holes were drilled and cored during the DSDP (Figure 3). During the 15-year period of its operation, CHALLENGER experienced 85 percent operational time, with an additional 11 percent of the time occupied by portside logistics handling. With only 4 percent of the time lost to weather and equipment downtime, the program was both an operational and a scientific success.

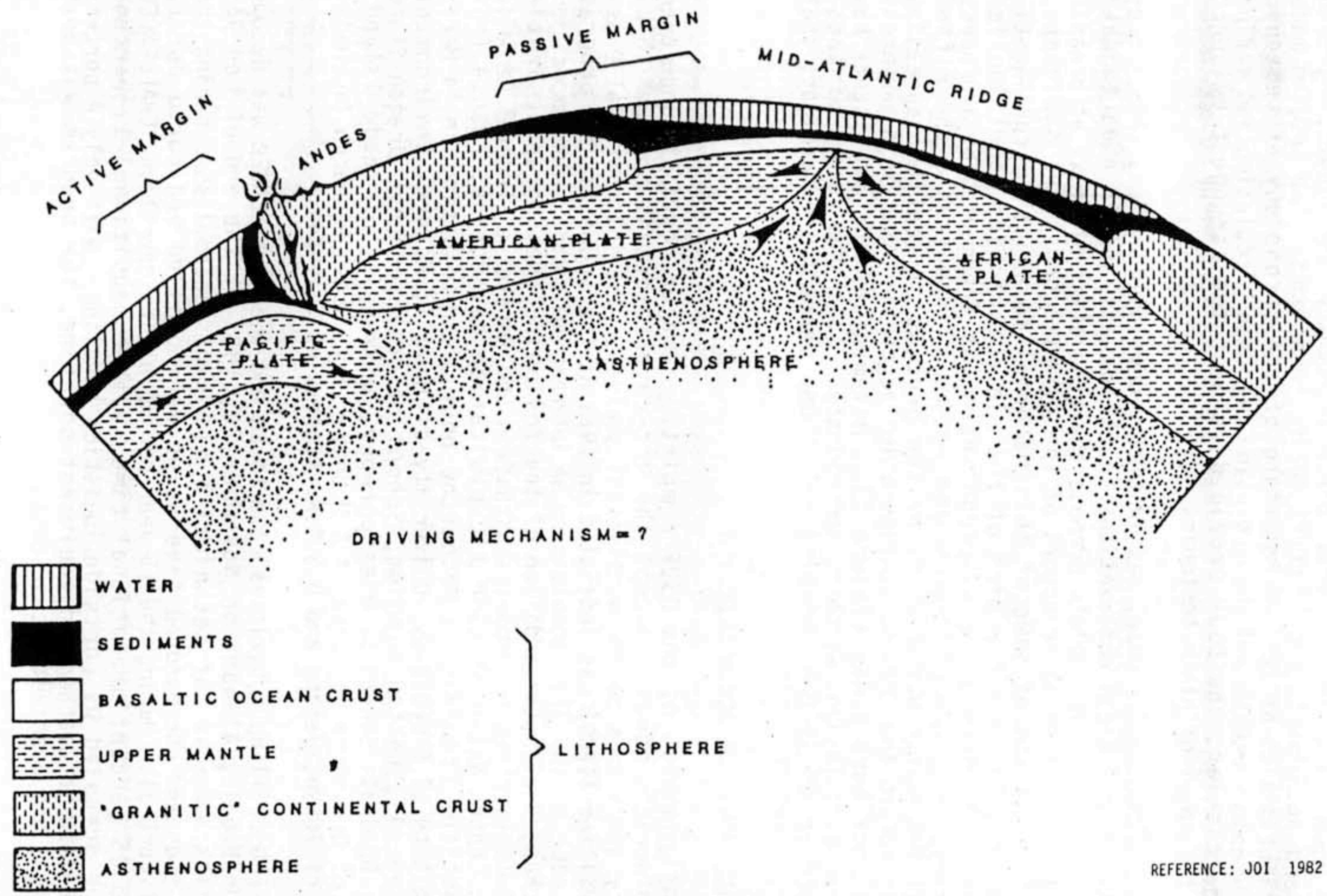
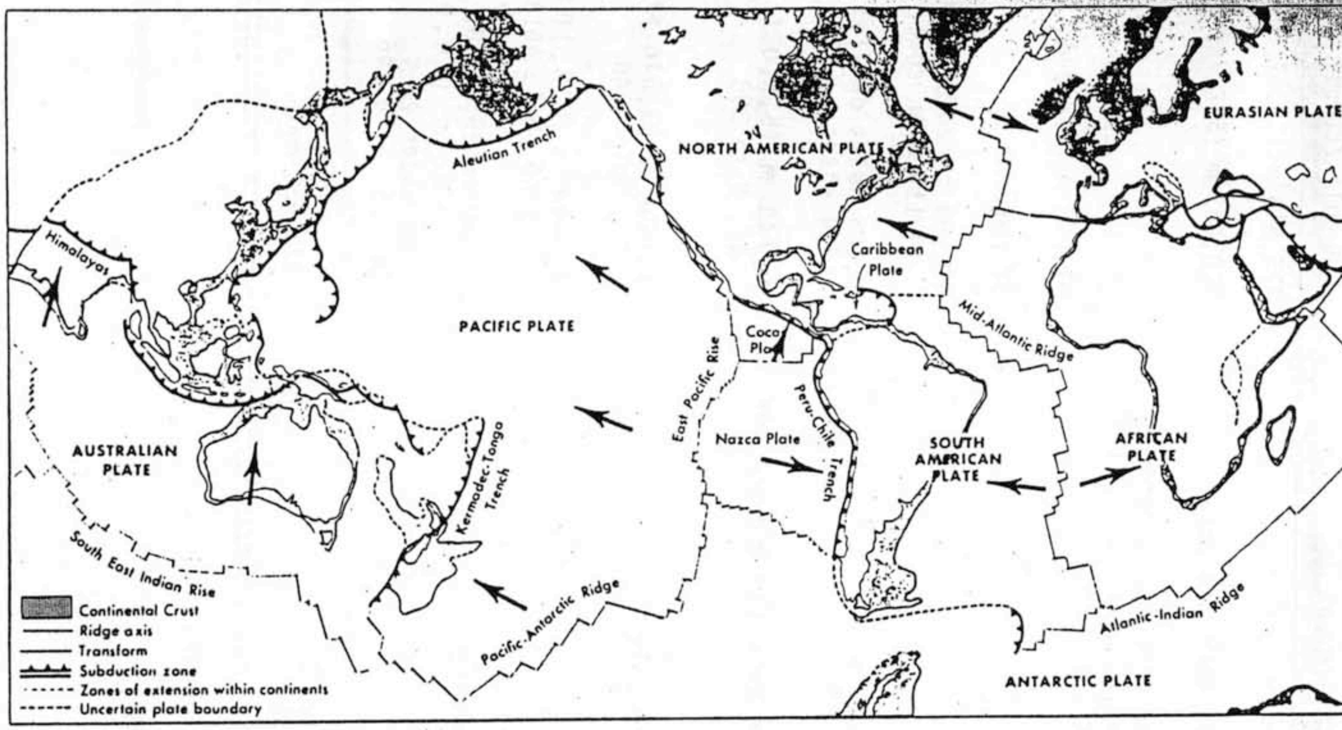


Figure 1. Cross section illustrating basic idea of plate tectonics.



REFERENCE: JOI 1982

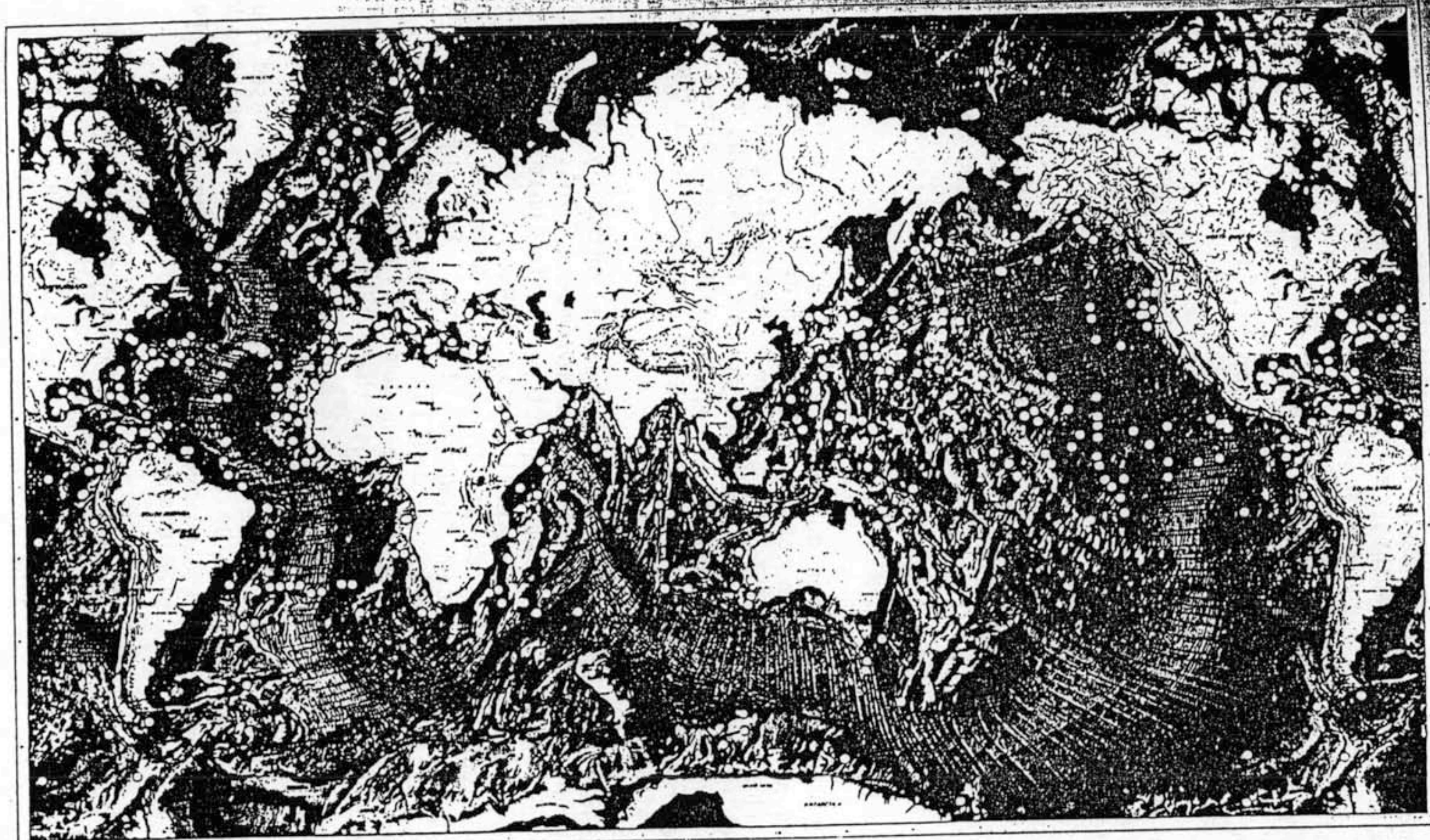
Figure 2. The major plates of the earth's crust.

TABLE 1. DEEP SEA DRILLING PROJECT TECHNICAL ACHIEVEMENTS AFTER 96 CRUISES[a], AUGUST 11, 1968-NOVEMBER 20, 1983

Technical Achievement	Results/Comments
Total distance penetrated below seafloor	325,548 m (1,067,797 ft)
Interval of penetration that was cored	170,043 m (557,741 ft)
Core recovered and placed in repositories at Columbia University, Lamont Geological Observatory, and Scripps Institution of Oceanography	97,056 m (318,344 ft)
Overall core recovery	57 percent
Number of cores taken	19,998 cores attempted; 19,119 with core recovery
Number of sites investigated	1,105 holes drilled at 624 sites
Deepest penetration beneath the ocean floor	1,741 m (5,710 ft), Leg 47, Site 398
Maximum penetration into basaltic crustal layers in any single hole	1,080 m (3,546 ft), Leg 83, Hole 504B
Deepest water worked in	7,044 m (23,104 ft), Leg 60, Hole 461A
First operational re-entry	December 25, 1970, in 3,062 m (10,043 ft) of water Leg 15, Site 146
Total distance traveled by D/V GLOMAR CHALLENGER	375,632 nmi

[a] Including the IPOD phase.

Reference: DSDP (1984).



REFERENCE: JOI 1979

Figure 3. Locations of some of the 624 sites at which 1,105 holes were cored during the Deep Sea Drilling.

OCEAN MARGIN DRILLING PROGRAM

It was recognized that the capabilities of CHALLENGER were not adequate to meet the remaining scientific goals of ocean drilling. A drilling platform to operate in greater water depths, remain on station for longer time periods, achieve deeper penetrations, and carry greater loads was required. Moreover, some scientific objectives required a vessel with an ice-strengthened hull and improved weather-handling capabilities for operations in otherwise inaccessible areas. A key conference (i.e., the FUSOD conference) was held in March, 1977 to discuss the direction of future scientific ocean drilling and to detail a program of future work.

In 1980-1981, the Ocean Margin Drilling Program (OMDP) was sponsored jointly by the NSF and a consortium of 10 major U.S. oil companies. This program called for an advanced state-of-the-art drillship to drill in thick sedimentary sequences on the ocean margins. As originally conceived, the OMDP would have converted the U.S. government-owned ship GLOMAR EXPLORER into a drill ship to carry and deploy a 4,000-m (13,120-ft) riser and subsea well control system. When the oil companies withdrew support in October, 1981, the NSF alone could not support such a program and the OMDP was terminated.

ADVANCED OCEAN DRILLING PROGRAM

The OMDP had created serious debate in the ocean science community because of its narrow focus on continental margin drilling. The proprietary interest of the oil companies had made international participation and support, which was central to the success of the DSDP/IPOD, difficult to obtain. The Advanced Ocean Drilling Program (AODP) represented an attempt to combine the broad-based scientific objectives of the DSDP with the technical capabilities of the OMDP.

Scientific plans for the AODP were formulated primarily at the Conference on Scientific Ocean Drilling (COSOD) in November, 1981. The AODP also centered around the use of EXPLORER, but with a two-phase conversion that would delay riser operation for several years. However, when the preliminary design for EXPLORER conversion was completed in November, 1982, it became apparent that costs would exceed budgetary limits. Fortunately, in 1982, the charter rates for commercial drillships dropped dramatically. The NSF therefore, moved to charter a modern commercial drillship that could meet program requirements at a lower cost than EXPLORER.

OCEAN DRILLING PROGRAM

To distinguish the revised project from the EXPLORER-based AODP, the name was shortened to the Ocean Drilling Program. In fact, the scientific objectives, management plans, and budget of the ODP were identical to those of the AODP; only the ship plan changed.

In February, 1984, JOI, the ODP management contractor, announced the charter of the modern, dynamically positioned drillship JOIDES RESOLUTION. With relatively minor conversions, the ship satisfied the program's technical requirements (e.g., larger laboratory space, greater sea-keeping ability, ice-strengthened hull, longer drill string, and riser capabilities) to meet scientific goals that were unachievable with CHALLENGER. The ODP and its vessel are described in detail in Chapter 2.

The ODP will be a long-term program of fundamental research on the earth's crust beneath the ocean. The scope is global, extending eventually into every ocean, and combines the reconnaissance capability of the DSDP with modern offshore technology and a 2,000-m (6,560-ft) riser. The research agenda addresses some of the most important questions concerning the structure, processes, and evolution of the crust of the earth.

Section 1.3
PROGRAM OBJECTIVES

ODP objectives proposed by the scientific community focus on the following subject areas: tectonics of the ocean basins, the generation and destruction of ocean crust, paleoclimatology, paleonotology, and paleoceanography. In addition, investigations of thick sedimentary sequences in water depths to 2,000 m (6,560 ft) are expected to reveal the history of the margins themselves; the erosion of the adjacent continents; and the deposition, thermal history, and chemistry of the sediments. Four study categories can be defined:

- Oceanic crust
- Active margins
- Passive margins
- Ocean paleoenvironment.

A brief explanation of each category is provided in this section. More detailed descriptions of the objectives than presented here can be found in reports by the Committee on Post-IPOD Science (1979), JOIDES (1981, 1982), and NSF (1983).

OCEAN CRUSTAL STUDIES

Studies of dredged rocks, investigations of ophiolite complexes on the continents, analyses of marine geophysical data, results of theoretical modeling, and data from deep-ocean crustal drilling by CHALLENGER provided the elements of a working model of the formation of oceanic crust. Research on mid-ocean ridges and oceanic basins is needed to test the essential elements of this model and to explain the relationships between its component parts and new concepts of geological processes.

Advanced deep-ocean drilling capability is necessary to meet some objectives of ocean crustal studies. One objective is to study the composition, structure, and properties of the deep-ocean crust (Layer 3). Hypotheses concerning its origin are diverse. If its origin, composition, and physical properties can be determined accurately, use of seismic refraction data for geological interpretation will be enhanced considerably. Reaching Layer 3 will provide research opportunities not available with shallower holes. These include comparisons between ocean crust and ophiolite complexes, comparisons between crust formed at fast- and slow-spreading ridges, and the distribution of metamorphism with depth in the ocean crust. A second objective is to study the nature of the zero-aged oceanic crust and accretion mechanisms at the active spreading centers. This objective requires new bare rock spud-in technology that is being developed for the ODP. A third objective is the development of drilling technology to improve core recovery and condition, and development of downhole logging techniques and in-hole experiments to extend the usefulness of the holes.

ACTIVE MARGIN STUDIES

Studies of active (or convergent) ocean margins will explore the nature, extent, and significance of the transfer of portions of oceanic lithosphere to the continents. Creation of the continents and conversion of oceanic crust to continental crust can be revealed through an understanding of this process. The plate tectonics theory proposes that disposal of crust generated at mid-ocean ridges occurs at active margins between converging lithospheric plates. However, the process of subduction and the structure of convergent margins are largely inferred. A primary objective of drilling into active margins is to verify these inferences.

The major scientific problems addressed by drilling into active margins can be summarized by four questions:

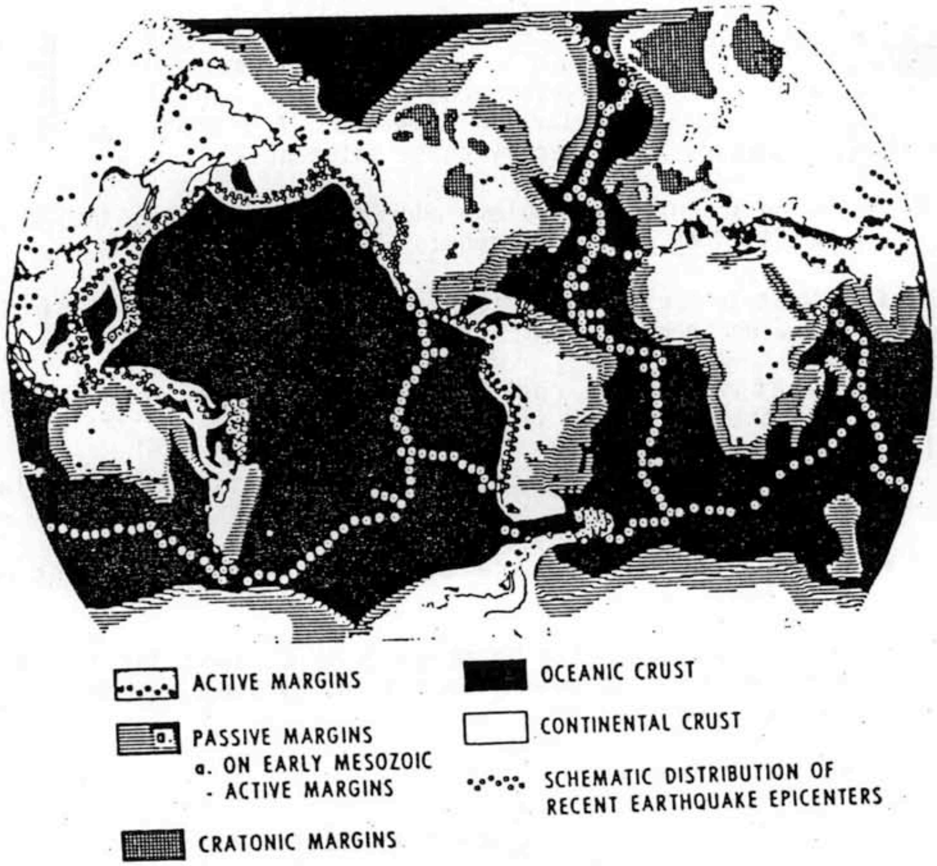
- What processes are active at modern convergent margins and how do they proceed?
- What volume of rock is strained by convergence and what is the time-space fluctuation of the rate of strain?
- What are the temporal and spatial histories of island arc tectonics?
- By what processes are ancient convergent margins exposed on land?

Many of these questions can be answered in a few critical areas by samples from 5- to 6-km (3.1- to 3.7-mi) depths and by long-term downhole instrumentation.

PASSIVE MARGIN STUDIES

Studies of passive ocean margins center on causes and mechanisms of continental break-up and on ocean basin development. The widely accepted model for the evolution of passive margins depicts rifting of continental crust and seafloor spreading. However, the underlying geophysical studies are not sufficient to verify that the model is accurate. Interpretations of ocean-continental crust boundaries will vary until present theories can be tested by drilling.

The genesis and evolution of sedimentary sequences in passive margins is a second major area for intensive study. Sampling of various sediment facies will shed light on sequences of deposition, on the initiation of rifting and drift, and on mass movements of ocean sediments. Passive margins offer relatively undisturbed accumulations of these sediments in contrast to the deformed sediments associated with the active margins. The relative global positions of active and passive margins are displayed in Figure 4.



REFERENCE: JOI 1982

Figure 4. Classification of continental margins.

OCEAN PALEOENVIRONMENT STUDIES

Sediments of the ocean floor contain the most complete record of the history of the earth's environment over the past 200 million years. Examination of these sediments can help delimit the evolution of oceanic circulation, the ocean's role in maintaining the earth's chemical balance, and the evolution and distribution of marine life.

One specific objective is to investigate the evolution of the world ocean during the Mesozoic era. The Mesozoic is characterized by the first appearance of most of the microorganisms that provide the basis for oceanic biostratigraphy. To allow more precise dating of the sediments and to understand world climatic changes, it is essential to know the early forms of these organisms and to understand the evolutionary changes they underwent when establishing their worldwide distribution.

A second objective is to study high-latitude paleoceanography, especially in the circum-Antarctic region. Two major elements of Cenozoic paleoceanographic evolution (i.e., the development of the circumpolar current, and the evolution of Antarctic Bottom Water, including its distribution to the deep oceans of the earth) cannot be studied without additional selected drilling in the Antarctic region. The opening of the Drake Passage is known to represent the primary structural event in the development of Southern Ocean circulation. However, the time of the opening is not known. Relationships between climatic changes and biogeographic changes following this new exchange between oceans might be revealed with information derived from these high-latitude studies.

Section 1.4
OVERALL SIGNIFICANCE OF THE PROGRAM

The advent of deep-sea drilling led to major advances in our understanding of the earth. Not only has scientific drilling validated the concepts of seafloor spreading and plate tectonics, but drilling results have provided the essential physical samples with which to interpret thousands of miles of seismic reflection records. Scientific drilling results are continuing to provide critical evidence that will make it possible to reconstruct the history of the earth's geology, climate, ocean circulation, and evolution of living organisms over the past 200 million years.

The continuing importance of scientific drilling in the oceans as a tool for acquiring geologic information is widely recognized. Despite recent advances in geophysical techniques, many problems remain which can best be addressed by drilling at carefully selected locations. Improved knowledge of the ocean floors will provide a sound scientific basis for the evaluation of potential hydrocarbon and other mineral resources beyond the continental shelf, in both passive and active margin areas, well in advance of any possible commercial activity. The tools and expertise developed to attain the scientific goals may well serve as a basis for the management of such deep-sea resources as may be identified. This work should be very useful in setting national energy strategies and permitting establishment of criteria for environmentally responsible development.

Understanding oceanic crust is important not only for its own sake, but also for understanding continental crust. The relatively simple processes of oceanic crust formation hold the clues to the much more complicated continental crust formation. Understanding the nature and evolution of the earth's crust and its state of stress in various tectonic settings could contribute to better predictions of major natural geologic hazards (e.g., earthquakes, volcanic eruptions).

Insights into the natural variability of long-term climatic changes and the ocean's role in those changes may be gained by seafloor exploration. The most complete history of changes in global climate, prior to the last few thousand years, is contained in the sediments and fossils of the ocean floor.

Because of the broad significance of the planned program, it is not unexpected that more than one government agency is involved in the program. Indeed, in keeping with their missions, the U.S. Geological Survey and the Department of Energy have shown an active interest in the ODP. Such interest only serves to emphasize the broad significance of the work to the public interest and assures the central role of basic scientific research in the continuing development of society.

CHAPTER 2

PROPOSED ACTION AND THE ALTERNATIVES

Section 2.1
INTRODUCTION

This chapter contains a detailed description of the proposed action, alternatives evaluated during the course of selecting the proposed action, and alternatives considered for environmental impact evaluation. A summary of the impacts of the proposed action and alternatives is presented following these descriptions to facilitate comparison.

Section 2.2
PROPOSED ACTION

The proposed action (i.e., development and implementation of the ODP) is a complex set of activities. This section provides details on specific components of the ODP, development of the program plan, roles of the program participants, and specific operational details. Activities that relate to potential impacts of the program are emphasized. Where possible, the reader is referred to other sources for further information.

PROGRAM COMPONENTS

The ODP components include planning, management, design, fabrication and construction, testing, field operations, sample handling, and data handling. Each component is summarized below.

Planning

Scientific planning for the ODP is provided primarily by the JOIDES international scientific committee structure. The JOIDES Executive Committee (EXCOM) sets the general policies of the program. Within the framework of these policies the Planning Committee (PCOM) formulates plans based on recommendations of the various JOIDES panels. These plans then become scientific objectives and drilling targets for the program. ODP program planning started in March, 1982, when the ODP proposal was approved unanimously by the National Science Board. Since then, the PCOM and advisory panels have been refining scientific plans at two levels: 1) a long-range plan for a 9-year program of ocean drilling preceded by a 1-year planning and ship conversion phase, and 2) a short-range plan for the early legs of the ODP (i.e., the first 2 years). Ship conversion is complete and operational activities commenced in January, 1985. Planning for subsequent legs continues.

Management

The overall management plan for the ODP is shown in Figure 5. The NSF through its Ocean Drilling Program office, provides oversight and review. Through the same office, the NSF coordinates the international ODP council and other international membership relationships. The NSF also administers ODP funding. Primary management responsibility for the ODP resides with JOI, a consortium of major oceanographic institutions in the United States. JOI is responsible for overall management of the ODP. In turn, JOI is assisted by several contractors, including:

- Texas A & M University, responsible as science operator for directing the ODP science and shipboard operations, as well as designing and maintaining permanent laboratories and support facilities, and curating and disseminating scientific information.

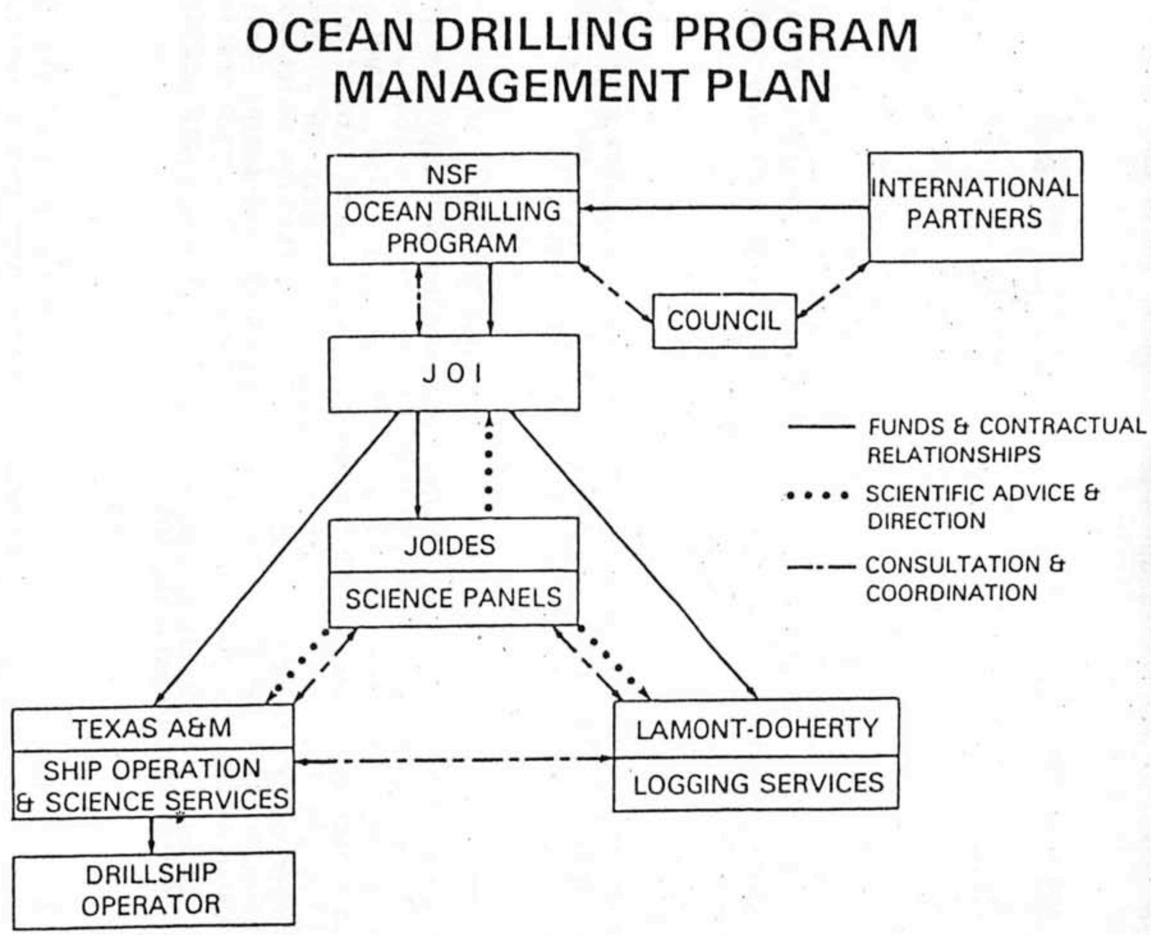


Figure 5. Ocean Drilling Program management plan.

- Lamont-Doherty Geological Observatory (L-DGO) of Columbia University and its team subcontractors: Stanford University and the Tectonophysics Branch of the U.S. Geological Survey, responsible for new tool acquisition and modification; and Schlumberger Offshore Services, responsible for acquiring and operating routine geophysical logging tools and ship- and shore-based logging analyses and dissemination.

Fabrication and Construction

In March, 1984, TAMU contracted with Underseas Drilling, Inc., an affiliate of SEDCO, Inc., of Dallas, Texas, for the charter and conversion of SEDCO/BP 471 (informally renamed JOIDES RESOLUTION) as the ODP drillship. TAMU prepared the engineering designs for the ship conversion. Conversion began in October, 1984; was completed in January, 1985; and included construction of the main laboratory structure, installation of a downhole measurements laboratory, installation of the library and study area, construction of an underway geophysics laboratory, and creation of additional scientific office and storage space. Major changes in the ship's drilling systems and equipment were also made.

Testing

The remodeled ship and the newly-fabricated drilling system were extensively and successfully field-tested between January 11 and 29, 1985. Equipment had also been tested on land before the sea trials.

Field Operations

Operation of the drillship, including planning and implementation of the work at sea, is managed from the ODP science operator's headquarters at TAMU. SEDCO operates the vessel under TAMU's direction. TAMU also coordinates with visiting marine scientists, who are expected to take advantage of the drillship's long residence times (i.e., up to 30 days for riserless drilling, longer for riser operations) on station for studies which would otherwise be very costly in ship-time (e.g., intensive time-series sampling of the upper water column). L-DGO will manage the wireline logging operations, a procedure to measure physical characteristics of rocks and sediments downhole by electrical, acoustical, and other means.

Sample Handling

Collection and handling of cores is an integral part of the ODP. Sample handling procedures for the ODP will resemble those used successfully for several years in the DSDP. Detailed procedures for treatment of cores onboard ship, offloading at shore-based facilities, transport to the central repository, and curation are described in the Shipboard Scientists Handbook (ODP 1985). L-DGO will provide a repository for cores obtained from the Atlantic and Antarctic oceans, and Mediterranean and Caribbean seas. TAMU will serve as a repository for cores from the Pacific and Indian oceans. DSDP cores remain at the satellite repositories at L-DGO and Scripps Institution of Oceanography, also managed by TAMU.

Data Handling

The ODP can be expected to generate tremendous amounts of engineering and scientific data. Engineering data will arise chiefly from new technological developments that take place as the ODP is designed and implemented. These data will be available as part of the public record of the program.

Scientific data anticipated from the ODP will be mostly geological and geophysical. Extensive geophysical field surveys and analyses will be initiated well in advance of drilling, but will continue in concert with the drilling effort. Both regional studies and site-specific surveys are anticipated. In addition, physical oceanographic surveys may be conducted near proposed drilling sites. Data to be collected during drilling and in the drill hole itself will include standard well-logging information, other non-coring data, long-term downhole measurements involving the emplacement of instruments in the hole, and, possibly, measurements while drilling. Data from subsequent analysis of cores will be produced over a period of years. Each cruise of the drilling vessel is expected to generate two formally published scientific report volumes within 3 years following the cruise. The first report will include initial core descriptions and site discussions. The second report will provide analyses and interpretations of cruise results.

PROGRAM DEVELOPMENT

Since 1973, a series of conferences, meetings, and planning sessions addressing deep-sea drilling in the future have been held. These have resulted in the notable reports described below.

FUSOD Report

A key conference was held in Woods Hole, Massachusetts in March, 1977 to discuss "the Future of Scientific Ocean Drilling" (the FUSOD conference). Results are documented in the FUSOD Report (JOIDES 1977) and detail a program of future work that builds on the knowledge gained in the DSDP and in the IPOD. Subsequently, several other committees and panels were convened to assess and direct future drilling.

HUSOD Report

One hundred and twenty scientists and engineers met in Houston, Texas in March, 1980 to evaluate scientific objectives and engineering considerations of a program of ocean margin drilling. Results of this meeting are recorded in the HUSOD Report (JOI 1980). The HUSOD Report provided the basis for the formal establishment of the OMDP in mid-1980 and identified priority objectives in ocean margin drilling. Conference participants recommended the use of an advanced state-of-the-art drillship and further recommended that the U.S. government-owned ship GLOMAR EXPLORER be converted for this purpose.

COSOD Report

As part of continuing scientific discussions, JOIDES initiated the Conference on Scientific Ocean Drilling (COSOD), held at the University of Texas at Austin in November, 1981. COSOD Working Groups identified top priority scientific topics to address through scientific ocean drilling and related programs in the following decade. Recommendations are listed in Table 2 [see COSOD Report (JOIDES 1981) for details]. Objectives outlined at COSOD are now the working objectives of the ODP. To meet these objectives, the COSOD Working Groups recommended tools, techniques, and studies. GLOMAR EXPLORER was again endorsed as the preferred vessel, except that riser drilling capacity was postponed. The Working Groups stressed the need for drilling deeper into both sediment and rock, recovering a greater percentage of the rock cores, and maintaining or improving core condition. To enhance scientific returns, they suggested extensive logging in the deep oceans and recommended techniques for the long-term emplacement of instruments in the hole. Finally, the Working Groups emphasized solving geologic problems rather than continuing the quest for more reconnaissance information that characterized much of the DSDP.

Crustal Studies Report

The Ad Hoc Advisory Group on Crustal Studies was asked by the NSF to "review long-range plans for crustal studies within the university-based earth and ocean sciences." In addition, the group was asked to "assign relative priorities to initiatives in crustal studies ... with particular attention to the relative priority to be assigned to ocean drilling" and "... to advise on the relative merits of CHALLENGER, EXPLORER, or a third platform." The Ad Hoc Advisory Group presented its report to the NSF in April, 1983 and recommended that nine initiatives be pursued to meet the goals of a crustal studies program [see The Ad Hoc Advisory Group on Crustal Studies (NSF 1983), for details]. The group endorsed a long-term international program of ocean drilling as an essential part of that effort. The group also recommended the use of a commercial, dynamically positioned drillship, which, due to the world oil situation, had become economically feasible to lease. This latest development, coupled with the science objectives laid out at COSOD, formed the operational guidelines of the ODP.

PROGRAM PARTICIPANTS

The ODP combines the participation of the Federal government, the academic community, and several international participants. Given the technical and scientific complexity of the ODP, this diversification and range of skills is a strength. Roles of program participants are described below.

Role of the National Science Foundation

The ODP, like the DSDP, has its roots in the research interests of the academic community. The NSF is the lead agency for Federal support of this kind of research and the primary Federal focus for program development. The NSF Director and the National Science Board have joint responsibility and authority for all NSF programs.

TABLE 2. MAJOR GOALS OF SCIENTIFIC OCEAN DRILLING

1. Origin, evolution, and tectonics of ocean crust

    History and structure of crust
    Hydrothermal processes
    Tectonic evolution
    History and tectonics of magnetic anomalies
    Magnetism at convergent margins

2. Origin of sediment sequences

    Pelagic and continental margin sequences
    Post-deposition alteration of sequences

3. Tectonic evolution of continental margins

    Passive
    Convergent
    Transform fault dominant

4. Long-term changes - oceans, climate, cryosphere, biosphere, and magnetic

    Paleoceanography and climatology
    Biogeography and evolution
    Special areas needing elaboration from DSDP
    Magnetic field

The ODP is part of the Oceanographic Centers and Facilities Section, Division of Ocean Sciences, Directorate for Astronomical, Atmospheric, Earth and Ocean Sciences (see Figure 6). An ODP office was formed at the NSF to administer the program and associated efforts. The Program Director oversees and administers contractual arrangements with JOI and relationships with international members of JOIDES while maintaining close liason with ODP contractors and the JOIDES advisory structure. The Program Director also administers funding for unsolicited research proposals in topics related to ocean drilling.

Role of the Management Contractor

JOI manages the ODP under contract to the NSF. JOI was established in 1976 to focus the collective capabilities of individual U.S. oceanographic institutions (i.e., the 10 U.S. members of JOIDES, see Section 1.2) on large oceanographic research projects and to provide a contractually responsible party for such activities. Three major functions of the ODP are coordinated by JOI: long-term scientific direction (subcontracted to the JOIDES office; see Section 1.2 and Role of International Participants, this section), scientific and drillship operations (subcontracted to TAMU; see Role of Science Operator, this section), and logging services (subcontracted to L-DGO).

Role of the Science Operator

TAMU was designated in March, 1984, as the ODP science operator. Acting under the guidance of the JOIDES PCOM, the tasks of the science operator are to:

- Provide shipboard science management and technical supervision
- Obtain geophysical, oceanographic, and meteorological data for safety review and final site selection affected by operational constraints
- Develop an efficient ship schedule and procure proper clearances, drilling permits, etc.
- Develop operational plans, ensure equipment availability, define operational limitations, and provide an adequate supply of consumables (e.g., beacons, reentry cones, drill bits, etc.)
- Assess safety and operational procedures prior to drilling by considering recommendations of the JOIDES Pollution Prevention and Safety Panel, an internal (i.e., TAMU) Safety Review Committee, and an internal engineering panel
- Store, archive, and disseminate cores and other scientific data
- Disseminate public information; educational materials; publication of cruise proceedings volumes; and engineering developments of the program.

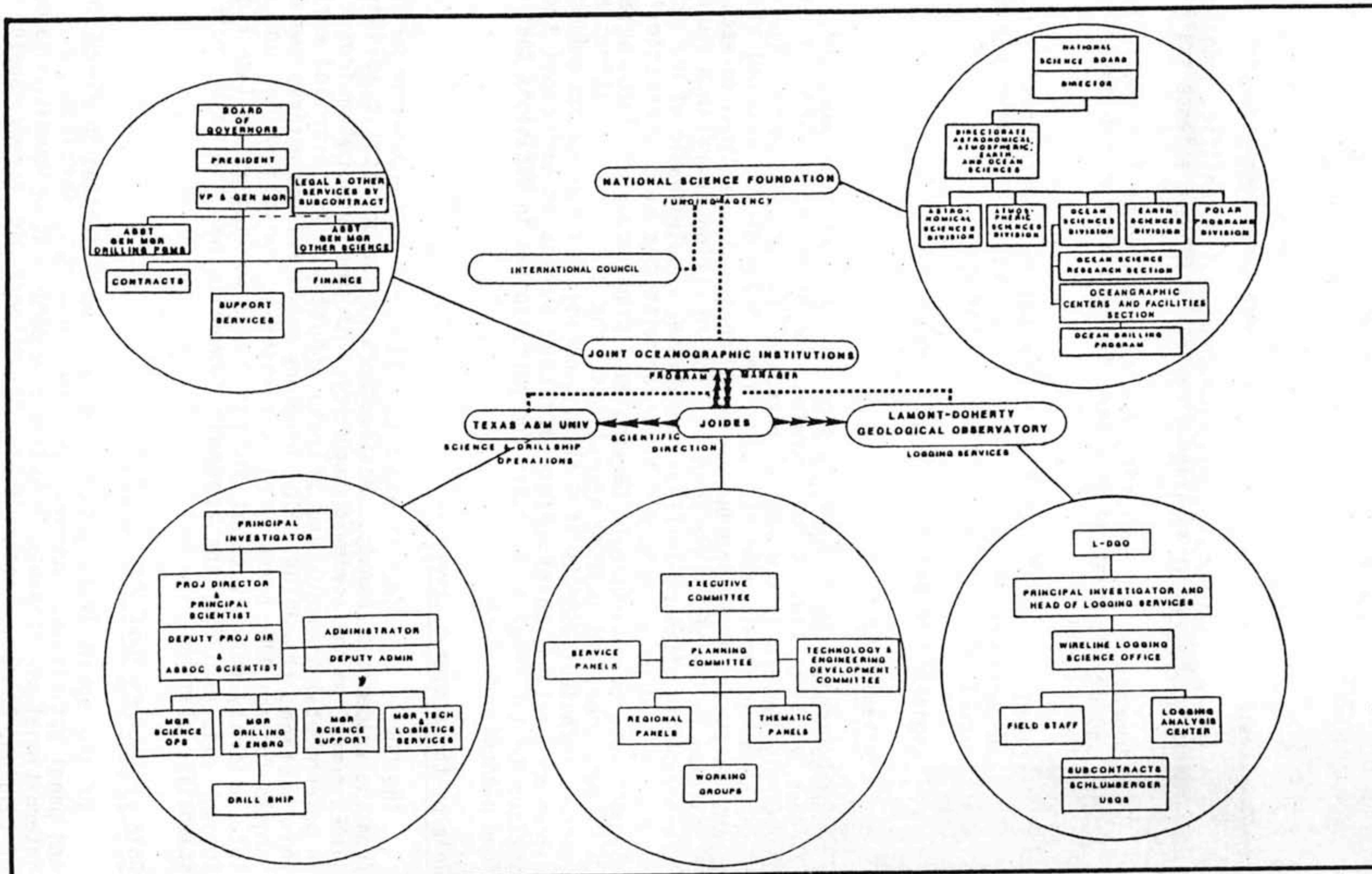


Figure 6. Ocean Drilling Program organizational chart.

As science operator, TAMU is also responsible for the following drillship-related tasks:

- Design, furnishing, and maintenance of scientific, lodging, and recreational facilities for the shipboard science staff

- Improvement of existing drilling and downhole technologies and development of new ones to meet scientific goals of the program

- Staffing the scientific and technical support crews (e.g., shipboard scientists, electronics and marine technicians, experienced drilling operations manager)

- Logistics of the drilling program.

Role of the Vessel Operator

JOIDES RESOLUTION is owned by SEDCO and British Petroleum, Ltd., through Overseas Drilling, Ltd. SEDCO operates the vessel under TAMU's direction. They supply the drill crew and all personnel to run the vessel. The captain of the ship has final authority concerning safety of the ship and its crew. A TAMU shipboard Drilling Operations Manager is assigned to each cruise in addition to the SEDCO personnel. The Drilling Operations Manager is experienced in offshore drilling operations; knowledgeable of ODP policies, procedures, and guidelines; and familiar with the ship contractor's mode of operation. In addition to serving as liaison among drilling, scientific, ship contractor, and logging operations, the Drilling Operations Manager oversees technical aspects of drilling, coring, instrumentation and mechanical operations; acts as chief safety officer; serves as principal technical advisor to the chief scientists; and participates in decisions that deviate from planned operations.

Role of the Academic Community

The ODP is a program of basic scientific research with active participation from the academic community. Most members of the scientific advisory body JOIDES come from the academic community, with some participation from scientists in governmental agencies and private industry. As described earlier in this section, the JOIDES PCOM develops scientific objectives and drilling targets for the ODP, normally by coordinating, consolidating, and setting into priority the advice of its panels and working groups (see Figure 7). Through this process, the academic community has the major role in ODP scientific planning.

Role of International Participants

Of the approximately 180 scientists participating in JOIDES committee and panel activities, one-half are from non-U.S. institutions. JOIDES' international participants include the European Science Foundation (a consortium of Belgium, Denmark, Greece, Italy, The Netherlands, Norway, Spain, Sweden, and Switzerland) and ocean research institutions from Canada, France, Germany, Japan, and the United Kingdom. As of November, 1985, there were four regular

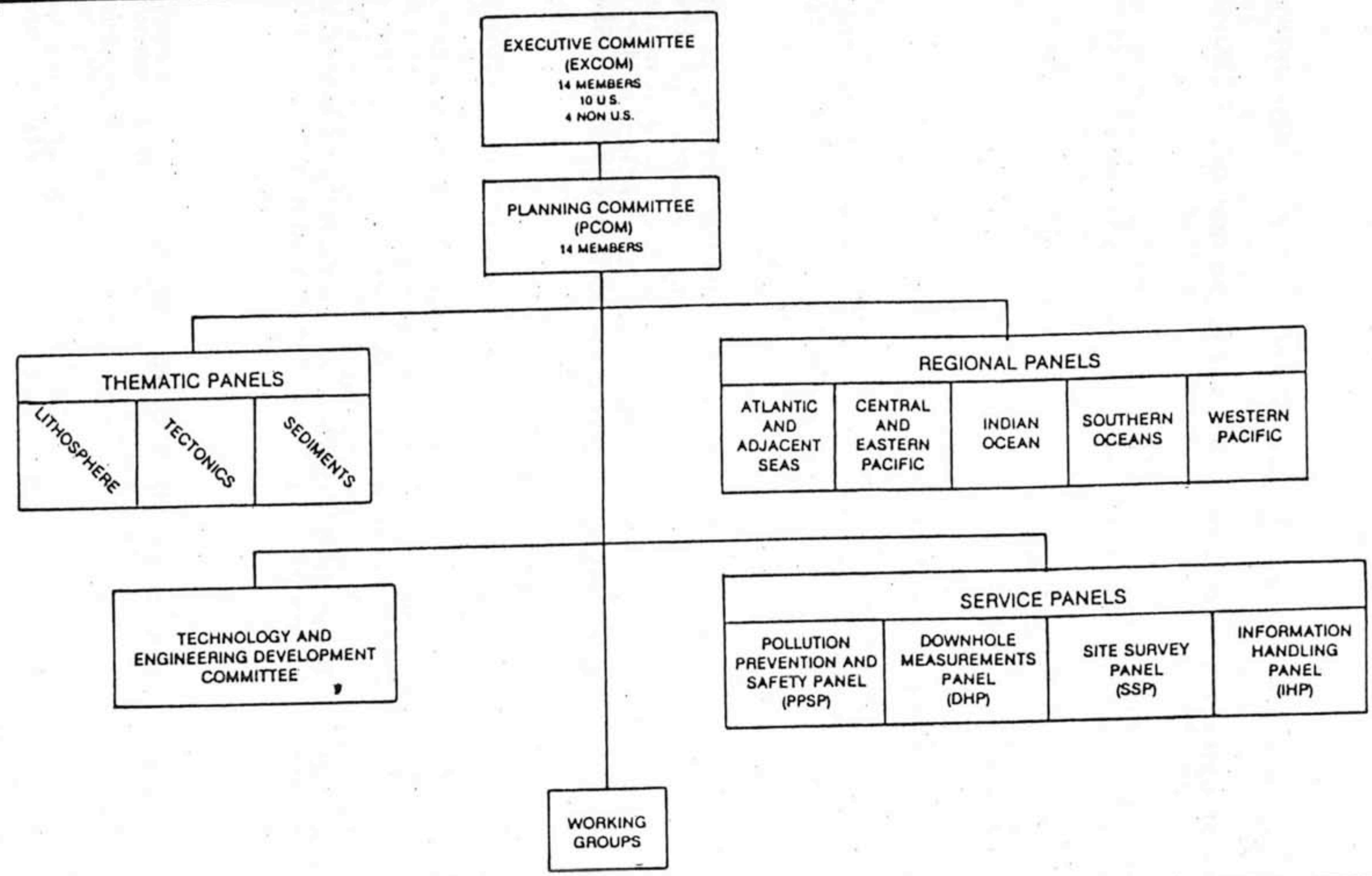


Figure 7. JOIDES organization.

members of the ODP making full financial contributions (i.e., Canada, France, the Federal Republic of Germany, and Japan), and two candidate members (i.e., the European Science Foundation and the U.K.). Each full member agrees in principle to take part in a decade-long program and to provide a share of operating support ($2.5 million is the base for FY 1985; shares will be indexed for inflation over the life of the program).

Another feature of the ODP organizational structure is the International Council, the only body in which members are represented as countries rather than scientific organizations. All countries, whether participating as individual members or as part of a consortium, are members of this council. Although only a consultative body, the International Council permits organizations that provide financial support for the ODP an opportunity to discuss the program's status and direction.

Liaison Between Program Participants

The NSF maintains the necessary links between all participants in the program (see Figure 6). The Ocean Drilling Program office in the NSF's Ocean Sciences Division has primary responsibility for this coordination.

SPECIFIC DETAILS OF THE PROGRAM

The science objectives of the ODP are discussed in Section 1.3. Drilling plans to meet the objectives are in preparation by the panels and committees of JOIDES. These plans are being designed to fit into a schedule built around high latitude "weather windows" in the North Atlantic during the summer of 1985 and in the Antarctic during the austral summer of 1986-1987.

Proposed Drilling Locations

The candidate drill sites for the first 2 years of the drilling program are presented in Figure 8. Specific plans are made 1 year in advance of drilling operations. The first 14 legs of the ODP are listed in Table 3. As of November, 1985, the drilling schedule had been confirmed for the first 12 legs. Under tentative long-range plans, the vessel will proceed to the Indian Ocean in 1987, the northwest Pacific Ocean in mid-1989, the northeast Pacific Ocean in mid-1990, and the vicinity of Panama on about January 1, 1991. Future drill sites under consideration are indicated in Figure 9.

Drilling Platform

JOIDES RESOLUTION is the ODP drilling platform. It is a modern, technologically up-to-date, dynamically positioned ship that is acknowledged to be among the world's best drillships (Figure 10). With conversions for the ODP [i.e., addition of lab space, the adaptation of drilling equipment to maximize coring efficiency, and the upgrading of drilling equipment to handle a 9,000-m (29,520-ft) drill string], the ship now offers capabilities particularly well-suited for scientific drilling:

- Lab Space - 1,009 m^2 (10,900 ft^2) of dedicated laboratory space is available. Specific laboratory space is allocated to paleomagnetics, paleontology, petrology, chemistry, physical

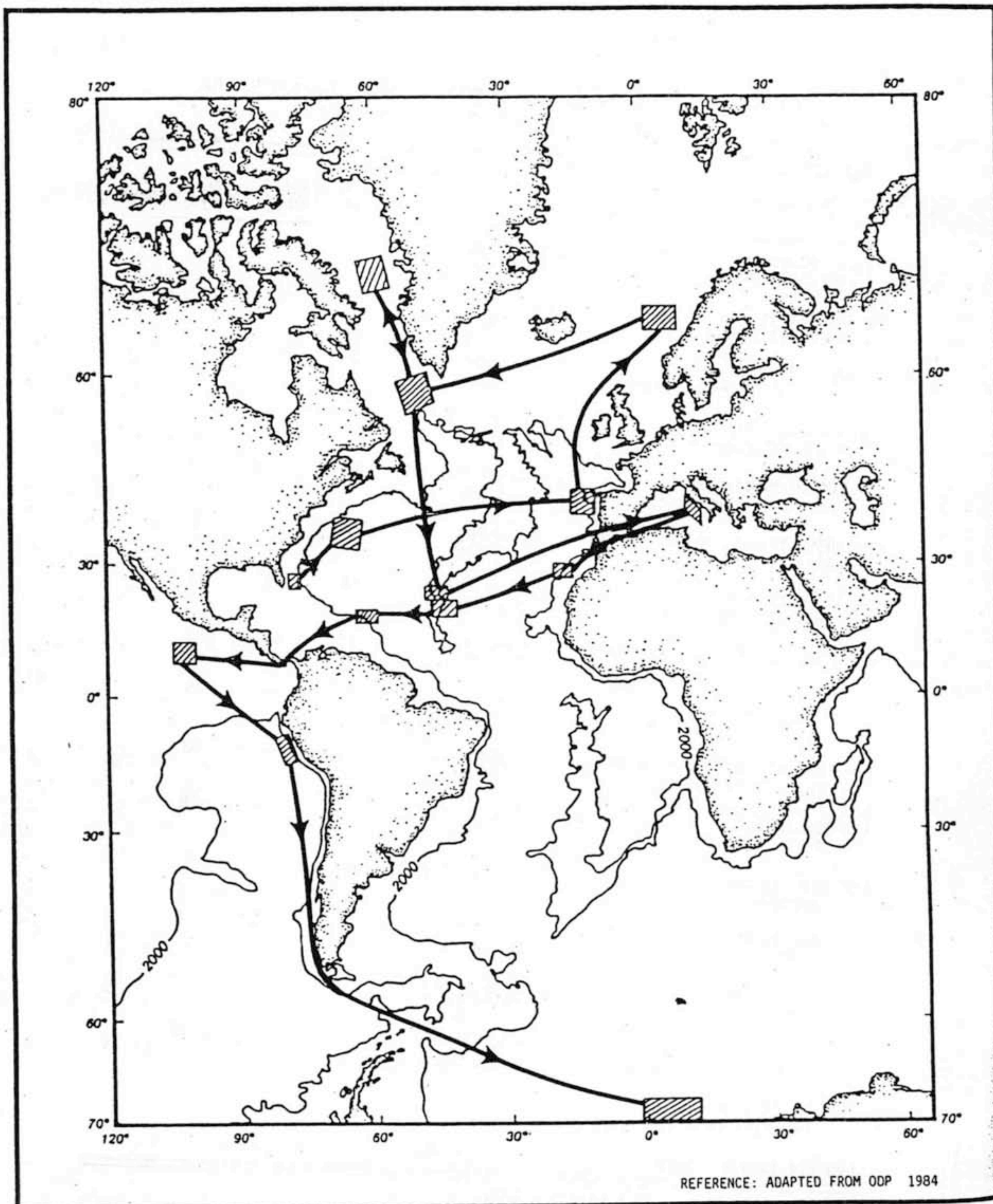


Figure 8. Candidate drill site areas and the cruise track for the first two years of the drilling program.

TABLE 3. OCEAN DRILLING PROGRAM SHIP SCHEDULE FOR THE FIRST 2 YEARS OF THE PROGRAM

	Dates[a]	Operating Days	Transit Days	Total Days	Port Days
Leg 101 (Bahamas)	31 Jan-14 Mar	38	5	43	
Portcall (Miami)	14-19 Mar				5
Leg 102 (418a)	19 Mar-10 Apr	16	6	23	
Portcall (Norfolk)	11-16 Apr				6
Leg 103t (transit only)	16-25 Apr	0	10	10	
Portcall (Puerto Delgada)	25 Apr				1
Leg 103 (Galicia)	26 Apr-20 Jun	42	13	55	
Portcall (Bremerhaven)	20-25 Jun				5
Leg 104 (Norwegian Sea)	25 Jun-11 Aug	42	6	48	
Portcall (Stavanger)	11-15 Aug				4
Leg 105t (transit only)	16-23 Aug	0	8	8	
Portcall (St. John)	24-29 Aug				5
Leg 105 (Labrador Sea)	29 Aug-27 Oct	54	6[b]	60	
Portcall (St. Johns)	28 Oct-1 Nov				4
Leg 106 (Mid-Atlantic Ridge/KFZ)	1 Nov-26 Dec	39	17	56	
Portcall (Malaga)	27-31 Dec				4
Leg 107 (Tyrrhenian Sea)	1 Jan-18 Feb 1986	--	--	49	
Portcall (Marseilles)	18-23 Feb				5
Leg 108 (N.W. Africa/Cenozoic)	23 Feb-21 Apr	--	--	58	
Portcall (Dakar)	21-26 Apr				5
Leg 109 (MARK-2)	26 Apr-22 Jun	--	--	58	
Portcall (Barbados)	22-27 Jun				5
Leg 110 (Barbados North)	27 Jun-17 Aug	--	--	52	
Portcall (Babados)	17-19 Aug				2
Leg 111t (transit only)	19-26 Aug	0	8	8	
Portcall (Panama)	26-31 Aug				5
Leg 111 (EPR 13° N)	31 Aug-24 Oct	--	--	55	
Portcall (Callao)	24-29 Oct				5
Leg 112 (Peru Margin)	29 Oct-27 Dec	--	--	60	
Portcall (Valparaiso)	27-31 Dec				4
Leg 113 (tentative)					
Portcall (Punta Arenas)					
Leg 114 (Weddell Sea)	Jan-Feb 1987				

[a] Effective dates as of 1 November 1985.

[b] Includes transit times to and from drillsites in Baffin Bay from Labrador Sea.

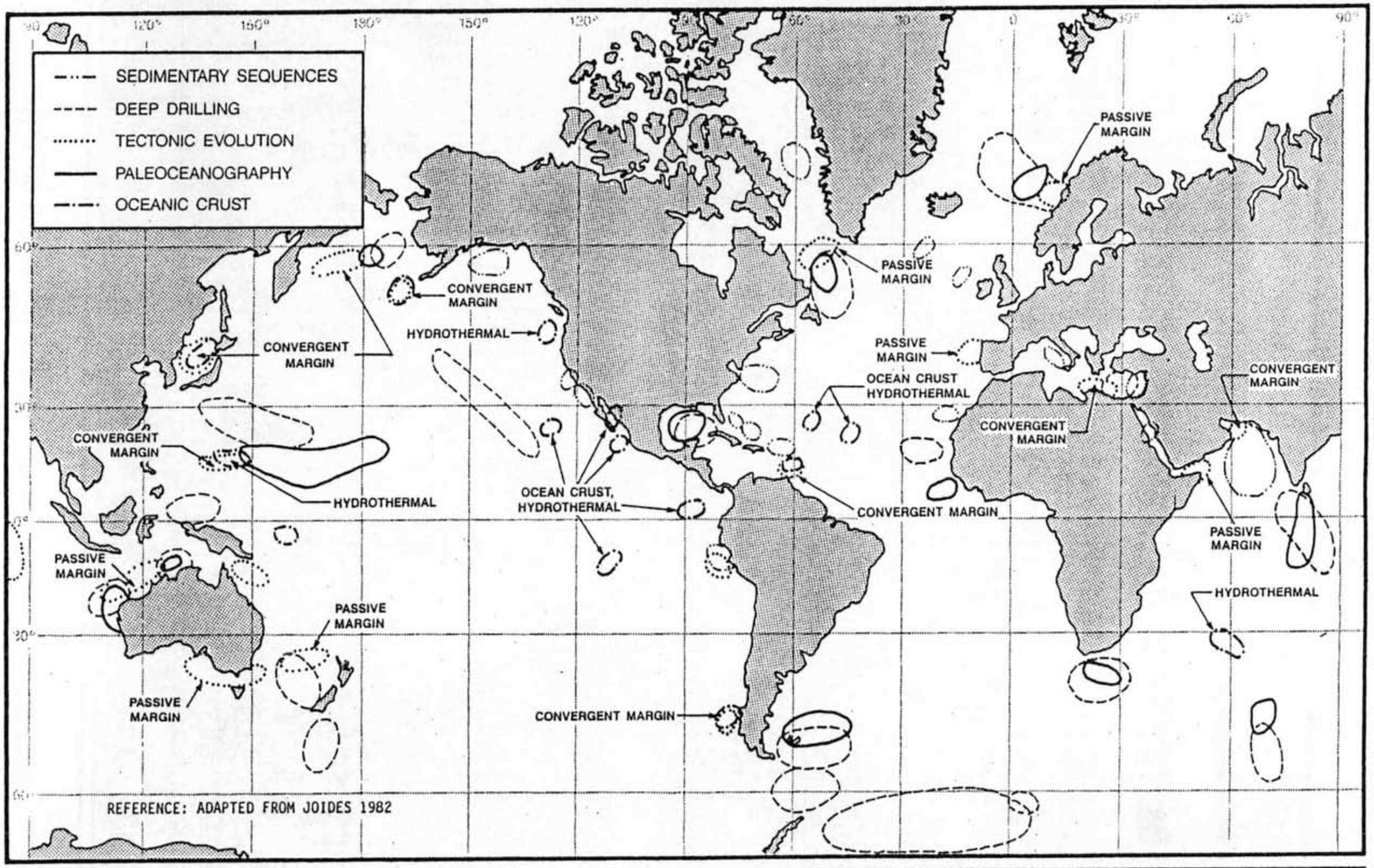


Figure 9. Areas of specific scientific interest that are under consideration as potential future drill sites.

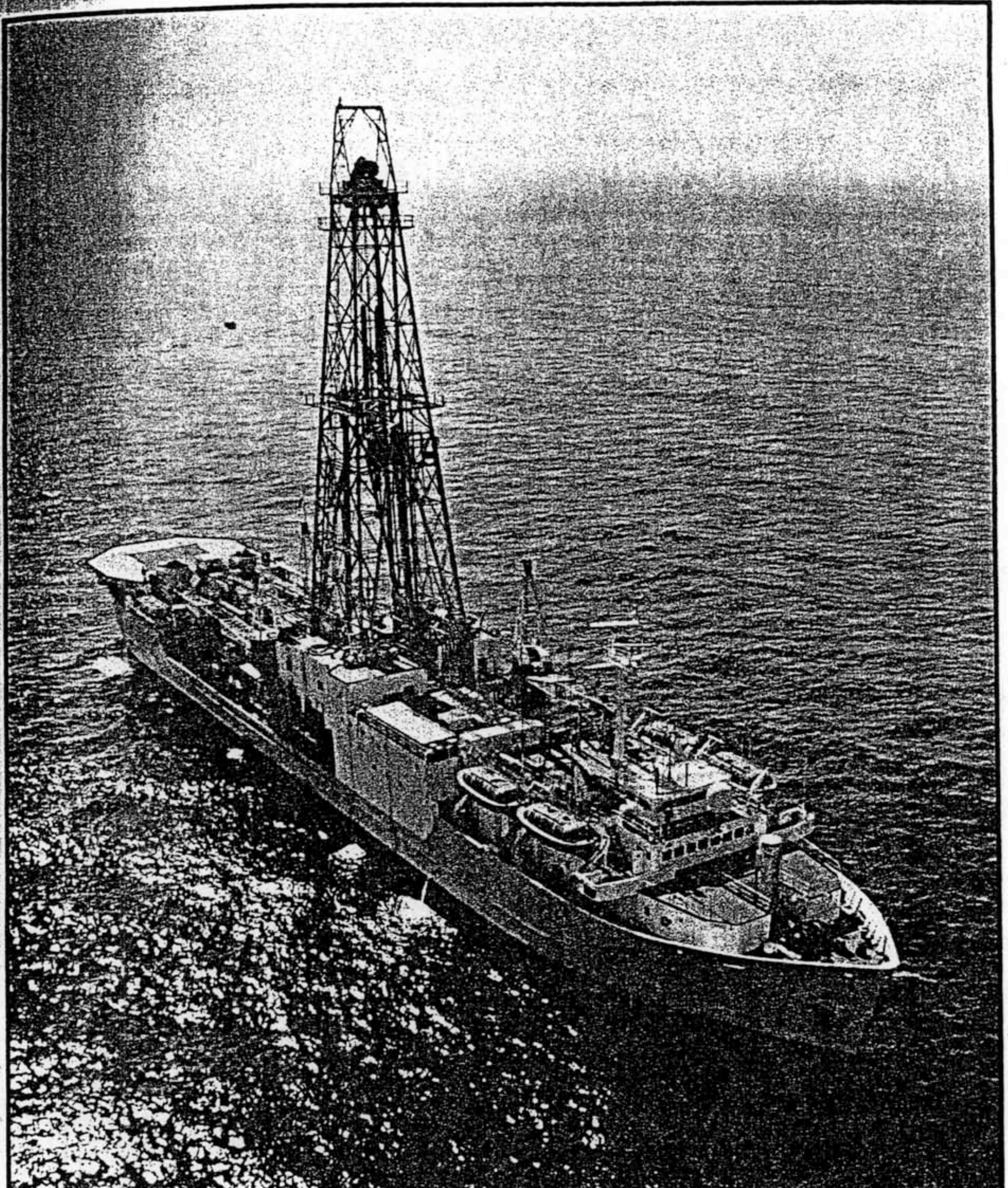


Figure 10. Drillship JOIDES RESOLUTION (SEDCO/BP 471).

properties, and underway geophysics. There is also a library, logging lab, meteorology center, photography lab, computer room, lounge, workshops, and repair rooms. An additional 232 m^2 (2,500 ft^2) is dedicated to scientific storage.

- High Latitude Drilling - The ship is ice-strengthened and capable of high-latitude operations, permitting drilling in regions previously not accessible.

- Core Bit Stability - The ability to obtain undisturbed core samples is directly related to stability of the bottom hole assembly. The ship has a relatively large displacement, good surface stability, a modern drill string heave compensator, and a computer-controlled dynamic positioning system coupled with a responsive and powerful thruster system. This enables the ship to keep position precisely over the drill hole and keep the drill bit in firm contact with the bottom of the hole.

- Penetration - Deep penetrations require the ability to stay on station for a long time, an efficient drill rig, drilling mud to strengthen and maintain the walls of the hole, and casing to prevent the hole from caving in. JOIDES RESOLUTION'S size and equipment provide these capabilities. Ultimately, a 2,000-m (6,560-ft) riser and blowout preventer may be employed.

- Long drill string - JOIDES RESOLUTION can deploy a 9,000-m (29,520-ft) drill string.

- Quarters - A 50-person scientific crew can be accommodated, nearly double the space aboard GLOMAR CHALLENGER. The increased scientific berthing enables greater participation by international scientists, graduate students, and others.

Specifications of JOIDES RESOLUTION and the previous drillship, GLOMAR CHALLENGER, are listed in Table 4.

Drilling Procedures

Scientific Coring vs. Oilfield Drilling--

Although similar principles of drilling practice apply for both industrial and scientific drilling, there are important differences in equipment and procedures. In oilfield drilling, the prime objective is to reach the target depth as quickly and efficiently as possible. Logging and coring are done only as appropriate. In scientific drilling, reaching target depth is desirable, but of secondary importance compared to understanding the composition and properties of the intervening strata in the earth's crust. This objective requires nearly continuous coring and logging, and, the recovered cores must remain undisturbed. In addition, drilling and coring of the oceanic basement (usually basalt) are also required. Hence, scientific drilling may take considerably longer than commercial drilling to achieve the same penetration depth (Sutherland and McLerran 1984).

TABLE 4. COMPARISON OF THE SPECIFICATIONS OF THE JOIDES RESOLUTION WITH THE PROGRAM'S PREVIOUS DRILLSHIP THE GLOMAR CHALLENGER

Specification	CHALLENGER	RESOLUTION
Drill string	7,012 m (23,000 ft)	9,000 m (29,520 ft)
Heave compensation	Antiquated 460,000 lb 15 ft stroke	Modern 800,000 lb 20 ft stroke
Mud/cement systems	Limited	Good
Riser and BOP	No	2,000 m (6,560 ft) (Capability pending funding)
Drawworks	2,000 hp	2,800 hp
Weather limits for drilling	Fair	45 kn wind 4.6/7.9 m (15/26 ft) seas 2.5 kn current
Sea keeping/dynamic positioning	Fair	Good/state-of-the-art
High latitude capability	No ice strengthening	Ice class 1B
Scientific space	417 m^2 (4,500 ft^2)	1,115 m^2 (12,000 ft^2)
Length	122 m (400 ft)	143 m (470 ft)
Beam	20 m (65 ft)	21 m (70 ft)
Operating draft	6.7 m (22 ft)	7.6 m (25 ft)
Operating displacement	10,772 mt (10,600 long tons)	16,870 mt (16,600 long tons)
Installed power	7,700 kW	13,500 kW
Speed	12 kn	14 kn
Crew	45	55
Scientific party	29	50
Quarters	74	116
Liveability	Poor	Good
Age	Built 1968	Built 1978

Most known offshore hydrocarbon concentrations are located along the continental margins, under thick layers of sediments, in relatively shallow water, where oilfield drilling is concentrated. Scientific drilling probes unknown parts of the ocean. Because of this, extensive geophysical surveying and data analysis are required to select scientific drilling sites, even when located in deep ocean plains and basins -- regions devoid of the formations in which oil and gas are typically found. Rigorous safety considerations are included in the pre-drilling routine. During drilling, sediments are carefully examined for traces of oil, methane, or other hydrocarbon indicators as well as H_2S. If any are found, drilling is suspended and the hole is immediately capped (Sutherland and McLerran 1984). These procedures, used throughout the DSDP and to be used during the ODP, are discussed in detail in Chapter 4.

Riserless vs. Riser Drilling--

Past experience in scientific drilling has been limited to riserless drilling. The early goals of the DSDP were to provide worldwide reconnaissance of the seafloor by drilling and coring numerous relatively shallow holes in deep water. Use of a riser is typically not necessary for shallow penetrations in deep water, and is economically prohibitive on a large scale. Riserless operations permit rapid set up and break-down, and facilitate drilling many holes in widely separated locations. Nevertheless, future scientific drilling objectives are expected to require occasional use of a riser and subsea equipment, as the ocean margins become increasingly important targets for scientific research.

All commercial offshore exploratory, development, and production drilling requires the use of a riser and blowout preventer (BOP). The riser is a large-diameter pipe surrounding the drill pipe. It extends from the ship to the seafloor and creates an annular space between itself and the external diameter of the drill pipe. The BOP, located at the seafloor, is attached between the riser and casing that has been cemented into the drill hole in the seafloor. The BOP has pipe rams, which can form a seal around the drill pipe and shear rams, which can be activated from the surface in an emergency to cut through the drill pipe and seal off all flow from the hole.

In drilling a riser hole, a fluid chemical mixture (called mud) is used to control formation pressures. The density of mud can be carefully controlled. It is pumped down the center of the hollow drill pipe. The mud exits through holes in the drill bit and flows back up to the ship through the annulus between the drill pipe and the riser and casing. The mud carries drilling cuttings, lubricates the hole, and facilitates hole stability, thus helping the drill pipe to penetrate deeply into the ocean floor. This system also permits drilling through overpressured zones which can be encountered in thick sedimentary sequences (Sutherland and McLerran 1984).

If an overpressure zone is penetrated, a device in the BOP (called a preventer) is remotely closed. It stops the flow in the annular space between the drill pipe and casing. The density of the mud at the surface is increased, and pumped down the drill pipe, through the bit, and up the hole to the BOP. There the mud is remotely shunted into small-diameter conduits (called choke and kill lines) which carry the higher density mud back to the drillship. This higher density creates sufficient counterpressure in the well to overcome and balance the overpressure.

Deep Drilling vs. Shallow Drilling--

Typically, scientific drill sites are in water deeper than 3,000 m (9,840 ft). Working in these depths requires the use of dynamic positioning, and acoustic stationkeeping; conventional mooring is not feasible. Drill string reentry systems also must be specially designed for the depths encountered in scientific drilling.

In commercial drilling, which is typically in shallow water, the drilling equipment and suspension system gradually experiences an increasing load as the drill penetrates into the seafloor. Drilling equipment is usually subject to an average load about one-half to two-thirds of the maximum load experienced in drilling each hole. This is not the case in deep water with shallow penetration. The load experienced at the start of drilling is usually only slightly below the final maximum load. Because scientific drilling components operate at much higher average loads than do commercial components, they are susceptible to increased wear and stress, and require more powerful and rugged equipment.

Applicable Laws and Regulations

Numerous laws and regulations apply to the general construction and operation of offshore drilling vessels. Some statutes apply only to vessels working in U.S. or other coastal nations waters on the continental shelf. Many rules also apply to ships operating in international waters. This section describes statutes and regulations most likely to affect the ODP. As the program has developed, these requirements have been carefully studied to ensure that JOIDES RESOLUTION complies with all existing national and international laws.

All vessels operating in U.S. navigable waters must comply with U.S. Coast Guard regulations for certification, inspection, safety, and design of equipment. The Coast Guard is the primary enforcement agent for Federal ship safety laws and for pollution abatement regulations pertaining to ship-generated pollutants. The agency maintains a specialized staff to enforce these regulations throughout the United States and at selected overseas ports.

JOIDES RESOLUTION was built to comply with the International Convention for the Safety of Life at Sea (SOLAS) Rules, 1974, and the 1978 Protocol to SOLAS. The vessel was also built under classification by the American Bureau of Shipping under the Rules for Building and Classing of Offshore Mobile Drilling Units, 1973, and Rules for Building and Classing Steel Vessels, 1974. These rules apply primarily to the hull structure, main propulsion machinery, and main auxilliary equipment required for safe vessel operation. JOIDES RESOLUTION is classified by the American Bureau of Shipping as a Category A-1 drilling unit and is approved for unrestricted ocean service. Reclassification because of conversion operations is unnecessary. The ship complies with all regulations for electrical engineering, marine engineering, load lines, and pollution control. JOIDES RESOLUTION is certificated under Liberian government maritime rules and regulations.

Special rules and regulations apply to ship-generated pollutants (specifically, the 1978 Protocol Relating to the International Convention for the Prevention of Pollution from Ships - MARPOL 73/78). The International Maritime Organization (IMO) has adopted special requirements for the control of pollution from drilling vessels that address oily discharges from the ship and establish maximum concentrations for the release of undiluted discharges.

In accordance with the Federal Water Pollution Control Act (FWPCA), and the Marine Protection, Research, and Sanctuaries Act (MPRSA), the Environmental Protection Agency has established regulations for the discharge and dumping of pollutants such as sewage, solid wastes, oil, and drilling muds. Some of these regulations may apply to the ODP operations. For example, the National Pollution Discharge Elimination System (NPDES) provisions of the amended FWPCA apply to point source discharges from vessels engaged in drilling operations.

The Minerals Management Service (MMS) regulates all drilling activity on the U.S. continental shelf through a series of operating orders. These regulations are contained in the "Revised Outer Continental Shelf Orders Governing Oil and Gas Lease Operations," dated December 21, 1979 and will be observed when JOIDES RESOLUTION operates in waters under MMS jurisdiction. However, one provision of these rules is that the Federal government does not need to issue permits to itself for operations on the U.S. Outer Continental Shelf.

When operating within the territorial seas of another country, full compliance will be sought with the applicable laws and regulations of that country. Under international law, as reflected in the 1982 Convention on Law of the Sea, drilling within the Exclusive Economic Zone (EEZ) or on the continental shelf of a coastal nation, requires that country's prior consent. The Office of Marine Science and Technology Affairs in the U.S. Department of State is the principal liaison between the science operator and other coastal nations.

Activities in the Antarctic (an important element of the ODP) are governed by the Antarctic Treaty of 1959, recommendations adopted under the treaty, and the Antarctic Conservation Act of 1978. The Antarctic Treaty provides for freedom of access for scientific work south of the 60° S latitude. The ODP's proposed scientific research drilling with free availability of the data retrieved differentiates it from resource prospecting which is voluntarily restrained under a 1977 treaty agreement on mineral resource exploration and exploitation (Treaty Recommendation IX-10). NSF's Division of Polar Programs, by annual transmittal of planned activities through diplomatic channels, will provide advance notice of Antarctic drilling operations to the governments of all other Antarctic Treaty Parties and to the Scientific Committee on Antarctic Research (SCAR is the primary scientific advisory body to the treaty nation). This EIS and information on planned research synopsis, ship's tracks, and participating scientists will be compiled and made available in the furtherance of the principles contained in Treaty Articles III(1) and VII(5). Thus, proposed ODP activities are consistent with the Antarctic Treaty and with the policy of voluntary restraint from mineral exploration and exploitation in Antarctica.

Article II of the Convention on Conservation of Antarctic Marine Living Resources (CCAMLR) of 1980 establishes a "conservation standard" to protect Antarctic marine living resources. The CCAMLR, and U.S. legislation implementing it (which took effect in 1982 and December, 1984, respectively), have effect in the ocean areas south of the Antarctic Convergence. Measures under the CCAMLR prohibit harvesting or other associated activities in violation of the Convention. Harvesting is defined as:

"(A) The harassing, molesting, harming, pursuing, hunting, shooting, wounding, killing, trapping or capturing of Antarctic marine living resources;

(B) Attempting to engage in any activity set forth in subparagraph (A);

(C) Any other activity which can reasonably be expected to result in any activity described in subparagraph (A); and

(D) Any operations at sea in support of, or in preparation for, any activity described in subparagraphs (A) through (C)."

Other conservation legislation that applies to ODP operations include the Endangered Species Act of 1973, the Marine Mammal Protection Act of 1972, and the Convention for the Conservation of Antarctic Seals. The Endangered Species Act of 1973 as amended, requires that the National Marine Fisheries Service be consulted to ensure that the continued existence of endangered or threatened species (or their critical habitat) is not jeopardized. The Marine Mammal Protection Act of 1972 as amended, places a moratorium on the taking of marine mammals. The definition of take includes, among other activities, harassment, killing and the negligent or intentional operation of an aircraft or any other negligent or intentional acts which result in disturbing or molesting of marine mammals. The Convention for the Conservation of Antarctic Seals (which took effect in 1978) is an international conservation agreement which specifically protects identified seal species from being captured or killed. ODP operations in the Antarctic are guided by the Convention for the Conservation of Antarctic Seals provisions outlined in the Antarctic Program Personnel Manual (NSF 1984).

Section 2.3
ALTERNATIVES TO THE PROPOSED ACTION

EXTERNAL PROGRAM ALTERNATIVES

No Action

Scientific objectives of the ODP have been established through extensive review by the scientific community and are based upon the findings of past deep-sea drilling. Many individuals and advisory groups (e.g., Committee on Post-IPOD Science 1979; JOIDES 1977; Marine Board, National Academy of Sciences 1978) have considered whether the scientific goals of ocean exploration can be achieved by means other than drilling at extreme depths. The consensus is that there is no alternative.

Curtailing implementation of the ODP will only delay attainment of program goals. The timeliness and importance of the ODP have been identified in Chapter 1, and the potential growth in scientific information is compelling. Canceling the program would postpone development of our understanding of the earth and would significantly reduce the chances that deep-sea resource development will be orderly and enlightened. Therefore, the NSF has rejected this alternative.

Program Deferral

Complete program deferral would not be appropriate because a five-year commitment of resources has already been made by the U.S. and several other countries, and the ship is already operating. Deferral would therefore result in ship expenses without the return of scientific information. In addition, ODP drilling procedures for the foreseeable future are identical to those used during the DSDP. The EIS for the DSDP/IPOD (NSF 1975) concluded that there are no significant environmental impacts from these procedures. Because complete program deferral would have financial disadvantages and no apparent environmental advantages, the NSF has rejected this alternative.

The ODP could be partially deferred by implementing new drilling technology (e.g., bare rock spud-in, logging tools, long-term downhole instrumentation) later than is now planned. This alternative offers no apparent environmental advantages, as implementation of new technologies is not expected to affect environmental impacts discussed in Chapter 4 or in the DSDP/IPOD EIS (NSF 1975).

Geophysical Surveys

Geophysical surveys of selected regions within ocean basins and continental margins can yield significant information. However, analysis of cores retrieved during the DSDP has shown that interpretation of geophysical data is often faulty. Without drilling in these areas, structure and composition would still be a matter of conjecture. In addition, information obtainable only from drilling (e.g., geochemistry, physical properties, paleoceanography) would be forfeited (JOI 1979, 1980). New information gathered from this alternative would meet few, if any, of the scientific objectives.

INTERNAL PROGRAM ALTERNATIVES

During program development, many design, drilling platform, and drilling system alternatives were evaluated. For example, alternatives considered for a drilling platform included semisubmersibles, submarines, and ships. Decisions were based on engineering and environmental considerations. The major internal program alternative is to drill only in areas not requiring a riser. However, this would put regions of considerable scientific interest out of reach of the ODP. The environmental consequences of this alternative are addressed in the impact evaluation, Chapter 4.

OPERATIONAL ALTERNATIVES

Planning and scheduling ODP drilling is a continuous process. Operational alternatives exist in the form of decisions on drill sites and schedules. Such decisions are made by assessing the degrees of risk and the probabilities of success for individual holes. Logistics (e.g., the proximity of sites to each other), the cooperation of coastal nations, and seasonal variations in physical and biological processes also influence operational scheduling. These operational alternatives are addressed in the impact evaluation, Chapter 4.

SECTION 2.4
SUMMARY OF IMPACTS FOR PROPOSED ACTION AND ALTERNATIVES

The impact assessment focuses on representative drill sites encompassing the range of scientific goals, geographic positions, and ecologic conditions expected during the ODP. Internal program alternatives, involving riserless and riser drilling, are evaluated. Operational alternatives, dealing with site locations, well planning, drilling procedures, and drilling schedules, are also analyzed.

Principally, ODP program elements occur at sea, and the analysis of environmental impacts centers on the ocean environment. Key program activities and elements that impact the environment include:

- Presence of the ship and drill string
- Release of drilling fluids and cuttings
- Potential oil and gas spills and blowouts
- Noise from drillship and drilling operations.

Table 5 summarizes impacts associated with areas of the proposed action. The ODP activity and the resulting portion of environment impacted are identified. Where an impact is identified, three aspects of the impact are assigned values or ratings. These aspects are: magnitude (or degree of change related to the impact), persistence (length of time the impact lasts), and probability (degree of likelihood that the impact will occur). Detailed description of these impacts is also indexed in Table 5.

IMPACT SUMMARY

The following provides a summary discussion of impacts associated with the proposed action and its internal alternatives. Terms used in description of impacts include negligible (limited in extent or range, with recovery in a short time period, as to not cause a measurable difference or decrease in a habitat or population) and minor (probability of occurrence or extent increased and/or recovery time extended but not expected to have population level impacts).

Impact of the Environment on the ODP

The environment will exert a considerable influence on the ODP, particularly in the area of drilling and field operations. High winds at a drilling site can force the drillship off station, damage the drilling system, or force abandonment of the drilling operation. At some drilling locations, extreme sea ice conditions can adversely affect station-keeping capabilities. Geological conditions of the formations to be drilled affect site selection and well planning, and could damage the drilling system.

TABLE 5. SUMMARY IMPACT MATRIX

ODP Activity	Impacted Environment	Magni-tude	Persis-tence	Proba-bility	Detailed Impact Discussion
Conversion of ship	Physical				
	Land	L	L	H	Section 4.4
	Air quality	L	L	H	Section 4.4
	Social, economic, legal				
	Economy	M	M	H	Section 4.6
	Technology dev./transfer	M	H	H	Section 4.6
Presence of ship and drill string	Physical				
	Air quality	L	L	H	Section 4.4
	Water quality	L	L	H	Section 4.4
	Sea bottom	L	H	H	Section 4.4
	Acoustical	M	L	H	Section 4.4
	Biological				
	Phytoplankton/zooplankton	L	L	H	Section 4.5
	Nekton	L	L	L	Section 4.5
	Benthos	L	L	H	Section 4.5
	Marine mammals/birds	L	L	M	Section 4.5
	Endangered species	L	L	L	Section 4.5
	Sensitive areas	L	L	L	Section 4.5
	Social, economic, legal				
	Other uses	L	L	H	Section 4.6
	Legal/regulatory	L	L	H	Section 4.6
	Technology dev./transfer	M	H	H	Section 4.6
Release of cuttings and drilling fluids	Physical				
	Water quality	L	L	H	Section 4.4
	Sea bottom	L	M	H	Section 4.4
	Biological				
	Phytoplankton/zooplankton	L	L	M	Section 4.5
	Nekton	L	L	M	Section 4.5
	Benthos	L	L	H	Section 4.5
	Marine mammals/birds	L	L	H	Section 4.5
	Endangered species	M	L	L	Section 4.5
	Sensitive areas	M	L	L	Section 4.5
	Social, economic, legal				
	Other uses	L	L	H	Section 4.6
	Legal/regulatory	L	L	H	Section 4.6
Potential oil and gas spills and blowouts	Physical				
	Water quality	H	M	L	Section 4.7
	Sea bottom	H	M	L	Section 4.7
	Biological				
	Phytoplankton/zooplankton	H	L	L	Section 4.7
	Nekton	H	M	L	Section 4.7
	Benthos	H	M	L	Section 4.7
	Marine mammals/birds	H	M	L	Section 4.7
	Endangered species	H	M	L	Section 4.7
	Sensitivie areas	M	L	L	Section 4.7
	Social, economic, legal				
	Economy	H	M	L	Section 4.7
	Other uses	H	M	L	Section 4.7
	Legal/regulatory	H	M	L	Section 4.7
Transportation of supplies and personnel	Physical				
	Air quality	L	L	H	Section 4.4
	Acoustical	L	L	H	Section 4.4
	Biological				
	Marine mammals/birds	L	L	H	Section 4.5
	Endangered species	L	L	L	Section 4.5
	Sensitive areas	L	L	L	Section 4.5

H = High (large, high, or long-term).
M = Medium (moderate or intermediate).
L = Low (small, low, or short-term).

Impact of the ODP on the Physical Environment

The operation of the drillship, air planes, and helicopters through the burning of fuel, the burning of refuse, and venting of laboratory solvent gases will locally increase air pollutant emissions. This is expected to be a temporary, minor impact on ambient air quality.

Riserless drilling discharges to the ocean floor of surface seawater, drilling mud, and cuttings will result in slight increases in temperature, oxygen, nutrients, dissolved gases, and suspended particulates. These minor water quality impacts are expected to be localized to the drill site. Water quality impacts from riser drilling will be limited to within 100 m (328 ft) of the drillship for elevated metals concentrations and 1,000 m (3,280 ft) for elevated suspended solids concentrations during discharge of muds and cuttings. These are considered temporary, minor impacts to water quality.

The seafloor will be impacted by the deposition of drilling muds and cuttings, surface casing and reentry cone assemblies, and dynamic positioning beacons. Impacts from metal structures or their breakdown products are minor. Muds and cuttings from riserless drilling accumulate in the immediate vicinity of the borehole. This results in local alteration of sediment characteristics and modification of bottom topography. Accumulation of drilling muds and cuttings less than 0.02 mm are predicted for riser drilling operations at any one location. This accumulation is expected to result in negligible impacts on the seafloor.

ODP operations will result in negligible impact to the terrestrial acoustical environment. Noise levels in the ocean will be significantly elevated through the lower frequency range in the vicinity of operations. The noise is similar to that produced by moderate vessel traffic and should produce a temporary, minor impact on the acoustical environment.

Impact of the ODP on the Biological Environment

With riserless drilling operations, drilling muds and cuttings will be discharged onto the seafloor. Thus, no impacts on phytoplankton and zooplankton populations are expected. Potential impacts to demersal nektonic organisms include the smothering of demersal eggs, acute and chronic toxicity, bioaccumulation, and indirect effects through food supply reduction. However, these are expected to be localized in the vicinity of the borehole, short-term, and therefore negligible. Benthic communities are expected to be affected. However, the size of the area will be negligible compared with the size of the ecosystem.

With riser drilling operations, surface discharges of drilling muds and cuttings are expected to have little (if any) impact on phytoplankton and zooplankton because of the brief, intermittent nature of the discharge, rapid dilution, and rapid population recovery. Impacts to demersal fishes are expected to be negligible. Negligible changes in benthic species composition and abundance are expected.

The drillship, either in transit or on station, could interfere with marine mammal movements. However, this interference is unlikely to have any significant impacts. Noise produced by ODP activities could disturb marine mammals or interfere with their vocalization. However, the overall effect is considered negligible. Surface discharges from the drillship could elicit avoidance reactions by marine mammals or have short-term affects on their food sources. With riserless drilling, muds and cuttings discharged on the seafloor will have no effect on marine mammals. Indirect effects on marine mammals (e.g., reduction of food organisms or bioaccumulation) are unlikely because effects on plankton and fish are expected to be localized and short-term, and the resulting secondary effects on marine mammal predators should be negligible.

Various discharges of the ODP could potentially affect marine birds through direct effects on birds on or in the water, or through indirect effects on fish or plankton on which birds feed. Discharges from the drillship occur in a very localized area. Thus, there should be negligible direct physical or toxicological effects on marine birds. The effects of ODP discharges on fish and zooplankton are expected to be minor and very localized, so that resulting indirect effects on marine birds will also be negligible. The ODP could also affect marine birds through disturbances of colonies by helicopter overflights. However these disturbances are expected to be very infrequent and temporary, and any induced egg mortality should have no significant adverse effects on the population.

Previously, it was concluded that the ODP would have negligible impacts on marine mammals and birds, and this generally would apply to endangered and threatened species of those groups. Their reduced population or limited ranges magnify any effects. However, these effects would only be temporary. A possible exception would be the potential impacts resulting from the avoidance of critical breeding, feeding, or migratory habitats by endangered whales due to ODP activities. However, impacts resulting from avoidance of areas would be limited to less than one season, and should therefore have negligible effects on any whale population. The ODP could affect sea turtles through direct and indirect effects of various discharges, and through collisions between sea turtles and the drillship. ODP discharges are expected to affect water quality in a minor and localized manner, and so would potentially impact relatively few sea turtles. In addition, collision situations will be rare, with only one ship involved and the low density of turtles in the open sea. The resulting effects on turtle populations are therefore expected to be negligible.

Biologically sensitive areas involving the terrestrial environment, ice-edge communities, and rookeries of marine mammals and birds will be negligibly affected, since ODP activities are located far offshore. Biologically sensitive features involving productive fish populations and commercial fisheries are not expected to be significantly impacted by the ODP. Other open-sea sensitive areas such as hydrothermal vent communities and critical breeding, feeding, or migratory habitat for endangered whales will be actively avoided.

Impact of the ODP on the Social, Economic, and Legal Environment

Direct ODP expenditures on payroll, goods, and materials have brought and will continue to bring economic benefits to program activity locales. By creating other jobs and new cycle of expenditures, fusion of that money into the local economies has had and will continue to have a multiplier effect in the regional economics of program locales.

Since the ODP will involve only one ship and drilling will not be conducted for the more than 3 months in any given area, it is unlikely that the program would have significant adverse effects on commercial fisheries, military operations, transportation resource development, and other scientific research.

ODP activities in other coastal nations requires consent of that nation, but this is expected with little difficulty. Drilling activities in the Antarctic are to be conducted in compliance with applicable international treaty provisions.

Significant technology development and transfer is involved with the ODP. Technology advances include a modern state-of-the-art drillship, complete program of scientific logging, and improved drilling and coring techniques. These advances will be openly available to the countries participating in the ODP as well as the petroleum industry.

Mishaps and Accidents

Mishaps and accidents occasionally occur in drilling operations. Mishaps could result from storms, unexpected geologic anomalies, or blowouts. Most resulting impacts would be caused by material fluxes into the environment. Storms or geological conditions could result in the loss of the drill string (riserless drilling) or riser and drill string (riser drilling), and all downhole or subsea equipment in use at the time. Following such a loss, failure to plug the hole (if conditions monitored during the earlier drilling suggested it was necessary) may result in chronic exchange of formation fluids and seawater. Depending on the direction of flow and composition of formation fluid, impacts could range between none and a persistent exchange of local bottom water with formation fluids that are toxic to the local benthic community. However, the probability of releasing substantial volumes of subsurface aqueous solutions is small and the impacts are expected to be localized and minor.

While the probability of a blowout of pressurized gas or formation fluids is unlikely, a blowout could result in the loss of downhole equipment and a continuing release of gas (including H_2S) or formation fluids into the water column. The portion reaching the surface (low molecular weight gases, including H_2S) would be released into the atmosphere, impacting air quality. Depending on the composition and persistence of the released accumulations, impacts could range from none to a continuing introduction of material toxic to the local bottom and demersal communities. Site review and safety procedures minimize the potential of release of significant volumes of gas and formation fluids into the marine environment.

The worst-case scenario (i.e., an uncontrolled blowout of hydrocarbons and the loss of the ship) would result in release of oil into the marine environment until another drillship could drill a relief well. Impacts to pelagic organisms in contact with oil include death caused by lethal toxic effects, altered physiology or behavior caused by sublethal toxic effects, tainting due to oil uptake, bioaccumulation or biomagnification, and smothering and suffocation.

Plankton populations would be extensively impacted in the vicinity of the spill. Adverse impacts are likely to be short-term and localized. Most nektonic organisms can avoid the spill, reducing impacts on these populations. Toxicity to eggs, larvae, and juveniles could impact fishes and fisheries, resulting in long-term population reductions. Significant toxic effects or smothering of benthic organisms could occur where oil is incorporated into the sediments. This should occur in high concentrations only in the vicinity of the blowout.

Impacts from an oil spill to marine mammals will be greatest on species that rely on fur or hair for insulation or that have greatly reduced populations. Foraging techniques and migratory concentrations also increase vulnerability. Low densities associated with pelagic distributions reduce impacts at the population level and impacts should be negligible to moderate.

Effects of oil on pelagic marine birds include mortality or disablement from fouling of plumage, toxic effects, and food losses. Factors affecting the likelihood of impacts include how much time a species spends on the water and how it forages. The increased densities found at rich foraging areas also increase vulnerability to impacts. Penguins are especially vulnerable, since they rely on their feathers for insulation. Depending on location, impacts can range from negligible to moderate.

Due to the distance of most drill sites from landfall, oil impacts to the more sensitive coastal, ice edge, and shoreline habitats are reduced. Dispersion and weathering of oil before reaching these habitats, if these habitat are reached at all, will greatly reduce its volume and toxicity. Impacts from spills to these habitats and the organisms associated with them should only be minor. Biologically sensitive regions and areas of concentrations of endangered and threatened species occur almost exclusively in these coastal zones, thereby reducing potential impacts from oil spills.

Spill prevention and cleanup procedures are expected to have negligible impacts on the environment. Any impacts from these operations will be more than offset by the reduction of oil-related impacts to the environment.

COMPARISON OF IMPACTS

Comparison of impacts of the program alternatives was addressed in the DSDP/IPOD EIS (NSF 1975). The comparison of impacts from operational alternatives, including site location, drilling schedule, and well planning, is an ongoing process throughout the program. A series of panels reviews alternatives to ensure safe operation and to minimize occurrence of potential environmentally damaging situations. The remaining internal program alternative to be acted upon is the future conversion to riser drilling capability. The main difference in environmental impacts between operation of riserless and riser drilling is the location of the discharge of drilling fluids and cuttings. The comparison of impacts of riserless and riser drilling is discussed below.

Riserless Drilling Operations

Riserless drilling operations will result in the discharge of surface seawater, drilling muds, and cuttings on the seafloor. Because these are not discharged into the water column, no impacts to pelagic planktonic and nektonic organisms (including marine mammals and birds) are expected. Potential impacts to demersal nektonic organisms and benthos include smothering of demersal eggs and benthos, acute and chronic toxicity, bioaccumulation, and secondary effects through food supply reduction and change in substrate characteristics. These are expected to be localized in the vicinity of the borehole, short-term, and therefore negligible.

Riser Drilling Operations

Riser drilling operations will result in the discharge of drilling mud and cuttings to surface waters. Due to the depths of most drill sites, impacts to demersal fish and benthic organisms are expected to be negligible. Impacts on plankton will be localized and minor because of the brief, intermittent nature of the discharge, rapid dilution, and rapid population recovery. Impacts to pelagic nekton (including marine mammals and birds) include localized reduction of food supply and possible ingestion of toxic particles. Impacts are considered negligible because of their localized, intermittent nature and because many pelagic organisms can avoid discharge plumes.

CUMULATIVE IMPACTS

ODP operations should result in negligible cumulative impacts above those already stated when considered together with effects of other operations occurring simultaneously in the same region. Interaction or overlap with other operations will be minimal, resulting in few, if any, regions where overlap of effects would cause a measurable difference in impacts to the marine environment. This primarily results from the remote locations and short-term occupation of drilling sites and the localized and temporary impacts attributed to ODP operations.

Cumulative impacts projected for the duration of the program will also be negligible. The localized and short duration of most perturbations to the environment results in a negligible impact when viewed at the longer time scale of the complete program. The geographical separation of drilling locations further reduces the cumulative effects. In addition, the percentage of any habitat that will be impacted over the course of the program is only a very small fraction of the total. In effect, the localized nature and short-term scale of impacts at each drill site precludes any cumulative impacts that could occur over the course of the ODP.

CHAPTER 3

AFFECTED ENVIRONMENT

Section 3.1
INTRODUCTION

The description of the environment affected by the ODP focuses on four representative drilling sites. Together they encompass the full range of scientific goals, geographic positions, and geologic and ecologic conditions expected during the ODP. The selection process by which the sites were chosen began with a review of the program's major scientific goals, as outlined by JOIDES. Potential drill sites were then evaluated by three criteria to identify sites that would represent the range of potential environmental impacts. The three criteria were:

- Environmental factors at each site
- Risk elements of site location
- Data availability.

Four sites were selected, as indicated in Figure 11 and Table 6. Potential impacts are also noted in Table 6. Although individual impacts are emphasized herein under only one site, they are also possible at others. Thus, important variations of potential impacts that could result at other locations are discussed as appropriate. In this way, the full range of potential effects is addressed under the four representative sites.

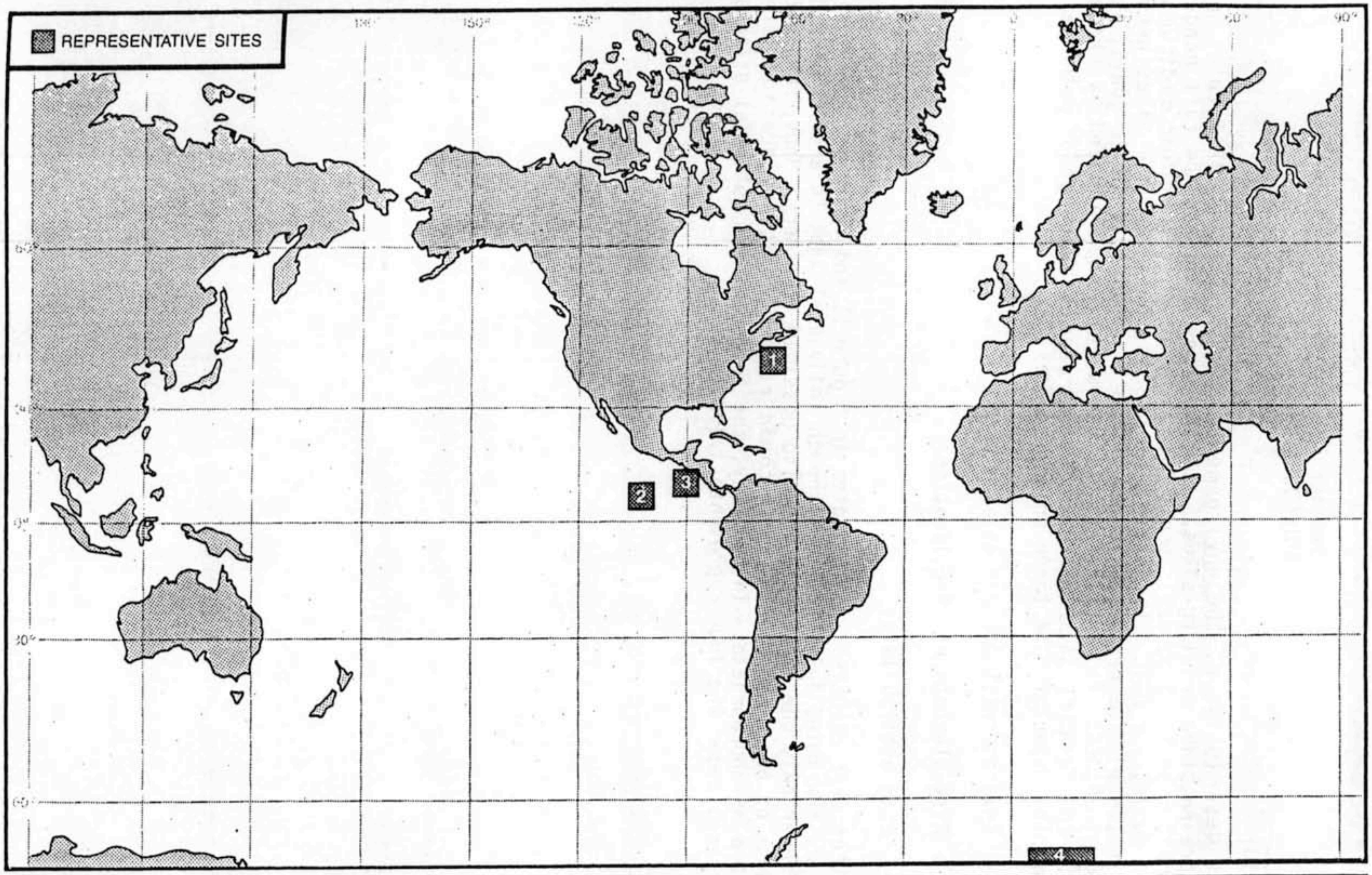


Figure 11. Representative drilling sites.

TABLE 6. REPRESENTATIVE SITES FOR THE EIS EVALUATION

Site Locations	Site Type	Technical Problems/ Development	Major Impact/Risk Assessment Focus
1. Georges Bank	Passive margin (thick sediments)	Riser system	Oil & gas blowout Fisheries Landfall/shore impacts Drilling muds
2. Eastern Pacific Rise	Spreading center Hydrothermal system	Bare rock spud-in High temp drilling	Magmas Hydrothermal tap-in Upwelling Challenger-type drilling discharges
3. Mid American Trench	Active margin	Gas hydrates	Acoustic environment Small coastal fisheries International boundaries
4. Antarctica (Weddell Sea)	High latitude	Ice Heave compensation	Antarctic treaties Biologically sensitive regions Marine mammals

Section 3.2
FEATURES OF THE OCEAN ENVIRONMENT THAT MAY AFFECT THE ODP

WEATHER

Weather affects all operational aspects of the ODP. Logistics can be affected by inclement weater. The design of the ship drill floor allows drilling activities under all weather conditions, except when the ship cannot physically be held on station. Drilling activities have been scheduled to minimize encounters with seasonal and extreme weather conditions (e.g., hurricanes, storms, sea ice).

SEA CONDITIONS

Sea conditions affect all ship-based operations. Drilling is postponed or suspended when the sea state exceeds the limits of the drill string compensation system; subsurface currents generate shear forces beyond design limits of the drill string or riser; surface currents exceed the station-keeping capability of the dynamic positioning system; or high seas limit the at-sea transfer of equipment or personnel by ship or helicopter.

GEOLOGICAL CONDITIONS

Geologic conditions can affect site locations, well design, and, under certain conditions, the drill assembly. Unstable surface sediments, faults, or overpressure zones could cause loss of the downhole assembly, drill string, or worse. As indicated in Chapter 2, drill sites are carefully chosen on the basis of both geologic conditions that minimize such risks and scientific importance. Mitigating measures used by the ODP to reduce geologic risks are discussed in Section 4.8.

Section 3.3

FEATURES OF THE OCEAN ENVIRONMENT THAT MAY BE IMPACTED BY THE ODP

PHYSICAL CONDITIONS OF THE REPRESENTATIVE DRILLING AREAS

Weddell Sea

The Weddell Sea, part of the Southern Ocean, lies to the east of the Antarctic Penninsula between 50° and 10° W longitude (Figure 12). This deep basin [greater than 4,000 m (12,832 ft) in many places] is topographically isolated by the Scotia Rise to the north and by the Maud Rise to the west. The basin extends into the Antarctic continent to within 10° of the South Pole. Shallower portions of the continental shelf along the peninsula and in the southern area are covered with shelf ice throughout the year. This ice sheet usually covers the entire Weddell Sea during the austral winter, retreating from east to west over the austral summer. Due to the ice coverage, drilling is feasible during only the austral summer. Drilling in the Weddell Sea (LEG 114) is scheduled for mid-January through February, 1987.

Meteorology--

Weather in the Weddell Sea is dominated by a persistent low pressure system over the eastern part of the sea. Its position and strength are important to sea-ice growth and decay because of resulting equatorward airflow over the western portion of the sea. The expected mean surface geostrophic winds generated by barometric pressure fields during the projected drilling period are shown in Figure 13. The important features are weak clockwise circulation in the Weddell Sea, strong circumpolar westerlies in the mid-latitudes, and weak easterlies along the coast. The easterlies are strengthened by cold airflow (katabatic winds) down from the continental plateaus (Weller 1969). These winds can exceed 70 kn for periods of hours. Mean surface air temperatures at the proposed drill sites seldom exceed 0° C, and usually range from -15° to 0° C (Zwally et al. 1983).

General Circulation--

Circulation in the Southern Ocean (Figure 14) is dominated by the Antarctic circumpolar current (Gordon et al. 1978), driven by the strong westerlies in the vicinity of 60° S latitude (Wearn and Baker 1980). Easterly winds nearshore drive a coastal current in the opposite direction. The Antarctic Divergence shown in Figure 14 is an area of intense upwelling of deep water. On rising to the surface, this water is cooled by the atmosphere and diluted by precipitation and melting ice. It flows north and is subsequently mixed at the Polar Front, or Antarctic Convergence. This denser water then sinks and flows north below the warmer surface layer. This process is important in reoxygenating subsurface water of the world oceans.

Circulation in the Weddell Sea is made more complex by an elongated cyclonic gyre extending from the Antarctic Peninsula to 25-30° E longitude (Figure 15) (Carmack and Foster 1975; Foster and Carmack 1976; Gordon et

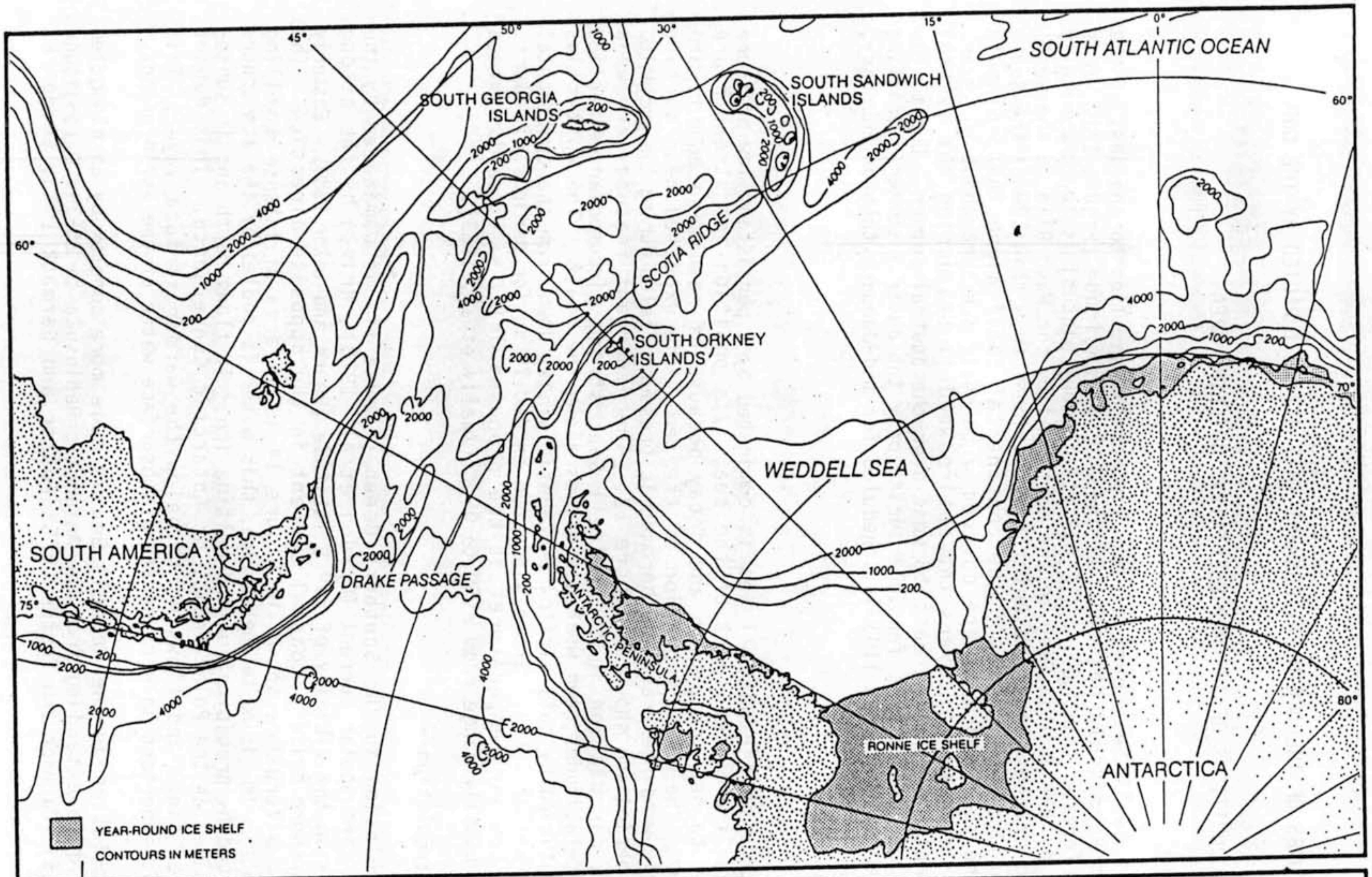


Figure 12. The Weddell Sea region.

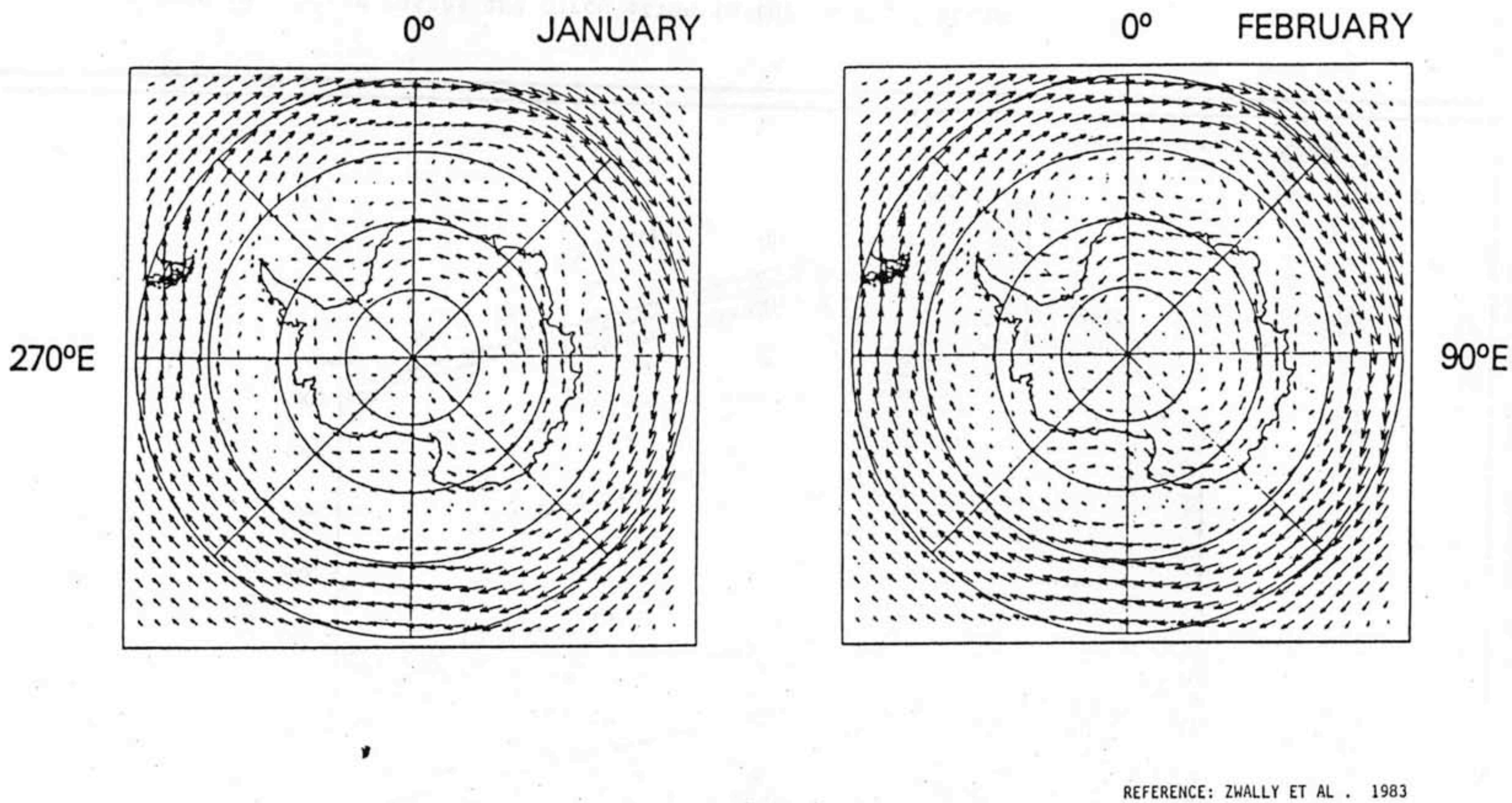
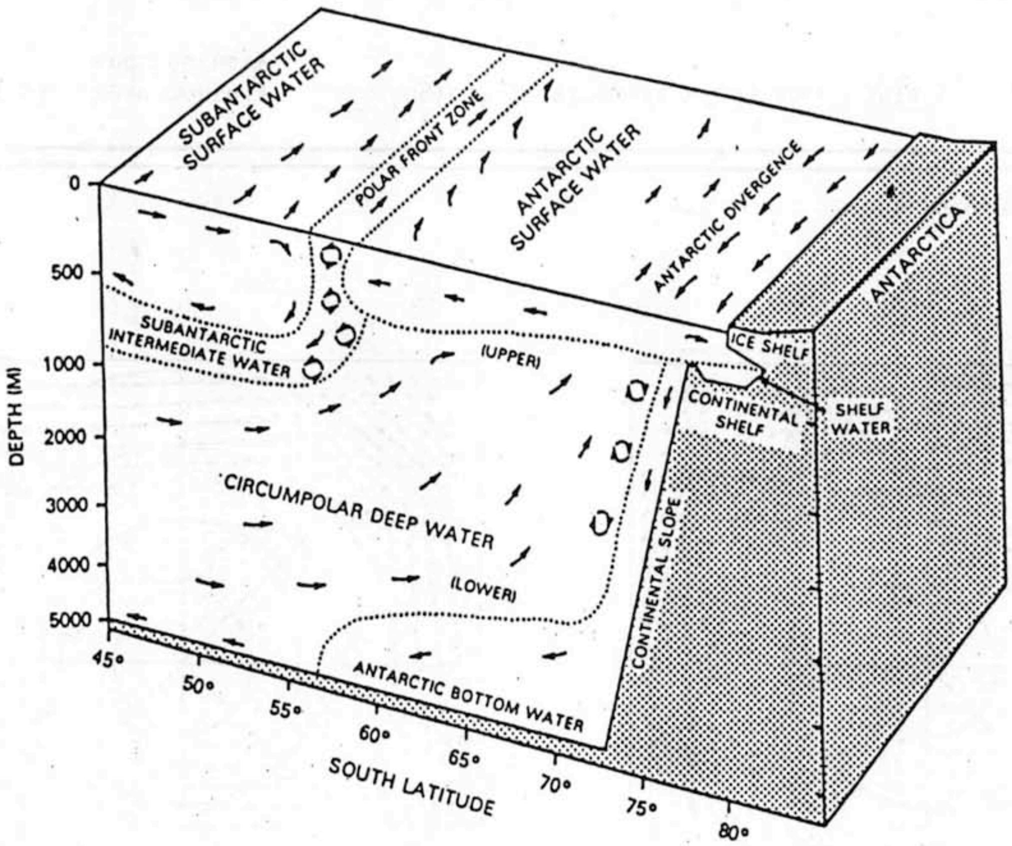


Figure 13. Mean monthly climatological geostrophic winds about Antarctica, January and February.



REFERENCE: GORDON AND GOLDBERG 1970

Figure 14. Water masses and circulation in the Southern Ocean.

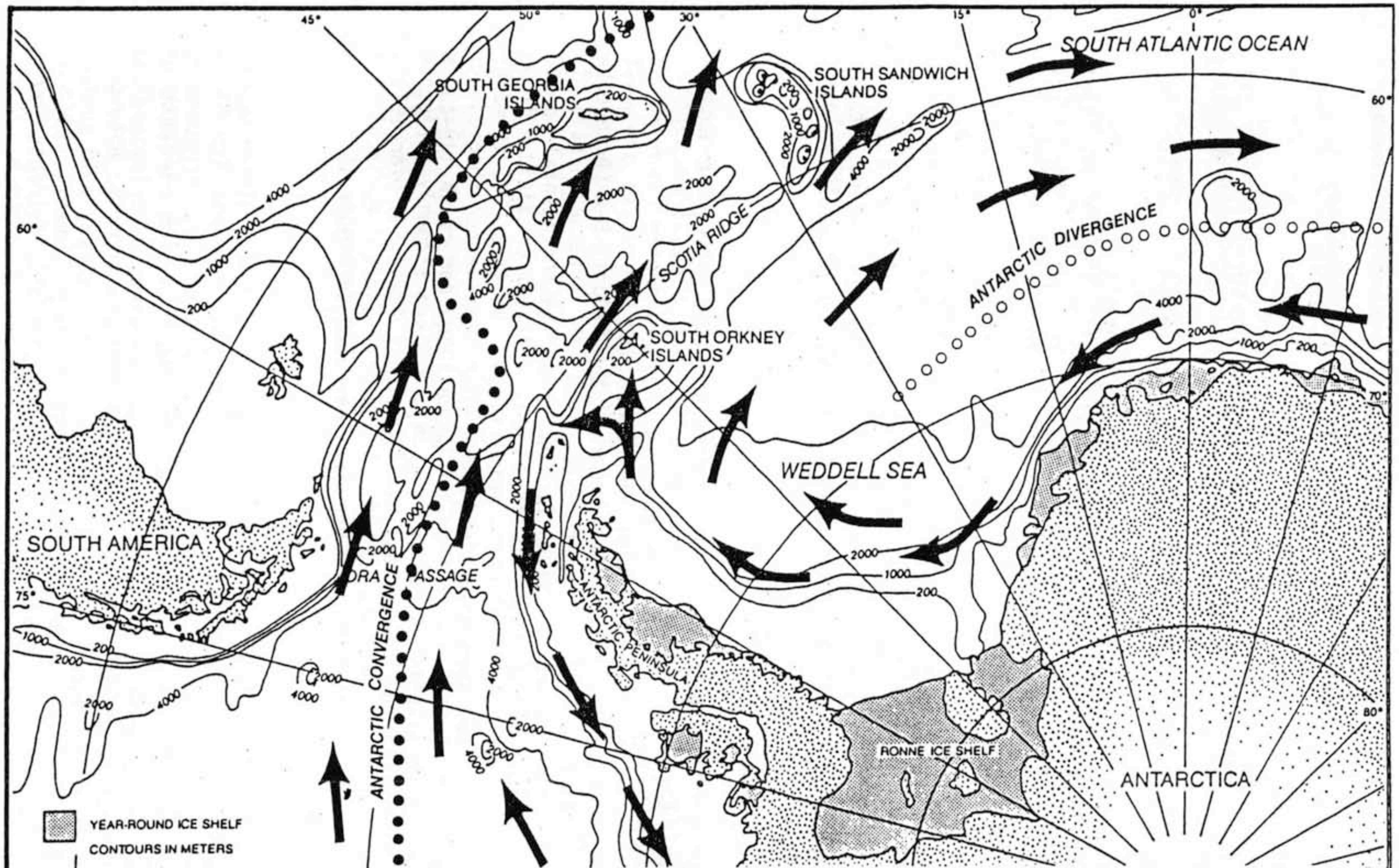


Figure 15. Surface circulation in the Weddell Sea and Southern Islands.

al. 1978; Deacon 1979; Gordon and Molinelli 1982). Evidence suggests that the entire water mass of the Weddell Sea has a slow clockwise motion (Deacon 1937). Speeds increase with distance from the center, up to mean speeds on the order of 4 cm/sec (0.13 ft/sec) (Carmack and Foster 1975). Tidal currents appear to be about half that speed.

Upwelling appears to occur throughout the interior of the gyre and recent measurements indicate a flushing time of 10 years or less (Weiss and Bullister 1984). Carmack and Foster (1975) suggest that 69 percent of the outflow from the Weddell Sea is associated with the bottom layer and that less than 5 percent is in the near-surface layer. Recent measurements indicate bottom water formed in the western portion of the Weddell Sea may escape in as little as 2 years (Foster and Carmack 1976).

The density structure of the Weddell Sea is unusual when compared with mid-latitude or tropical oceans. The surface layer is thin [about 100 m (328 ft)]. Throughout most of the water column, temperature and salinity profiles largely compensate each other, resulting in a thick, low-stability layer. The bottom is a colder, slightly less saline, stable layer associated with Antarctic Bottom Water (see Figure 14). This layer is often a few tens of meters thick (Foster and Middleton 1979).

Antarctic Bottom Water--

As the principal source region for Antarctic Bottom Water, the Weddell Sea has a significant effect on the circulation and abyssal properties of the world oceans. Antarctic Bottom Water is produced during the formation of sea ice (i.e., in the austral winter when freezing processes are most active), primarily in the southwest corner of the Weddell Sea (Brennecke 1921; Mosby 1934; Gordon 1971). Ice formation causes an increase in salinity and a decrease in temperature of the surface water on the continental shelf. When a sufficiently high salinity is attained, this water sinks, flows off the shelf, and moves down the continental slope. As it sinks, it mixes with warmer, more saline, deep water to form a water mass denser than either of its components. Bottom water from the Weddell Sea can reach 40°-45° N latitude in the western Atlantic Ocean (Wust 1936), and can strongly influence bottom circulation in the Indian and Pacific Oceans (Reid and Lynn 1971). The direction of mean flow is consistent with the general clockwise circulation of the bottom currents in the western Weddell Sea noted in Figure 16.

Ice--

Ice constitutes a major navigational hazard in the Southern Ocean. Most icebergs in the Southern Ocean originate from the Filchner Ice Shelf in the Weddell Sea and from the Ross Ice Shelf in the Ross Sea. Presumably, large year-to-year changes in ice cover are caused by ocean currents or by variations in atmospheric circulation and surface winds. During austral winter, the ice pack may stretch 1,400-1,600 km (870-994 mi) from the Antarctic coast to the Atlantic Ocean, covering the area of the very cold surface current flowing from the Weddell Sea. In later austral summer, the pack ice melts and begins to break up. The ice edge gradually retreats toward the continent, reaching its southernmost limit in February or March.

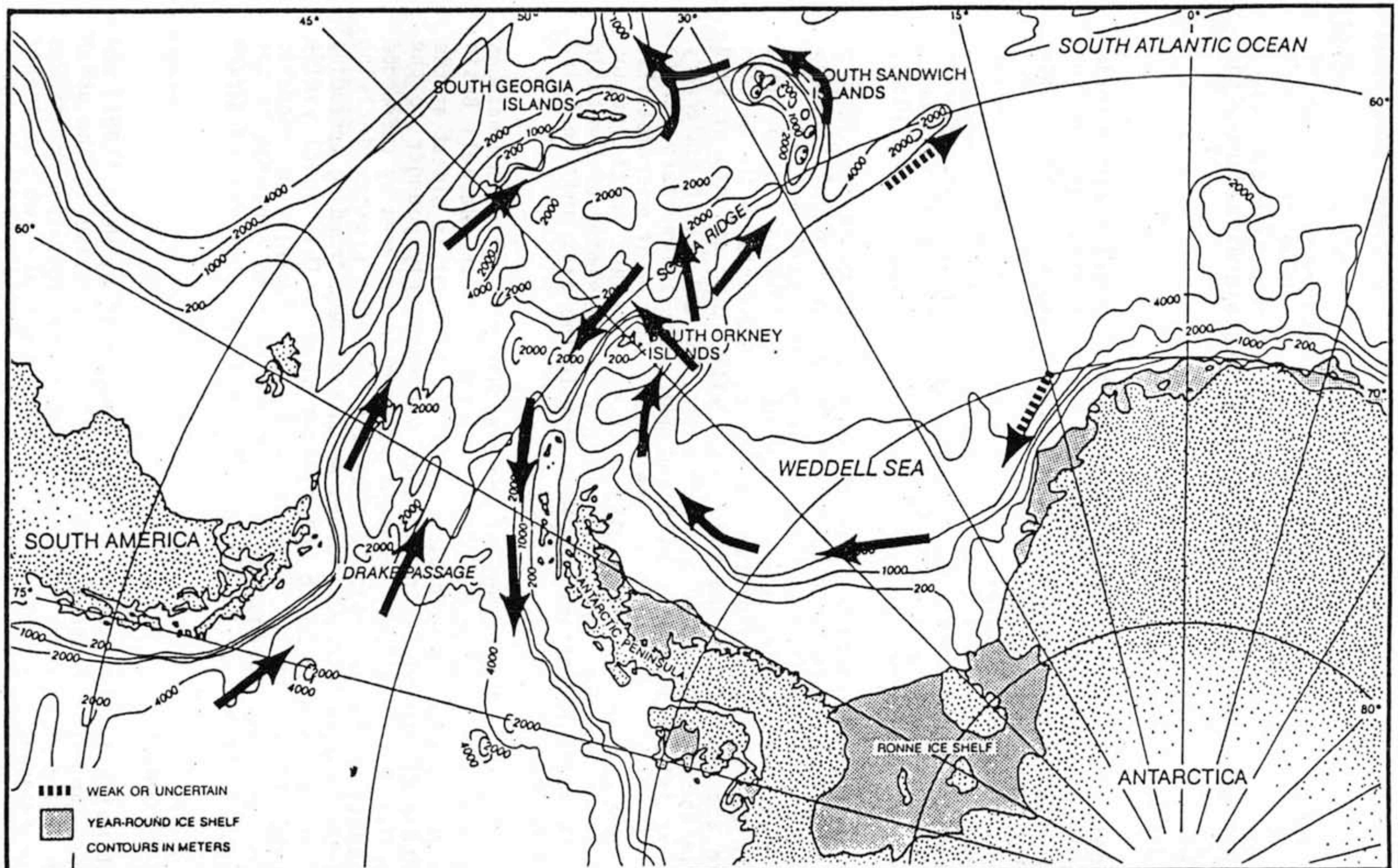


Figure 16. Bottom circulation in the Weddell Sea and Southern Islands.

Average ice concentrations for January and February (when the drill ship is expected to operate in the Weddell Sea) are shown in Figure 17 for 1973-1976. Since the ship cannot drill in any ice floe condition, the western portion of the Weddell Sea is not accessible even during the austral summer.

Geological and Geophysical Conditions--

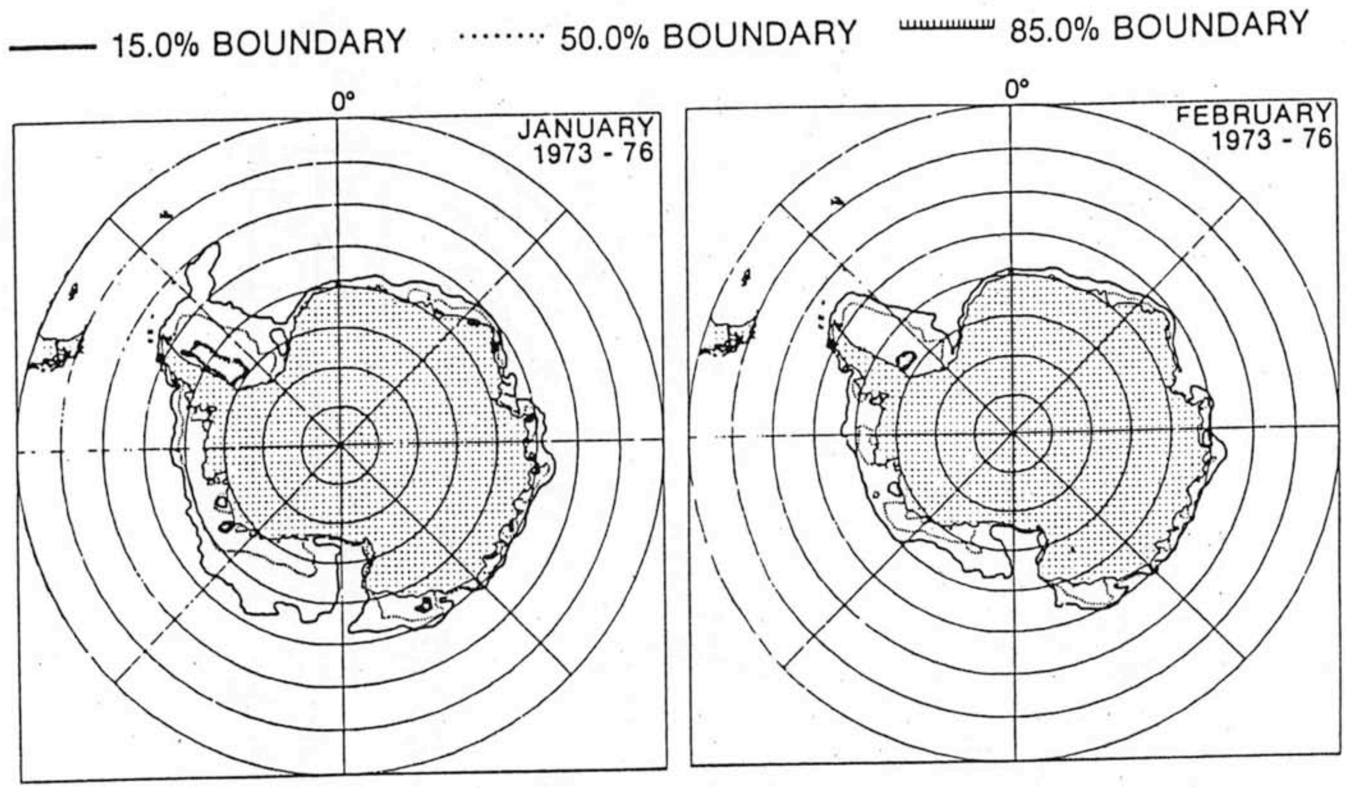
The Weddell Sea is a deep oceanic basin on the Antarctic lithospheric plate. Geologically, this basin separates the East Antarctic craton from the Antarctic Peninsula, which is a post-Paleozoic orogenic belt (Barker and Jahn 1980; LaBrecque and Barker 1981). The heavy ice coverage has allowed only limited geophysical coverage and the structure of the basin is poorly known, particularly in the west. The northern part of the basin shows substantial basement relief, which is attributed to several closely spaced, small-offset fracture zones trending northwest to west-northwest. This fracture zone topography increases to the north (Barker and Jahn 1980).

Surface sediment data in the area are very sparse, consisting largely of a series of piston cores briefly described by Graves et al. (1982). In the northeast, sediments are composed of pelagic clays and muds. In the northern part of the basin, surface sediments are composed of pelagic clay overlain by ash-bearing diatomaceous ooze. Sediments in the western abyssal plain are composed of pelagic clay, with minor amounts of sand and silt. In the easternmost part of the basin, the ubiquitous Quaternary pelagic clay is interbedded with silt and mud. The sedimentary strata in the Weddell abyssal plain proper are mostly barren of microfossils, making age determinations very difficult. Sediment thickness in the region varies from approximately 1,000 m (3,281 ft) in the center of the basin to less than 400 m (1,312 ft) near the Maud Rise to the east and the Caird Margin in the south.

Limited geophysical coverage of the area has made age determinations of the basement rocks somewhat difficult. Apparently the Weddell Basin is pre-late Jurassic to Cretaceous in age. The basement is oldest at the southern portion of the basin and becomes progressively younger to the north. Compilation of available magnetic profiles in the area by LaBrecque and Barker (1981) seems to indicate that the basement crust underlying the Weddell Sea is oceanic crust, formed at an east-west trending spreading center, with an age range of 35 to 162 million years. This model yields spreading rates of 0.6 to 0.9 cm/year (0.24-0.35 in/year). The magnetic anomalies display a strong east-west trend and seem to converge to the west (Bregman and Frakes 1970; Barker and Jahn 1980; LaBrecque and Barker 1981).

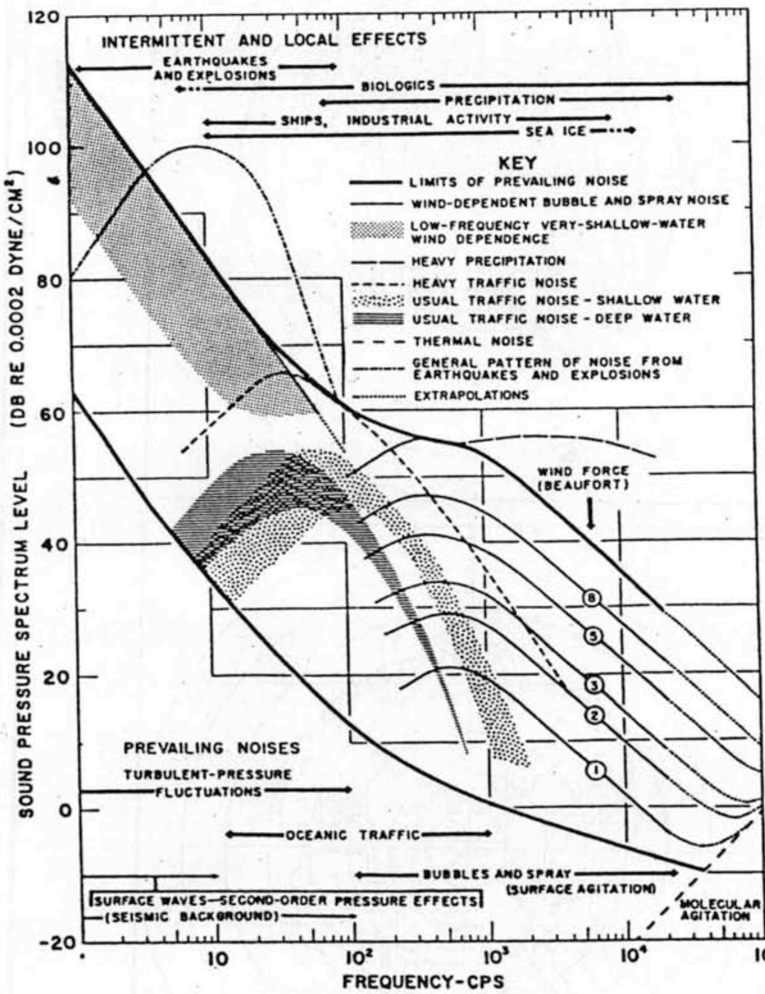
Acoustical Environment--

Ambient noise in the ocean has been summarized by Wenz (1962) and Urick (1983). The main components that contribute to noise in the ocean are shown in Figure 18. Thermal noise due to molecular agitation contributes to the higher frequencies (greater than 20 kHz). There are two components of hydrodynamic noise from spray, rain, bubbles, waves, and turbulence: a higher-frequency component (100-1,000 Hz) that is highly correlated to wind strength and a wind-independent, lower-frequency component (10-200 Hz).



REFERENCE: ZWALLY ET AL. 1983

Figure 17. Mean monthly ice concentration contours around Antarctica, January and February.



REFERENCE: WENZ 1962

Figure 18. Sources, mechanisms, and the spectrum of ambient noise in the ocean.

Both near and distant ocean traffic can contribute to ambient noise, depending on transmission properties of the water masses. Seismic sources (e.g., undersea earthquakes, slides, and slumps) contribute to lower frequency noise (1-100 Hz). Biological sources contribute a wide range of frequencies (10 to over 10 kHz), usually in short repetitive bursts. Variability is the dominant feature of ambient ocean noise and an individual site cannot be characterized by a single specific background signature.

Sea ice affects ambient noise levels through mechanical noise from ice motion and other poorly defined means. Noise levels are highly variable and uncorrelated to wind (Milne et al. 1967). Pan ice produces median noise levels of 70 dB at 10 Hz (Verrall 1981). Noise levels peak at the ice edge, where they average 86 dB at 100 Hz due to the interaction between waves and ice (Diachok 1980). Shore fast ice produces noise from thermal stress cracking and from pressure ridges. Mean values of 133 dB at 5-200 Hz have been reported (Buck and Greene 1979).

Georges Bank

Georges Bank, part of the outer continental shelf between Massachusetts and Nova Scotia, is approximately 300 km (186 mi) long and 150 km (93 mi) wide. It is separated from Nantucket Shoals by the shallow [depth of 70 m (230 ft)] Great South Channel (Figure 19). Seaward of the 70-m (230 ft) isobath, the Georges Bank shelf is continuous with the New England shelf to the west.. To the northeast, Georges Bank is separated from the Scotian shelf by the deep [depth of 220 m (722 ft)] Northeast Channel, which cuts across the outer shelf to the shelf break. The crest of the bank [shallower than 60 m (197 ft)] is shaped into a series of northwest-trending ridges. The tops of some of these ridges are less than 5 m (16 ft) below the sea surface.

Meteorology--

Westerly and northwesterly winds prevail in the Georges Bank region from October through March. During these months, mean wind speeds are 7-12 kn, with the highest speeds often in the easternmost regions of the area. Southwesterly winds with speeds of 3-6 kn occur in June, July, and August. Summer wind speeds also peak in the eastern reaches of the Georges Bank region (Godshall et al. 1980).

Storms of both tropical and extratropical origin pass through the area. Tropical storms originate over the warm waters of the Caribbean, Gulf of Mexico, or the Atlantic Ocean south of Cape Hatteras, North Carolina. Tropical cyclones (wind speeds 34-63 kn) and hurricanes (wind speeds greater than 63 kn) move into the area along the east coast or offshore during late summer and autumn (Godshall et al. 1980). These storms are usually less intense in the North Atlantic, than they were in the southern latitudes. Extratropical storms are extensive (600-1,500 nmi), low-pressure systems that enter the area from either the west or the southwest. Those moving through the area from the southwest can be particularly severe in terms of precipitation and winds. The frequency of storm winds greater than 34 kn at Georges Shoals is indicated in Table 7.

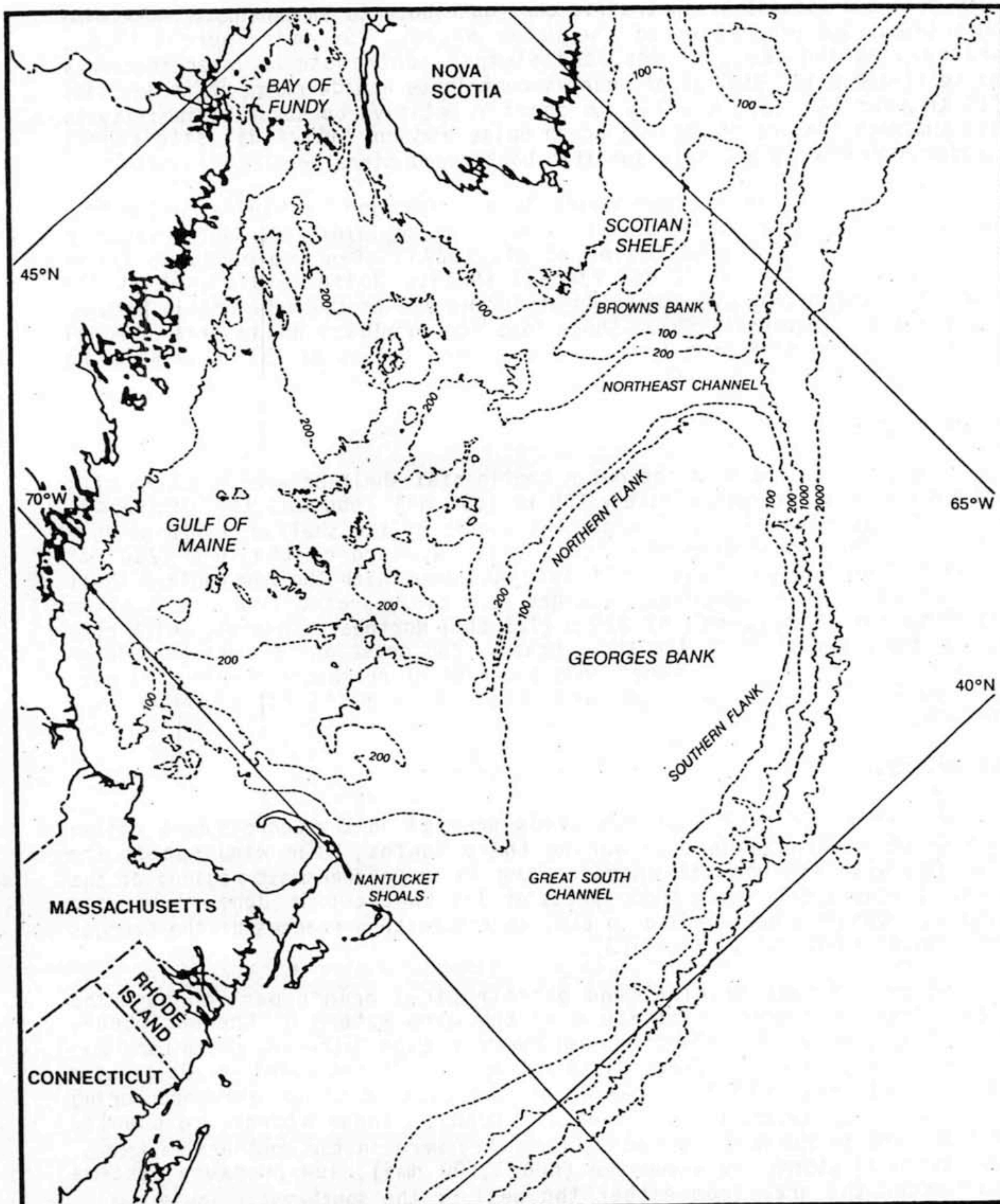


Figure 19. The Georges Bank region.

TABLE 7. OCCURRENCE OF STORM WIND SPEEDS GREATER THAN 34 kn AT GEORGES SHOALS

Month	Percent Observation of Storm Winds Greater than 34 kn
December	11.1
January	13.9
February	11.6
March	13.2
April	7.9
May	2.3
June	0.8
July	0.7
August	0.9
September	2.1
October	6.9
November	4.1

Reference: Adapted from Godshall et al. 1980.

Visibility, commonly defined as the maximum distance at which a prominent object can be seen against the background, can be restricted by precipitation, fog, and spray. Visibility is restricted to less than 2.0 nmi 15 percent of the time in May, 18 percent in June, and 16 percent in July. Visibility is restricted to less than 0.5 nmi most often during May (12 percent), June (13 percent), and July (11 percent).

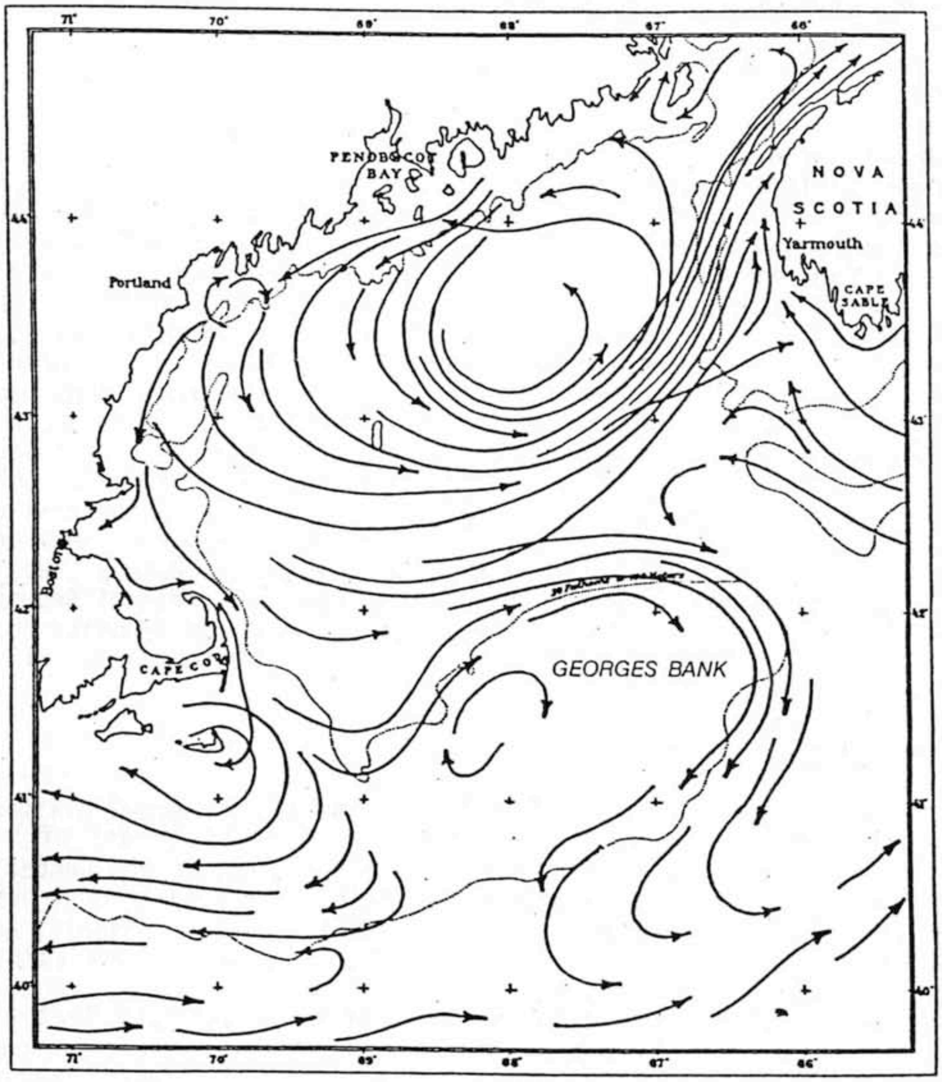
General Circulation--

Mean circulation in the Gulf of Maine is counterclockwise and circulation around Georges Bank is clockwise at speeds of 5-10 cm/sec (0.16-0.33 ft/sec) (Figure 20) (Bigelow 1927; Bumpus and Lauzier 1965; Bumpus 1973, 1976). Westward and northward flow into the Gulf of Maine south of Nova Scotia and southwestward flow out of the Gulf of Maine across Nantucket Shoals have been observed in all seasons. Clockwise circulation around Georges Bank is strongest in spring. In summer, the surface circulation in the Gulf of Maine weakens and surface flow at the eastern end of Georges Bank is slightly offshore. In winter, the near-surface flow is primarily wind-driven, offshore, and southerly across Georges Bank and the Gulf of Maine, with continued, although reduced, westerly drift along the shelf and across the Great South Channel. Deeper mean flow along the shelf does not exhibit seasonal trends but has a larger offshore component than does the near-surface flow (EG&G 1979, 1980a). Seasonal variation in mean current speeds on the shelf at Georges Bank is greater during the summer, with maximum mean flow decreasing with depth. Mean flow along the shelf in winter is uniform with depth.

Butman et al. (1982) conducted detailed current measurements that verified the clockwise circulation around Georges Bank described above. A fast [30 cm/sec (1.15 ft/sec)], jet-like current was found along the northern slope of the bank. The current enters the Gulf of Maine through the eastern side of the Great South Channel, flows along the northern slope, then passes through the Northeast Channel back out onto the shelf. The same water mass may transit the bank more than once. Some of the inflow through the Great South Channel may enter the counterclockwise gyre farther north in the Gulf of Maine.

Residence times of water masses for the entire Georges Bank increase gradually from a minimum in the winter to a maximum in the fall. Mean residence time within the bank is 54 days (EG&G 1982). However, depending on the site of release, some drifters used to determine residence times moved directly off the bank, while others completed more than one revolution around it (EG&G 1982).

Waters at depths shallower than 60 m (197 ft) are vertically well-mixed year-round by strong semidiurnal tidal currents (Bumpus 1976). Frontal zones separate these waters from those in the Gulf of Maine to the north and from those in the slope to the south (Butman et al. 1982). During winter, the northern front is weaker and deeper than the southern front. This northern front can be seen in salinity and density profiles in water shallower than 100 m (328 ft) (Butman et al. 1982). During winter, the southern front is sharply defined by strong temperature and salinity gradients that intersect the bottom at approximately the 80-m (262-ft) depth contour and separate the cooler, fresher shelf water from the warmer, saltier slope



REFERENCE: BIGELOW 1927

Figure 20. Circulation in the Gulf of Maine and on Georges Bank.

water. These frontal zones may inhibit but do not preclude inflow and outflow onto the 60-m (197-ft) isobath environment. Most of the water on Georges Bank may be contributed by a southerly component of the eastward-flowing, jet-like current on the northern flank (EG&G 1982). This may account for the high primary productivity of the shallow central area (EG&G 1982).

Tidal Currents--

Semidiurnal tidal currents associated with the Gulf of Maine-Bay of Fundy system are amplified over the relatively shallow depths of Georges Bank, leading to enhanced energy dissipation, vertical mixing, and secondary flows on Georges Bank (Brown 1984). Strong, rotary, semidiurnal tidal currents are a major feature of the Georges Bank area within the 60-m (197 ft) depth contour, where speeds of 76 cm/sec (2.9 ft/sec) have been recorded (Moody and Butman 1980). The western boundary of the Georges Bank, the Great South Channel, is also subject to strong tidal currents, where speeds as high as those within the 60-m (197-ft) isobath have been observed. Tidal currents are strong enough to vertically mix both these areas and Nantucket Shoals to the southwest (Garrett et al. 1978). Deeper water is less responsive to tidal influence. On the south flank of Georges Bank, recorded tidal current speeds are almost half those observed in the shallow area of the bank [e.g., 40 cm/sec (1.5 ft/sec) in the southern flank and less than 5 cm/sec (0.19 ft/sec) south of Cape Cod (Moody and Butman 1980)]. Tidal currents and storms may winnow fine sediments from the crest of Georges Bank. Mean flow along the shelf carries them westward and deposits them south of Cape Cod, where the tidal currents decrease sufficiently to allow settling (Bothner et al. 1981).

Geological and Geophysical Conditions--

Georges Bank is a large [67,000 km^2 (25,900 mi^2)], submerged platform on the eastward continuation of the continental shelf southeast of New England. The Georges Bank Basin is a broad trough of Mesozoic and Cenozoic sedimentary rocks that underlies the general platform and adjacent areas. It includes Georges Bank, the Great South Channel, Nantucket Shoals, and part of the continental slope. The southern edge of Georges Bank (slope of approximately 6 degrees) is heavily incised by submarine canyons and gulleys, which were probably eroded during the Quaternary and late Tertiary glacial stages. East of the continental slope, the New England Seamount Chain, extends as linear feature for over 1,000 km (621 mi). Comprehensive reports have been published on the area (e.g., Schlee et al. 1975; Schlee 1981) and on two deep test wells in the area [Continental Offshore Stratigraphic Test (COST) Wells G-1 and G-2, Amato and Bebout 1980; Amato and Simonis 1980.] Physiography of Georges Bank Basin is discussed at length by Uchupi (1968), Schlee (1973), and Schlee and Klitgord (1981). Physiography of the adjacent seamount chain is discussed by Emery and Uchupi (1972).

Surficial sediments of Georges Bank consist of medium- to coarse-grained sand with small amounts of gravel. Current winnowing due to strong tidal flow has produced areas of coarse gravel in deeper waters around local shoals and areas of coarse- to medium-grained sand on the flanks of the ridges (Stewart and Jordan 1964; Stanley 1969; Schlee and Pratt 1970; Milliman et al. 1972; Trumball 1972; Schlee 1973). The southern two-thirds of the bank is a relatively flat shelf covered with rippled sand. The northern section of the bank is covered by a series of north and south trending sand ridges. Composition of the sand remains constant over much of the bank (Milliman et al. 1972), with median grain size decreasing to the south of Nantucket Shoals and along the southern edge of the bank (Schlee and Pratt 1970).

Subsurface structure, age, and lithology of the rocks underlying the surface sediments are summarized in Figure 21. Early rifting during the Triassic between North America and Africa was followed by the initiation of seafloor spreading in the early Jurassic. During rifting, large volumes of sediments were deposited on the new oceanic crust seaward of the boundary between rifted continental crust and oceanic crust. During late rifting or early seafloor spreading, evaporation resulted in the deposition of salt that subsequently formed diapir structures. Drilling results and deep geophysical profiling data indicate that the Georges Bank Basin had rapid sediment accumulation during the Jurassic, with much diminished accumulation thereafter (Schlee and Klitgord 1981). Upper sediment layers consist of eroded Tertiary coastal plain sediments followed by deposition of an extensive wedge of Pleistocene sediments (Lewis et al. 1980). Paleo-history of the area is summarized by Grow (1981) and Schlee and Klitgord (1981).

Detailed seismic studies indicate that the core of Georges Bank is a wedge of Triassic and younger sediments that overlies the rifted basement (Figure 21). Multi-channel, seismic-reflection profiles of the continental shelf, slope, and rise by the U.S. Geological Survey and the German Geological Survey between 1973 and 1979 defined the structure of the sedimentary fill along this portion of the Atlantic margin. The fill is approximately 16 km (10 mi) thick in the center of the basin, with up to 9 km (6 mi) of sediment beneath the continental rise. The sediment cover thins to an average of 3-4 km (2-2.5 mi) at the eastward edge of the area in the deep ocean basin (Schlee 1981).

The East Coast Magnetic Anomaly (ECMA) (Figure 22) defines the boundary zone between oceanic crust and the main part of Georges Bank Basin. Seaward of the ECMA, the low magnetic relief of the Jurrasic Quiet Zone grades into the normal relief of lineated oceanic crust. Landward of the ECMA, a series of magnetic anomalies associated with basement grabens is superimposed on the general variations associated with the relatively deep crystalline basement of the basin. The large fracture zones associated with Mid-Atlantic spreading are also shown in Figure 22. For the most part, these transform faults do not extend into the Georges Bank Basin.

Acoustical Environment--

Ambient noise levels are characterized by large variability due to numerous components, as discussed in detail under the Weddell Sea acoustic environment.

Eastern Tropical Pacific

The eastern tropical Pacific is defined in this report as the region between 20° N latitude and 20° S latitude, extending east from 130° W longitude to the coast of the Americas. Two representative drilling sites, one along

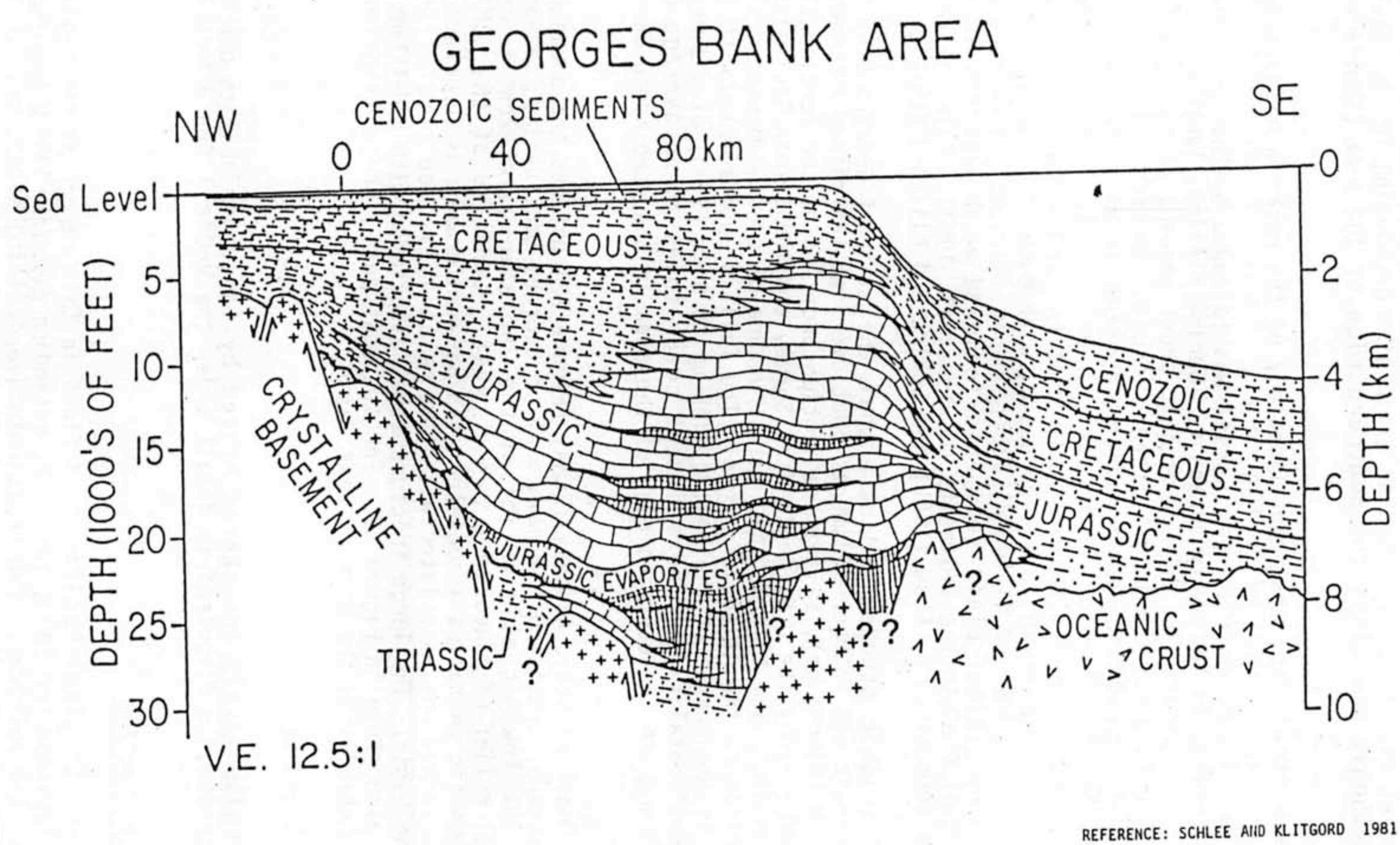


Figure 21. Schematic cross section of Georges Bank geologic structure.

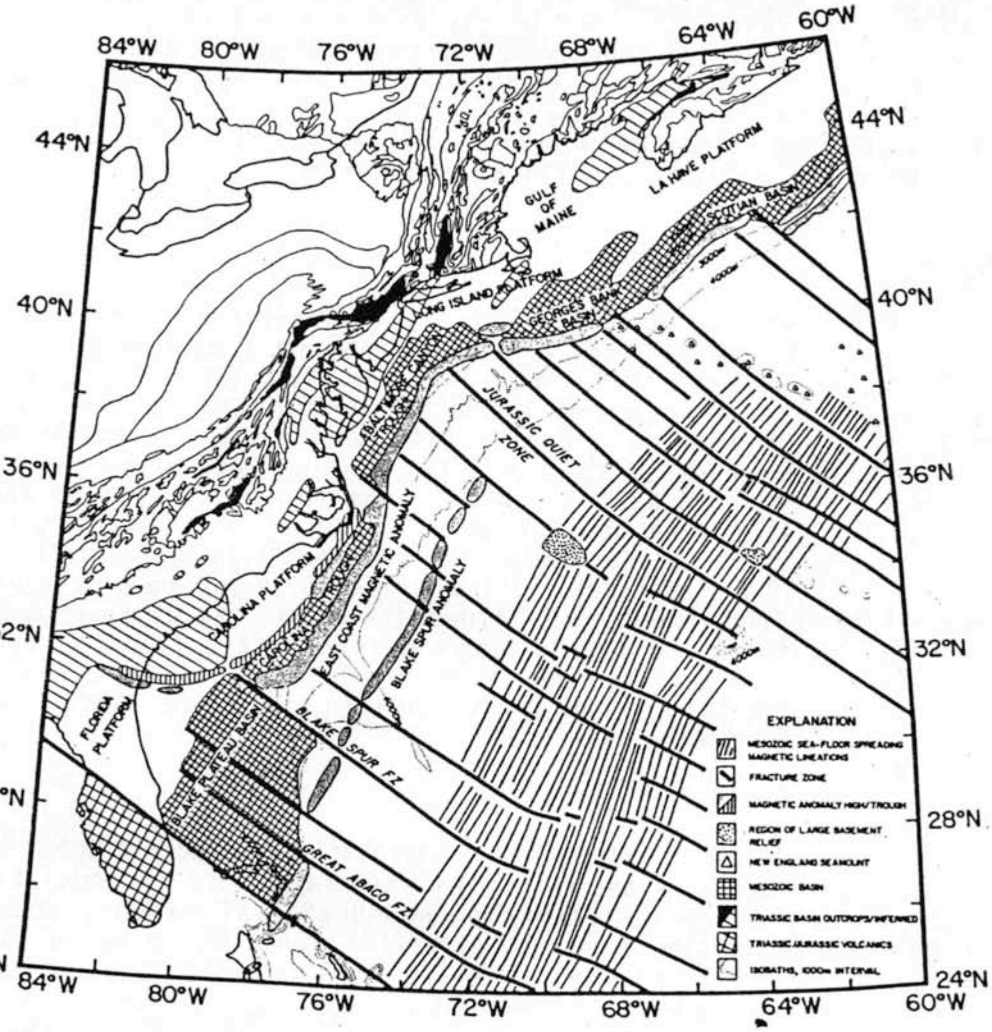


Figure 22. Tectonic map of Baltimore Trough and Georges Bank Basin.

the East Pacific Rise and one along the Mid-American Trench, are located within this region (Figure 23). The East Pacific Rise, an active spreading center, transects the ocean floor of this region (Figure 23). The Galapagos Spreading Center, a shorter series of ridges and transform faults, runs from the East Pacific Rise east to the northern end of South America. The oceanic crust generated from these rifting systems is subducted under the continents along Central and South America. The coast is characterized by a narrow continental shelf and a steep slope dropping into deep trenches. The system of ridges along the rifting axes creates a series of deep basins [3,500-4,500 m (11,480-14,760 ft)] throughout this part of the Pacific Ocean.

Meteorology--

The meteorology in the eastern tropical Pacific is dominated by the trade winds. The northeast trade winds are strongest from December through April, with maximum velocities occuring near 10° N latitude (Figure 24). The southeast trade winds reach their maximum in both velocity and northern extent from July to October. During this period, the northeast trades virtually disappear east of 120° W longitude and westerlies can develop around 10° N latitude. The trade winds converge at the Inter-Tropical Convergence Zone (ITCZ), an area of weak and variable winds. Depending on the strength of the trade winds, the mean position of the ITCZ in the region east of 120° W longitude oscillates from 15° N latitude in September to about 2° N latitude in March. Along the coast, the wind patterns are much more complex due to surface heating and cooling and to topographical barriers. During the northern hemisphere winter, airflow is generally equatorward along the coast. During the northern hemisphere summer, airflow along Central America can be poleward.

General Circulation--

The surface circulation in the eastern tropical Pacific Ocean varies considerably in response to the shifting of the major wind systems. Beneath the trade winds are the westward-flowing equatorial currents, which are part of the main anticyclonic current gyres of the north and south Pacific Ocean. The North Equatorial Current and the California Current are part of the gyre in the north Pacific Ocean, while the South Equatorial Current and Peru Current are part of the gyre in the south Pacific Ocean (Figure 25). The Equatorial Countercurrent runs between the two gyres when the ITCZ is sufficiently north of the equator. Because the gyres do not reach into the eastern tropical Pacific Ocean between Cape Corrientes in Mexico and Ecuador, this area has a variable and complicated circulation.

Three typical circulation patterns may be defined for the eastern tropical Pacific Ocean (Wyrtki 1966). The first pattern occurs from August to December (Figure 25), when the Equatorial Countercurrent is fully developed and the ITCZ coincides with its northern boundary at or north of 10° N latitude. During this time, most water of the countercurrent flows around the Costa Rica Dome (near 9° N latitude and 89° W longitude), into the Costa Rica Coastal Current, and on into the North Equatorial Current between 10° and 20° N latitude. This is the dominant and most stable circulation pattern.

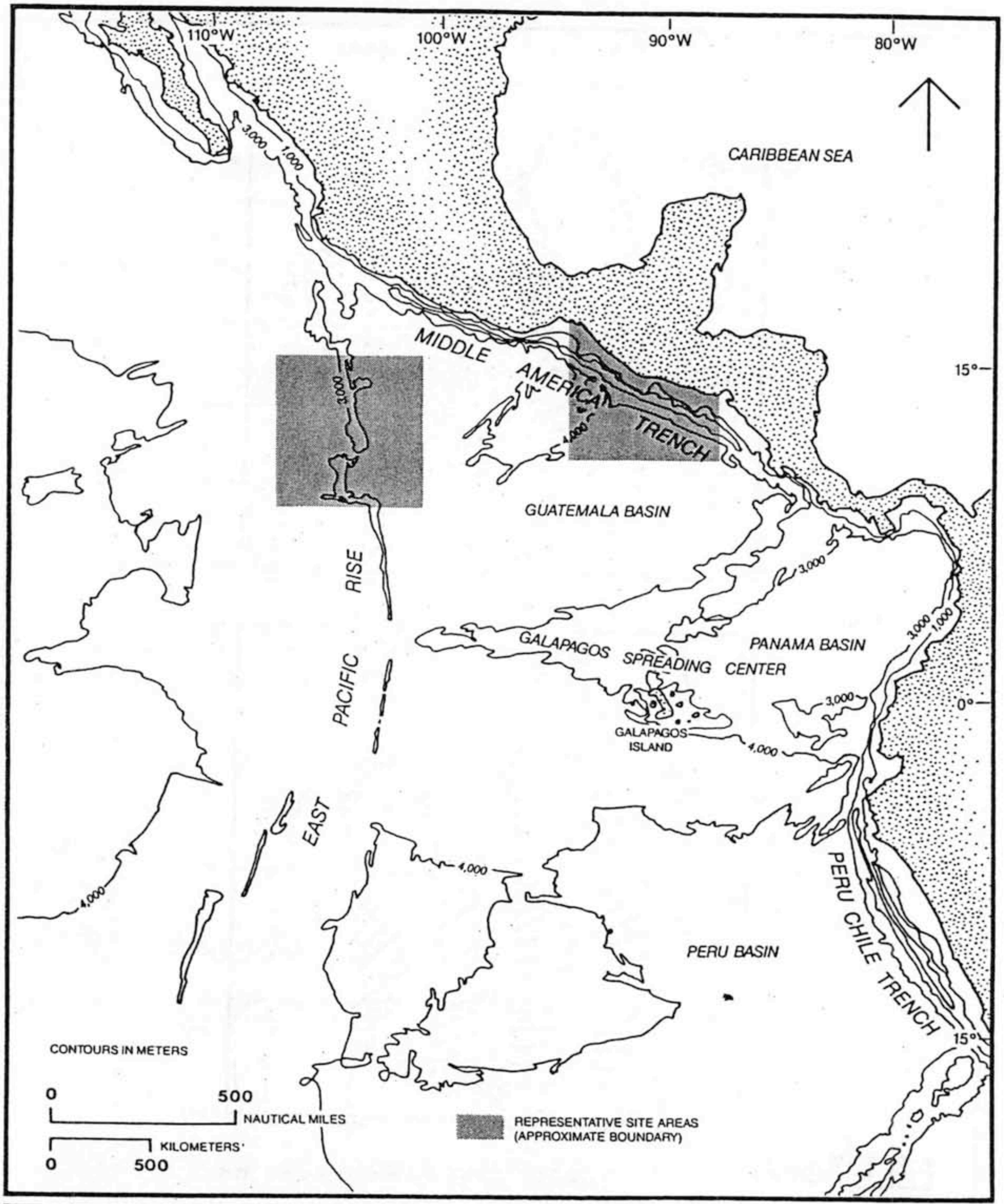


Figure 23. The eastern tropical Pacific region.

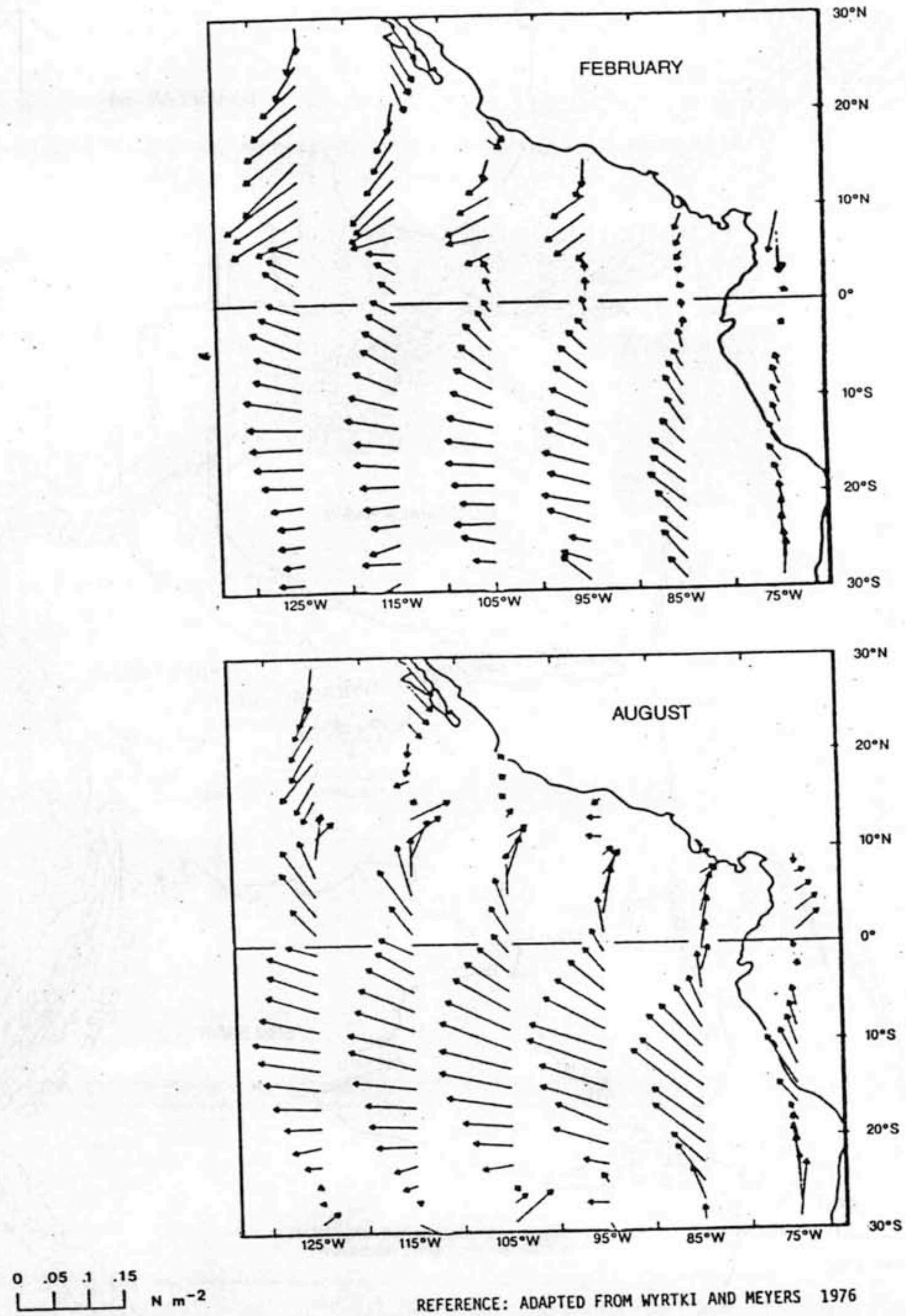
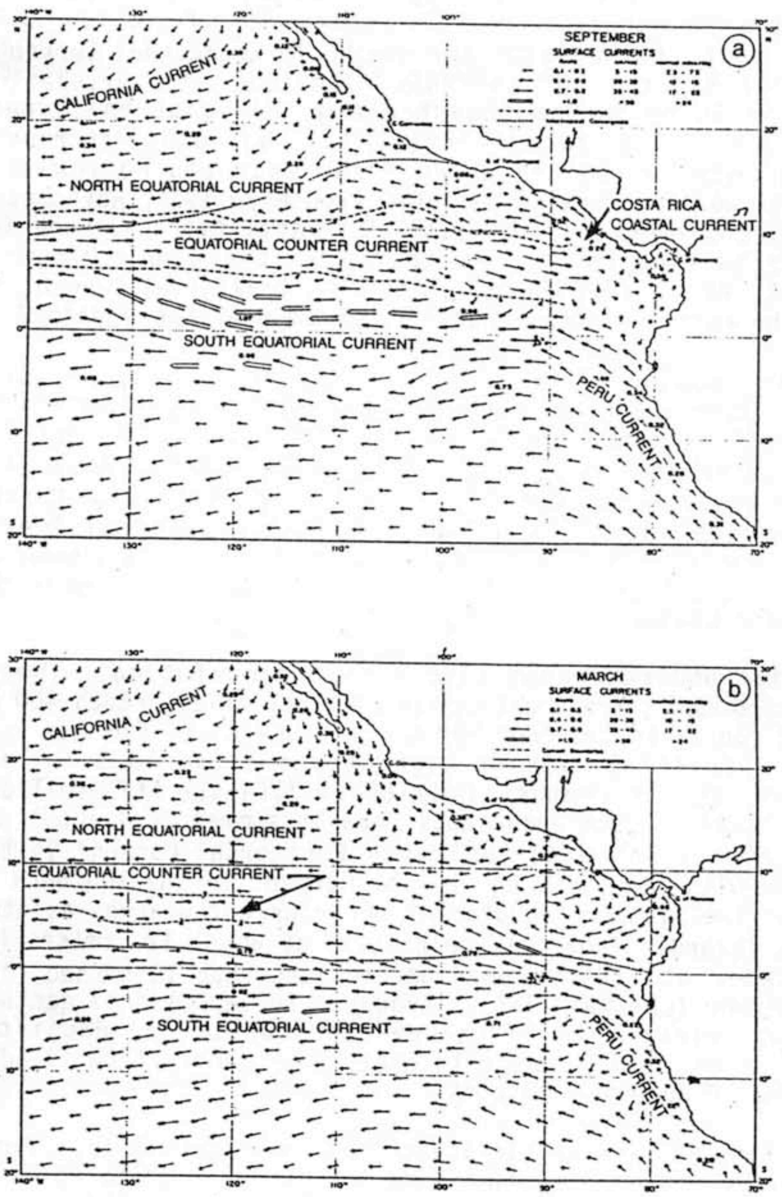


Figure 24. Surface winds in the eastern tropical Pacific Ocean.



REFERENCE: ADAPTED FROM WYRTKI 1965

Figure 25. Surface circulation in the eastern tropical Pacific Ocean.

The second circulation pattern occurs from February to April, when the ITCZ reaches its most southerly position near 2° N latitude. During this period, the California Current is strong, penetrates far to the south, and supplies most of the water for the North Equatorial Current. Off the coast of Mexico between 10° and 20° N latitude, the circulation is anticyclonic. Flow is to the southeast along the coast and turns westward off the Gulf of Tehuantepec (Figure 25). The countercurrent is weak or absent during this period and water flows west and northwest where the countercurrent would otherwise be found (Tsuchiya 1974; Hayes et al. 1982). Two large eddies develop off the coast of Central America: one is cyclonic around the Costa Rica Dome, the other is anticyclonic around a point at 5° N latitude, 88° W longitude. The South Equatorial Current is weak and currents to the east are occasionally reported near the equator.

The third typical circulation pattern occurs from May to July, when the Equatorial Countercurrent forms again, but the California Current is still relatively strong. During this period the ITCZ is again near 10° N latitude (which allows the countercurrent to develop). Most of the water from the countercurrent turns north into the Costa Rica Coastal Current during this period and flows along the coast of Central America as far as Cape Corrientes. The California Current is still strong and reaches far to the south, but does not significantly penetrate into the eastern tropical Pacific Ocean.

Equatorial undercurrents also affect circulation. These currents flow from west to east, are about 300 m (984 ft) thick, reach 400 km (249 mi) in width, and can be traced from 90° W longitude to as far west as 150°-160° W longitude (Knauss 1963). Their highest speed (up to 3 kn) is centered in the thermocline at depths of 50-150 m (164-492 ft), shallowing to the east. These subsurface countercurrents, nearly symmetrical about the equator, are usually identified with the North Equatorial Current in the northern hemisphere and with the South Equatorial Current in the southern hemisphere (White 1971). The southern equatorial undercurrent weakens as it approaches the Galapagos Islands, from peak velocities of about 120 cm/sec (4.6 ft/sec) near the equator at 110° W longitude to less than 10 cm/sec (0.38 ft/sec) at 85° W longitude (Leetmaa 1982). Evidence for additional eastward-flowing subsurface countercurrents in the eastern equatorial Pacific (Tsuchiya 1975; Hayes et al. 1982) suggests that the region's flow field is dynamic and may consist of numerous ribbons.

An important feature of surface circulation is El Niño. Through forcing of the equatorial currents by the trade winds, water piles up in the western Pacific Ocean. When the trade winds diminish, upwelling on the eastern boundary weakens. The water piled up in the west sloshes back at depth with the countercurrents, replacing the nutrient-rich water along the eastern boundary with warm, saline, nutrient-poor water. A mild El Niño typically occurs each year around Christmas. However, sometimes the whole process is magnified. Warm water reaches far north and south, pushing the California and Peru currents far offshore and transforming the circulation pattern in the eastern tropical Pacific.

Bottom Water Circulation--

Throughout the Pacific Basin west of the East Pacific Rise, there is general eastward transport of bottom water. The water passes through the rise at the deeper passages, usually along transform faults, into the Guatemala and Peru Basins (Figure 26). Different bottom water is supplied to the Peru and Panama Basins by northward flow along the Peru-Chile trench. Flow is generally slow, with little evidence of substantial bottom currents. However, average speeds of 33 cm/sec (1.3 ft/sec) have been reported at the sill into the Panama Basin (Longsdale 1976). Flow patterns in the Mid-America Trench have not been well-studied.

Residual tidal currents with no net transport and speeds of 10-20 cm/sec (0.38-0.76 ft/sec) have been measured across the East Pacific Rise. This creates a mixing zone in which the bottom water is modified by the addition of deep water and metalliferous particulates from active spreading center processes (Longsdale 1977a). Geothermal heating from these spreading centers also alters circulation. The heated plume from hydrothermal vents entrains water as it rises until the water reaches neutral buoyancy 200-500 m (656-1,640 ft) higher in the water column. Replacement of the entrained water produces local bottom flow toward the vents. This plume may drive a circulation at the level of neutral buoyancy that reaches hundreds of kilometers west of the ridge (Stommel 1982).

Oxygen Minimum Zone--

Eastern tropical Pacific waters are characterized by a warm surface layer and a sharp, permanent thermocline (a layer that separates the warmer upper layer from the underlying cold water). The thermocline inhibits mixing between the upper layer, which is high in dissolved oxygen and low in nutrients, and deeper waters, which are low in oxygen and relatively high in nutrients. Minimum dissolved oxygen concentrations (i.e., <0.25 ml/l) are found immediately below the thermocline and extend from depths of 100 to nearly 1,000 m (328 to nearly 3,280 ft). This oxygen minimum layer is caused by the biochemical process of oxygen consumption and its distribution is determined by circulation (Wyrtki 1962). It is thickest and closest to the surface north of about 10° N latitude (Wooster and Cromwell 1958).

Geological and Geophysical Conditions--

Mid-American Trench--The Mid-American Trench typifies an oceanic trench in a collision zone between oceanic (i.e., Cocos) and continental (i.e., Caribbean) plates. This zone also includes a deep siesmically active (Benioff) zone reflecting oceanic plate subduction, and a Quaternary volcanic chain. Recent investigations have shown that the subduction zone is both currently active and segmented (e.g., different tectonic fabrics found along the subducting margin) (Dengo 1983).

The Mid-American Trench has been studied intensely in order to understand the fundamental geological processes associated with subduction. In theory the overriding continental plate is envisioned as scraping rock and sediment from the surface of the downgoing oceanic plate. This off-scraped sediment and rock are then "plated" against the face of the overriding plate to form an "accretionary prism". Although there are a number of variations

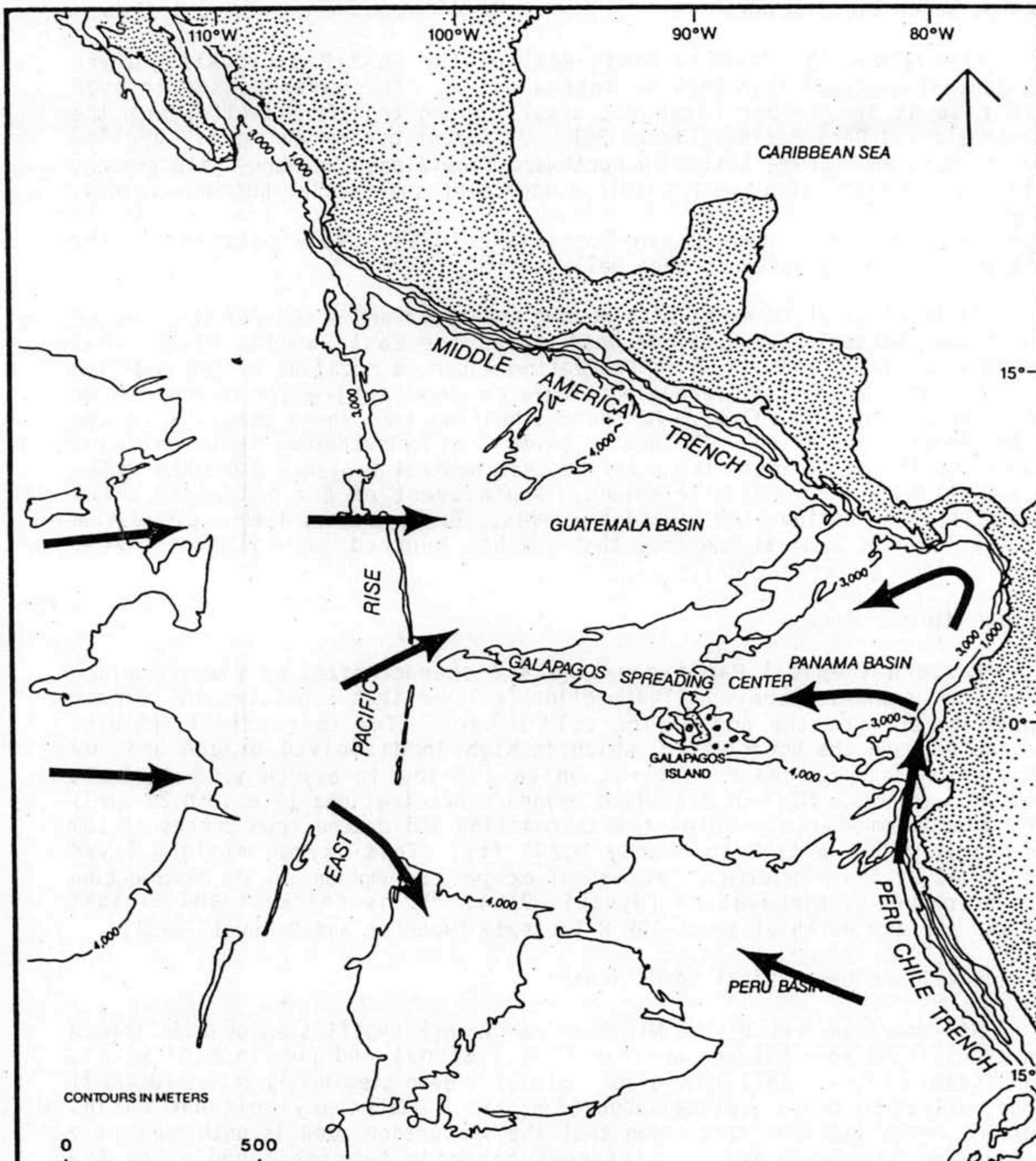


Figure 26. Bottom circulation in the eastern tropical Pacific Ocean.

on this theme, the model has gained general acceptance in the literature (Silver 1971; Grow 1973; Beck and Lehner 1974; Seely et al. 1974; Karig and Sharman 1975; Montecchi 1976; Coulbourn and Moberly 1977; Hamilton 1977; Ladd et al. 1978; Ladd and Watkins 1979; Le Quellec et al. 1980; Shipley et al. 1980). Some investigators argue that most of the incoming pelagic sediment and basalt are subducted. This is accompanied by tectonic erosion of some of the overriding plate (Scholl and Marlow 1974; Hussong et al. 1976; Scholl et al. 1977; Hussong and Uyeda 1981; Hussong and Wipperman 1981).

Several DSDP sites on the Mid-American Trench were drilled in an effort to answer some of these fundamental questions about subduction. DSDP Leg 66 drilled a transect of holes perpendicular to the subduction front off the coast of Mexico (Watkins, Moore et al. 1981). Results indicate that subduction has been active in this region for the last 10 million years and that the sediment input into the subduction zone is partitioned, with roughly equal amounts being off scraped, underplated, and subducted. The offscraped component appears to consist primarily of trench turbidites, with the subducted component primarily pelagic-hemipelagic sediments (Watkins, Moore et al. 1981). Major geological features associated with classic subduction along the Mid-American Trench at the Leg 66 drill sites are shown in Figure 27.

DSDP Leg 67 involved drilling a similar transect off the Guatamala portion of the Mid-American Trench and produced strikingly different results. In a hole 3 km (1.9 mi) landward of the trench, Leg 67 penetrated a Cretaceous to Pleistocene claystone and hemipelagic sequence before bottoming in igneous rocks atypical of ocean basalts. These results are inconsistent with that expected from an "accretionary prism" (Aubouin, von Huene et al. 1982). Gas hydrate (clathrate) compounds were recovered on both Legs 66 and 67 (Watkins, Moore et al. 1981; Harrison and Curiale 1981).

Off the Costa Rica section of the Mid-American Trench, the slope is composed of a deeper, apparently accretionary sequence beneath a thick slope apron. During DSDP Leg 84, one drill site (Site 565) was attempted to test the various models of accretionary zone formation, and this hole penetrated 328 m (1,078 ft) of mudstones of early Miocene and Quaternary age before being abandoned (Aubouin et al. 1984; Shipley and Moore in press). Gas hydrates were also recovered in this hole in the slope apron at a depth of 3,100 m (10,170 ft) below sea level.

Gas hydrates appear to present a major obstacle to drilling along the Mid-American Trench, with all three DSDP legs encountering them (Collins and Watkins 1985). One possible method to allow deep penetration into the accretionary prism is to use high-resolution seismic survey techniques to find areas where the characteristic seismic signature of clathrates does not exit (Shipley and Moore in press). Problems associated with drilling in clathrate zones are discussed in Chapter 4.

East Pacific Rise--Although there are some notable exceptions, the axes of mid-ocean ridges are generally characterized by broad central rift valleys for slow spreading rates and by axial highs for fast spreading rates. The East Pacific Rise (EPR) near 13° N latitude, which is opening at a fast rate of 11-13 cm/year (4.3-5.1 in/year), consists of a large

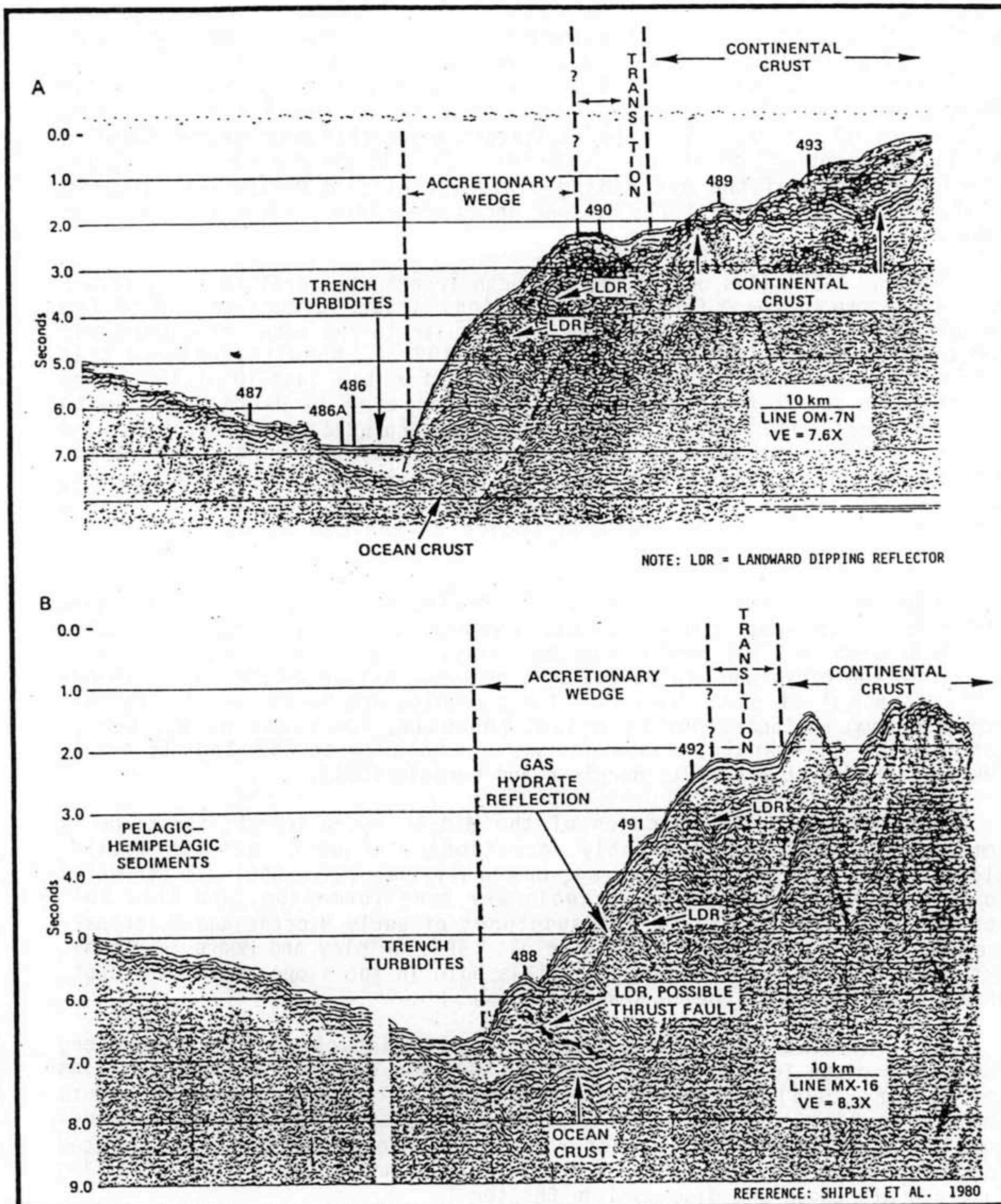


Figure 27. Seismic lines through DSDP Leg 66 drill sites showing major seismic structures.

bathymetric ridge, rising approximately 200-400 m (656-1,312 ft) above the surrounding terraine. The ridge is 2-10 km (1.2-6.2 mi) wide. Along-strike, the EPR can be characterized as a string of these bathymetric ridges, now recognized as individual spreading center "segments" each 25-150 km (16-93 mi) long (Figure 28) (Ballard and Francheteau 1982; Francheteau and Ballard 1983; Macdonald and Sempere 1984). The summit of the bathymetric ridge is characterized by recent glassy lava flows and a complete lack of sediment cover. In this neovolcanic zone, volcanic processes are responsible for most of the topographic relief. Recent discoveries indicate that adjacent ridge segments can have overlapping spreading centers (OSCs). These OSCs can range in scale from 3 to 30 km (2 to 19 mi) and are very common on medium- and fast-spreading ridges (Longsdale 1977b; Johnson et al. 1983; Macdonald and Sempere 1984). These OSCs are quite common along the ridge axis at 13° N latitude (Figure 28), with the shortest known ridge segment [25 km (16 mi)] isolated by OSCs at 12° 37' N latitude and 12° 54' N latitude.

The center of each ridge segment is the shoalest portion of that segment. The OSCs and zones of transform faulting are several hundreds of meters deeper than the ridge centers. This phenomenon is quite common along the EPR and has also observed at the Galapagos Rift, the Mid-Atlantic Ridge, and the Juan de Fuca Ridge. Several other along-strike gradients have been observed within given ridge segments. First, the abundance of sheet flows seems to increase toward the central high, with pillow basalts more common at the lower distal ends. Second, the degree and density of fracturing seems to be less as the central high is approached. Finally, the abundance of hydrothermal venting seems to increase toward the central high.

Since their discovery at the Galapagos Rift in 1977, hydrothermal vents have been shown to be a common feature of medium- to fast-spreading centers (Corliss et al. 1979; Ballard and Francheteau 1982; Francheteau and Ballard 1983). Active hydrothermal systems can have water temperatures in excess of 350° C and pH values close to 2. Hydrothermal alteration of the lower crustal layers in ophiolites and that observed below 600 m (1,968 ft) in DSDP Hole 504b clearly indicate that hydrothermal alteration is a major crustal formation process. As such, it is likely to be a major focus of any near-axis drilling of the EPR near 13° N latitude.

The French conducted an intensive survey of the EPR, using SEABEAM, followed up by submersible and deep tow camera surveys in the area near 13° N latitude. In 1982, a French expedition utilizing the submersible CYANA was conducted in the area of the axis at 12° 49' N latitude. Here, a series of high-temperature "black smoker" vent sites were located over a distance of 8 km (5 mi), and sulfide deposits on either end of this active zone were mapped for a total linear distance of 17 km (11 mi) (Ballard and Francheteau 1982). Individual vent deposits were 10-50 m (33-164 ft) in diameter, with 100-200 m (328-656 ft) between deposits. Subsequent dives in the area also located enormous massive sulfide deposits on the western flank of a seamount to the east.

These observations have led to a number of speculations about subcrustal structure near a spreading axis. Geochemical arguments almost certainly require a relatively shallow crustal magma chamber lying between 1 and 3 km (0.6 and 1.8 mi) depth. The shoaling of each individual ridge segment at the center has led several authors to argue that a permanent magma chamber

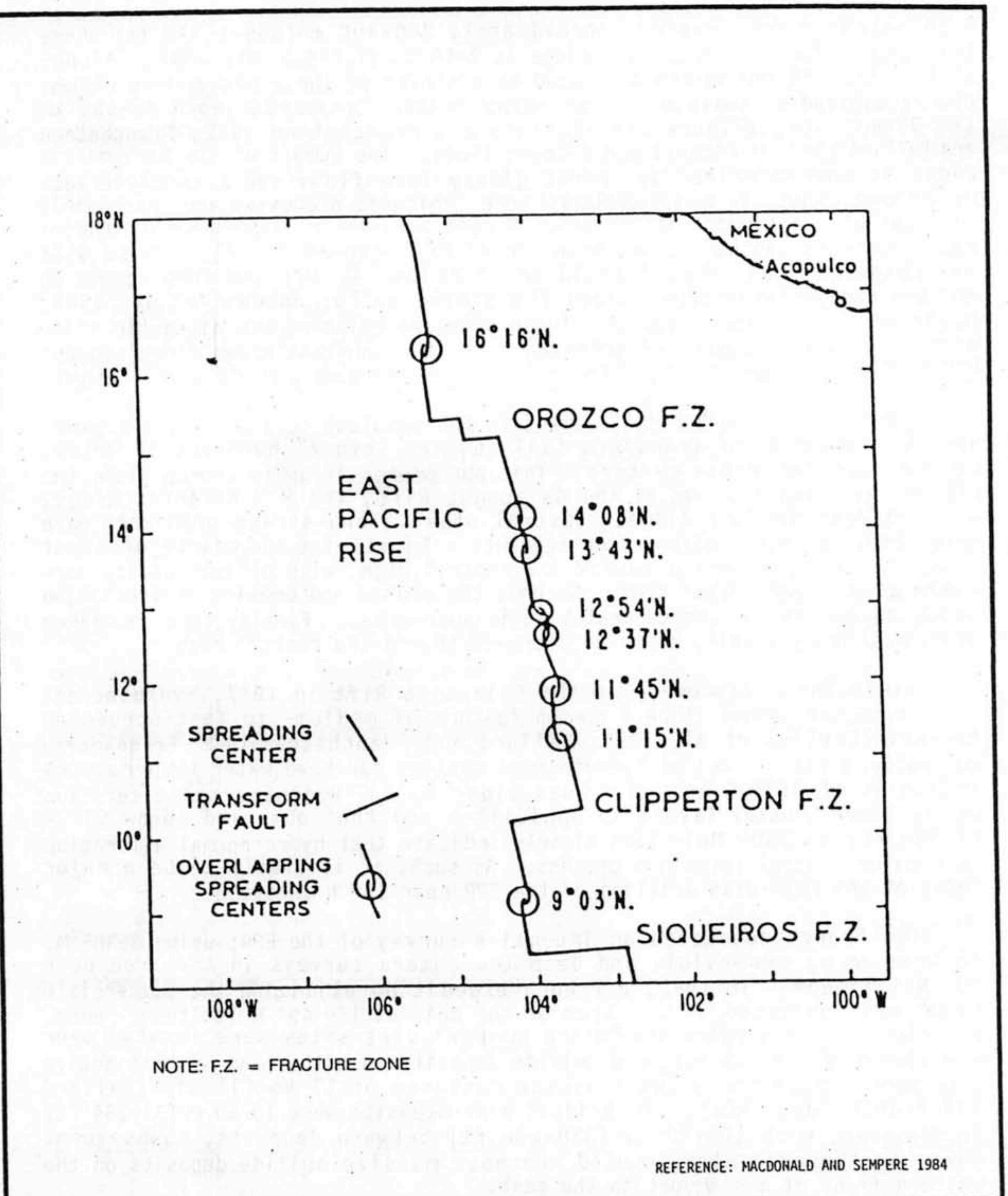


Figure 28. The East Pacific Rise Spreading Center in the representative drill site region.

underlies the central portion of the ridge segment and that there are only occasional magma excursions to the distal ends of the segments. Such a model is consistent with the observed hydrothermal activity at the shoalest portions of the segments and with all the other geological features.

Acoustical Environment--

Ambient noise levels are characterized by large variability due to numerous components, as discussed in detail under the Weddell Sea acoustic environment.

BIOLOGICAL CONDITIONS OF THE REPRESENTATIVE DRILLING AREAS

Weddell Sea

Phytoplankton--

Two phytoplankton communities have been documented in the Southern Ocean. One (pelagic) inhabits the water column and the other (epontic) inhabits the intersticies of sea ice. Both contribute to the extremely high primary production of the antarctic marine ecosystem, including the Weddell Sea.

The water-column phytoplankton community is dominated by diatoms, about 100 species of which are found in antarctic and subantarctic marine waters (Balech et al. 1968). Dinoflagellates are second in importance in antarctic waters. Other phytoplankters in antarctic waters and the Weddell Sea include silicoflagellates, naked flagellates, and radiolarians (Balech et al. 1968; El-Sayed and Turner 1977; Nelson and Gordon 1982). However, they have not been studied extensively because they are difficult to collect.

Photosynthetic activity in the water column is highest in the austral spring and summer. Whereas average yearly production for the Weddell Sea is estimated at 84 g C/m^2 (El-Sayed and Mandelli 1965), average primary productivity in the Weddell Sea during the austral spring is estimated at 220-420 $mgC \cdot m^{-2} \cdot day^{-1}$ (Jennings et al. 1984). Dense phytoplankton blooms which often occur near the marginal ice zone contribute to the higher productivity values estimated for the spring and summer months (Smith and Nelson 1985). Standing crops of phytoplankters in surface waters near the drilling area of 0-0.49 mgC/m^3 and photosynthesis rates of 0-29.9 mg $C \cdot m^{-2} \cdot h^{-1}$ have been measured (Balech et al. 1968). Similar standing crops and rates of photosynthesis were reported for stations in the drilling area that were sampled in the austral summer of 1977 (El-Sayed and Taguchi 1981). However, there is considerable regional and temporal variation (El-Sayed and Mandelli 1965; El-Sayed and Taguchi 1981; Hayes et al. 1984; Smith and Nelson 1985). Dense phytoplankton blooms may occur near marginal ice zones (Smith and Nelson 1985). Chlorophyll a values and photosynthesis rates are closely correlated (r=0.97) (El-Sayed and Mandelli 1965).

In contrast to other regions of the world ocean, nutrients necessary for primary production (i.e., nitrates, phosphates, silicates, trace metals, vitamins) are rarely, if ever, limiting in the antarctic (El-Sayed and Mandelli 1965; El-Sayed 1966; Hayes et al. 1984). For this reason, it is unlikely that nutrients caused the observed spatial and temporal variations. Water column stability, grazing, and proximity to land masses are more likely causes (El-Sayed and Taguchi 1981). Primary productivity is enhanced in areas where the water in the euphotic zone is well-mixed and water below the photic zone is stratified. Grazing by zooplankters (primarily krill and copepods) appears to consume a substantial proportion of the phytoplankton production. Finally, proximity to land masses appears to be correlated with high primary production (El-Sayed and Taguchi 1981), but possible causes of this relationship are unclear (Hayes et al. 1984).

The sea-ice phytoplankton community consists of the snow and epontic communities. The snow community occurs when the weight of the snow on the sea ice causes the ice surface to be depressed below the water surface. Seawater and planktonic organisms flood the snow, and a biological community 15-100 cm (6-39 in) thick begins to develop in the slush. This layer may be frozen during cold weather, although snow above the slush layer often insulates it (Horner 1976). Diatoms are important components of the snow community (Horner 1977). The average chlorophyll a concentration of the snow layer is estimated at 97 mg/m^2 (Horner 1977). Primary productivity is estimated at 0.19 mg $C \cdot m^{-2} \cdot h^{-1}$.

The epontic community consists of at least 32 species of diatoms plus other microorganisms that inhabit the undersurface of the ice or brine pockets in the ice (Horner 1977). Most species of epontic diatoms are adapted to light levels at the lower limit of the euphotic zone (e.g., less than 1 percent of surface light intensity).

Ice algae in the antarctic begin to multiply in the brash ice in July. By December, they may reach densities greater than 10^6 cells/l. Areas bare of snow tend to have the highest cell concentrations, while areas of heavy snow have lower concentrations. Annual production is on the order of 500-1,000 mg C/m^2 during the peak growing season (Horner 1976). Bacteria are also present in these epontic communities. It is hypothesized that the microalgae stimulate bacterial growth (Grossi et al. 1984), and that the bacteria are a source of secondary production (Sullivan and Palmisano 1984). Ice algae released from melting ice during the spring and summer months may serve as an innoculum for phytoplankton blooms which occur in the water column (Smith and Nelson 1985). Moreover, reduced surface salinity may increase water column stability and thereby promote the bloom (Smith and Nelson 1985).

The highest concentrations of epontic organisms in the Weddell Sea are found at depths of 0.65-2.15 m (2.1-7.0 ft) within the ice (Ackley et al. 1979) and are strongly associated with salinity maxima in the ice. Chlorophyll a concentrations of 0.31-4.54 mg/m^3 were found in the study area (Ackley et al. 1979). Based on these data, Ackley et al. (1979) concluded that standing crops of ice algae "can represent a minor but significant fraction of the total standing crop of the region."

Epontic communities also occur in arctic regions, and many of the mechanisms which are hypothesized to occur in antarctic regions are also hypothesized to occur in the arctic. For example, spring phytoplankton blooms often occur near ice melting edges where epontic diatoms may serve as an innoculum (Schandelmeier and Alexander 1981). The melting ice also appears to promote phytoplankton blooms in the marginal ice zone by reducing surface salinities and thereby increasing vertical stability in the water column (Alexander and Niebauer 1981; Niebauer et al. 1981).

Zooplankton--

Although zooplankton are the major link between primary producers (i.e., phytoplankton) and higher trophic levels in all oceans, antarctic zooplankton are relatively more important than those in other ocean ecosystems. First, antarctic food chains are very short (e.g., baleen whales, crabeater seals, penguins, fish, and squid occupy only the third trophic level in Figure 29). Second, relatively more energy transfer between primary production and higher trophic levels occurs via zooplankton because ice scouring inhibits attached algae at shallow depths. Third, standing stocks of zooplankton in the antarctic are substantially greater than those in most temperate and tropical water [e.g., 55.2 mg/m^3 for the upper 50 m (164 ft) and 25.6 mg/m^3 for the upper 1,000 m (3,280 ft) of water (Knox 1970)]. In addition, zooplankton growth is extremely intense, but temporally restricted due to the severe climate.

Antarctic zooplankton may be divided into two groups based on size and mobility. One group, net plankton, includes small species that are readily captured in a towed net with a mesh size of 1.0 mm (0.04 in) or less. Net avoidance by these species is minimal. The other group includes large, motile species that readily avoid small plankton nets, but that may be captured in trawls. The principal component of this group is euphausid crustaceans, commonly known as krill. Nearly all zooplankters in antarctic waters are holoplankton, or permanent members of the plankton community. Meroplankton (plankters that are larval forms of nektonic or benthic species) are uncommon (see Arnaud 1977).

Major components of the net zooplankton include copepods, chaetognaths, tintinnids, polychaete larvae, and ostracods (Hopkins 1971; Fukuchi and Tanimura 1981). Radiolarians, foraminiferans, medusae, siphonophores, amphipods, pteropods, echinoderm larvae, and appendicularians also occur, and may be locally or seasonally important. Although most net zooplankton occur in the upper 250 m (820 ft) of the water column, they are abundant as deep as 1,000 m (3,281 ft), the depth to which many species undergo annual vertical migrations (Hopkins 1971). Net zooplankton stocks are both spatially and temporally variable, with highest stocks generally occurring during the austral summer. Peak densities may exceed 4,000 individuals/m^3 (Fukuchi and Tanimura 1981).

Euphausids, or krill, are the most important single component of the antarctic zooplankton community. They are a major prey item for higher trophic levels (Figure 29) and they are very abundant. Although spatially and temporally variable, krill may constitute up to 50 percent of the total zooplankton biomass (Knox 1970; Rakusa-Suszczewski 1983). Krill biomass is estimated at 30-50 mg/m^3 for all antarctic waters (see Knox 1970; Everson 1981a). However, such estimates are crude, due to the difficulties of sampling patchily distributed, motile organisms.

Numerous euphausid species occur in antarctic waters. Each is distributed around the continent and each is associated with at least one water mass

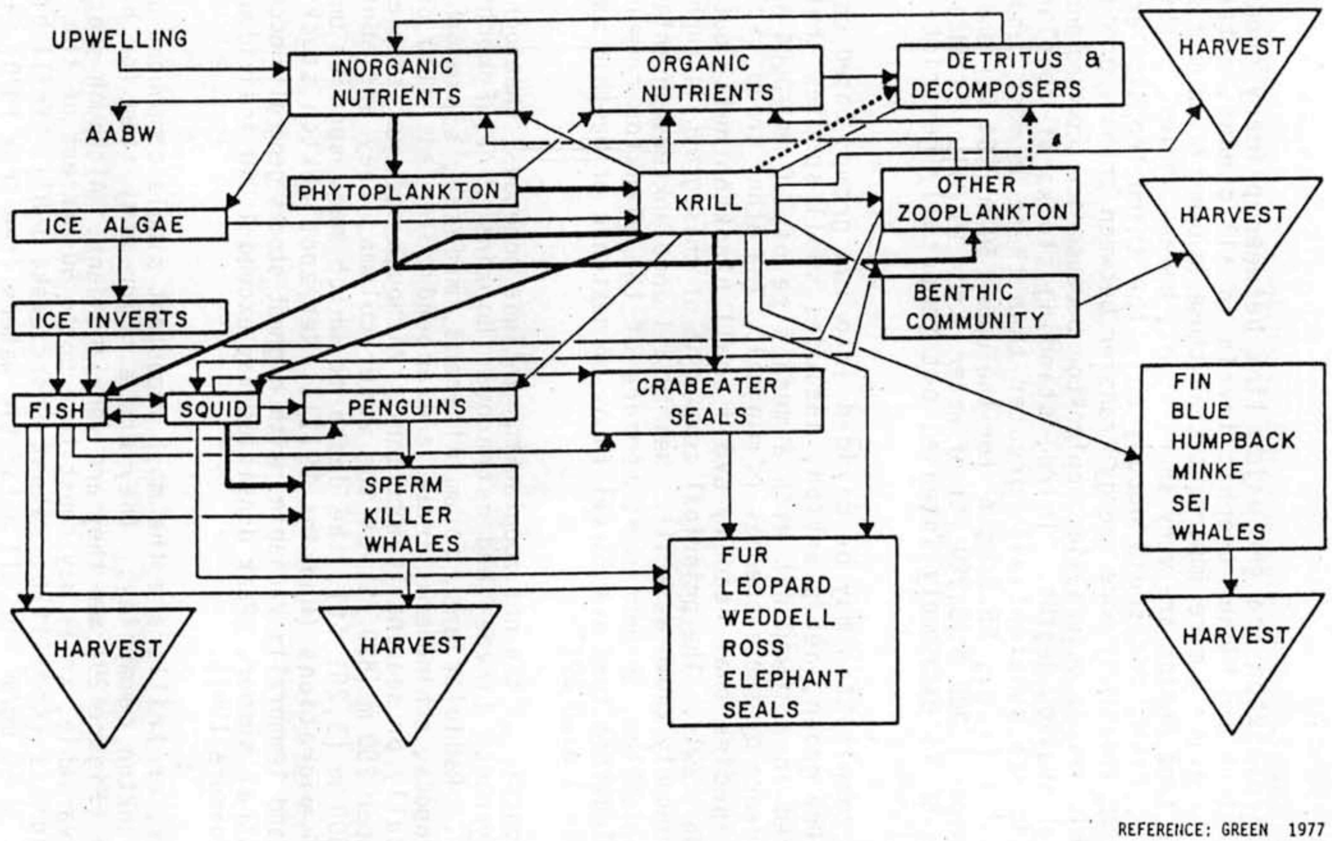


Figure 29. The Antarctic food web.

(Figure 30). Major krill concentrations occur in the northern and eastern portions of the Weddell Sea (Figure 31). Euphausia superba is the most abundant species and is therefore a key trophic link in the antarctic marine ecosystem. Its principal zone of distribution is between the continental shelf break and the mean extent of the pack ice.

Krill are often found in dense swarms 2-300 m (6-984 ft) long (Nemoto et al. 1981). Swarm densities have been estimated at 6-60 kg/m^3, but such estimates incorporate large error factors (Everson 1981a). Food availability, light intensity, turbulence, eddy currents, spawning, and hydrodynamic conditions have been suggested as causal mechanisms for the formation of krill swarms, but no cause has been demonstrated conclusively (see Everson 1981a; Rakusa-Suszczewski 1983).

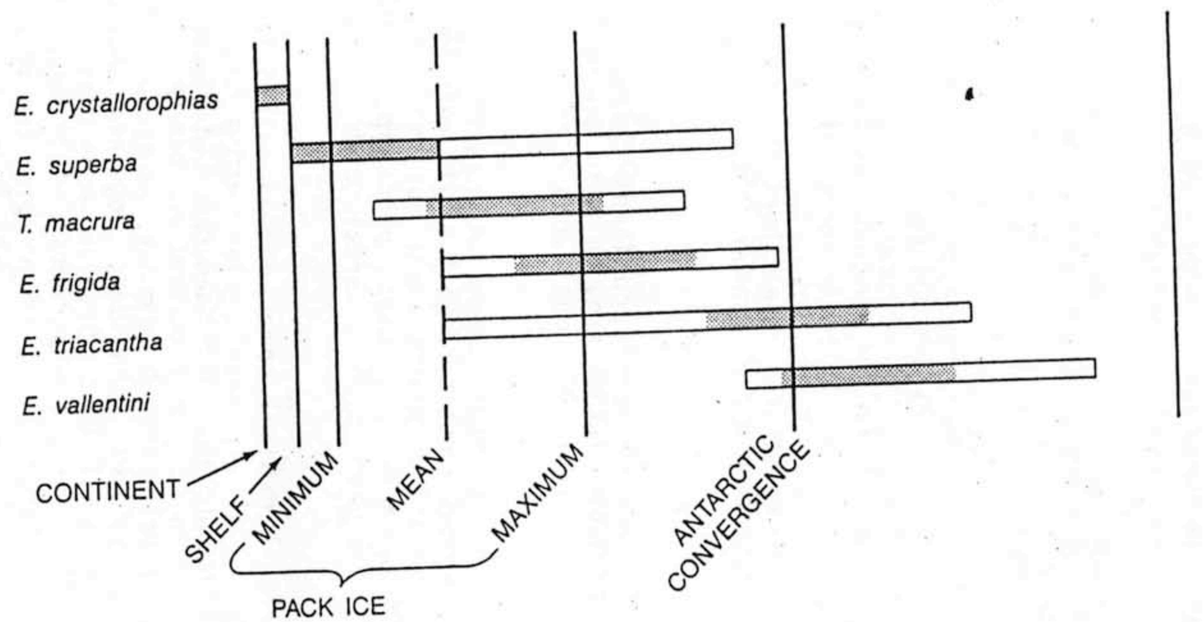
Krill spawn from November through April, with peak spawning in February or March. Released eggs develop as they descend through the water column. Upon hatching (which may be at a depth of several thousand meters), the nauplii ascend through the water column and continue developing (see Everson 1981a). It has been suggested that discrete stocks of Euphausia superba are maintained in the Weddell Sea and other antarctic regions where gyres occur. However, data collected by several researchers to test this hypothesis are contradictory (see Schneppenheim and MacDonald 1984).

Nekton--

Cephalopods and fishes are the most prominent members of antarctic nekton. As primary level predators (which are, in turn, consumed by marine mammals and birds), both are important components of the food web (see Figure 29).

Very little is known of the cephalopods in antarctic waters (Roper 1981), except that pelagic squids constitute most of the cephalopod biomass in antarctic waters and benthic octopods contribute the balance. Both serve as important prey for sperm whales, seals, penguins, pelagic birds, and fishes (Roper 1981). At present, 18 antarctic cephalopod species are known (Roper 1981).

The antarctic fish fauna exhibit some unusual attributes. First, the number of species is relatively small, considering the size of the region. Only 120 antarctic species have been recorded (DeWitt 1971), 10 of which are strictly abyssal forms. Most species are circumpolar. Second, four families of the suborder Notothenioidei dominate the fauna: Nototheniidae, Harpagiferidae, Bathydraconidae, and Channichthyidae. Together, they constitute 79 of the reported 120 species (DeWitt 1971) and more than 90 percent of the individuals (Targett 1981). Most (95 percent) of these Notothenioid fishes are endemic to the antarctic. Third, despite the great abundance of krill in the water column, highly motile, schooling species (such as tunas) which could prey on krill are not present in antarctic waters (Everson 1981b). Only one species is entirely pelagic, and it is not a schooling species. Three other nototheniid species live in association with the underice surface (DeWitt 1971). The remaining Notothenioid fishes are primarily demersal forms (DeWitt 1971), many of which have no swim bladder (Everson 1981b). Lastly, species in the family Channichthyidae lack hemoglobin and functional erythrocytes (see Everson 1981b).



REFERENCE: LAWS 1977 b

Figure 30. Oceanic zones occupied by selected species of krill (Euphausia, Thysanoessa).

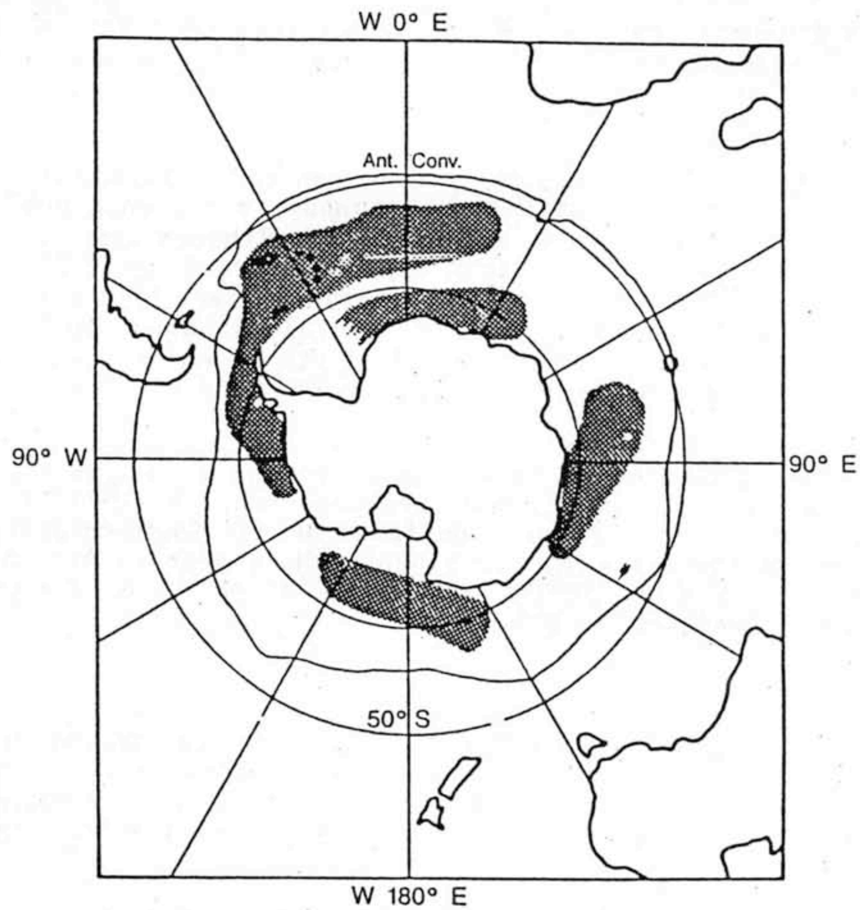


Figure 31. Distributions of major krill concentrations.

Two groups of antarctic fishes may be defined (DeWitt 1971): deep-sea species and coastal species. The two faunas overlap on the outer continental shelf and upper continental slope at depths of 500-700 m (1,600-2,300 ft) around the continent proper, and at greater depths offshore the Antarctic Peninsula. Characteristic deep-sea fauna include members of the families Synaphobrachidae (one species), Halosauridae (one species), Brotulidae (one species), and Macrouridae (seven species). The coastal fishes are dominated by species in the suborder Notothenioidei, although species in 10 other families are also present.

Coastal antarctic fishes typically feed upon krill and benthic invertebrates (e.g., polychaetes, amphipods, isopods, echiurans, ophiuroids, scaphopods, tunicates, shrimps, and mysids), although some species feed on pelagic chaetognaths and calanoid copepods (see Targett 1981; Naito and Iwami 1982; Takahashi 1983). Food resources are highly partitioned among the numerically abundant species of coastal fishes of South Georgia Island, the South Sandwich Islands, and the South Orkney Islands. However, a given species does not always consume the same prey at different study sites (Targett 1981).

Reliable estimates of species abundances for fishes in the Weddell Sea are not available. However, SCOR Working Group 54 (1977) listed 12 species believed to be of major importance in the Southern Ocean, 10 of which occur around the Antarctic continent. Many species are small, as evidenced by mean species lengths of less than 43 cm (17 in) for the notothenioid families (Andriyashev 1965).

Benthos--

The distribution of marine benthic invertebrates in Antarctica is generally considered to be circumpolar (see Knox and Lowry 1977). However, there are three major vertical zones of benthic fauna, as defined by the distribution of substrate types and the presence of sea ice (see Dell 1972 for a review).

Zone I occurs at depths of 0-15 m (0-49 ft). Intense ice scouring occurs within this zone and only motile benthic invertebrates are common. Representatives include echinoderms, nemerteans, snails, isopods, and a few pycnogonids (sea spiders). Typically these omnivorous and carnivorous organisms are sparsely distributed.

The second zone occurs at depths of 15 to 33 m (49 to 108 ft). The bottom of the zone [33 m (108 ft)] is well-defined, since this is the lower limit of anchor ice formation. Anchor ice forms by in situ crystallization, and may physically remove bottom biota when blocks become large enough to break free of the substrate. Sessile forms are common in Zone II. Dominant taxa include large hexactinellid sponges; demosponges, octocorals, anemones, and ascidians. The sponges, hydroids, and ascidians are suspension feeders, while the anemones typically prey on medusae. The motile organisms found in Zone I are also common in Zone II.

The upper limit of Zone III is sharply defined at the lower limit of anchor ice formation [33 m (108 ft) depth]. The lower limit is not well-defined, but often extends to depths greater than 500 m (1,640 ft).

This community is characterized by a nearly complete mat of living sponges, sponge spicules, bivalve shells, hydroids, gorgonian corals, and bryozoans. The sponge mat is usually at least 1 m (3.3 ft) thick, and forms a habitat for many other sessile and motile organisms. Overall, sponges and other sessile suspension feeders form the basis of this community. Other organisms that commonly occur in association with the sponge mat include suspension-feeding bivalve molluscs, gastropods, predatory and detritus-feeding asteroids, and predatory nudibranchs and snails.

Volcanic debris is sometimes encountered on the continental shelf within Zone III. This substrate supports a fauna of hexactinellid sponges and anthozoans. Associated with these sessile forms may be isopods, nemerteans, ophiuroids, asteroids, amphipods, mysids, cumaceans, tanaids, snails, and bivalve molluscs.

The suspension-feeding communities found at depths greater than 33 m (108 ft) may exhibit very high standing stocks. Biomass of a sponge-mat community off the East Antarctic Shelf is estimated to reach 1,347 g/m^2 at depths of 100-200 m (328-656 ft), 293 g/m^2 at depths of 200-500 m (656-1,640 ft), and 43 g/m^2 at depths of 500-1,000 m (1,640-3,280 ft) (Belyaev and Uschakov 1957). These dense, diverse assemblages on the continental shelf and slope depend directly on organic particulates generated in the water column during the austral summer.

Two deep soft-bottom communities are often found in antarctic waters. The deep-shelf assemblage occurs in areas of mud or sandy mud; erratic boulders may be present. Common organisms include tubiculous polychaetes, sipunculid worms, foraminifera, ophiuroids, rat-tailed holothurians, pycnogonids, corals, scaphopod molluscs, and asteroids. The deep-slope community is found at depths of 1,200-2,200 m (3,936-7,216 ft) on diatomaceous ooze. Infaunal and epifaunal invertebrates are sparsely distributed in this habitat.

In addition to the major benthic communities described above, occasional shallow-water, soft-bottom communities occur in antarctic waters. Such communities have been documented at Arthur Harbor on the Antarctic Peninsula (Lowry 1975) and in Chile Bay on Deception Island (Gallardo et al. 1977). Based on the limited information available, it appears that faunal composition differs substantially among these habitats.

In addition to benthic macrofauna, benthic macroalgae have been collected at scattered antarctic locations where conditions permit macroalgal growth (Balech et al. 1968). Red and brown algae appear to dominate such communities (Balech et al. 1968). As in temperate and tropical latitudes, an epifaunal community is associated with the algal canopies (see Price and Redfearn 1966). Polychaetes, molluscs, crustaceans, nemerteans, and turbellarians are typically present among the macroalgae.

Marine Mammals and Birds--

Seals--Seal species likely to inhabit the Weddell Sea are listed in Table 8. Pack-ice around the continent provides year-round habitat for four phocid species (true seals): crabeater, leopard, Ross, and Weddell seals. Distribution, habitat requirements, and prey vary from species to species (Table 8, Figure 32). Each species inhabits a different concen-

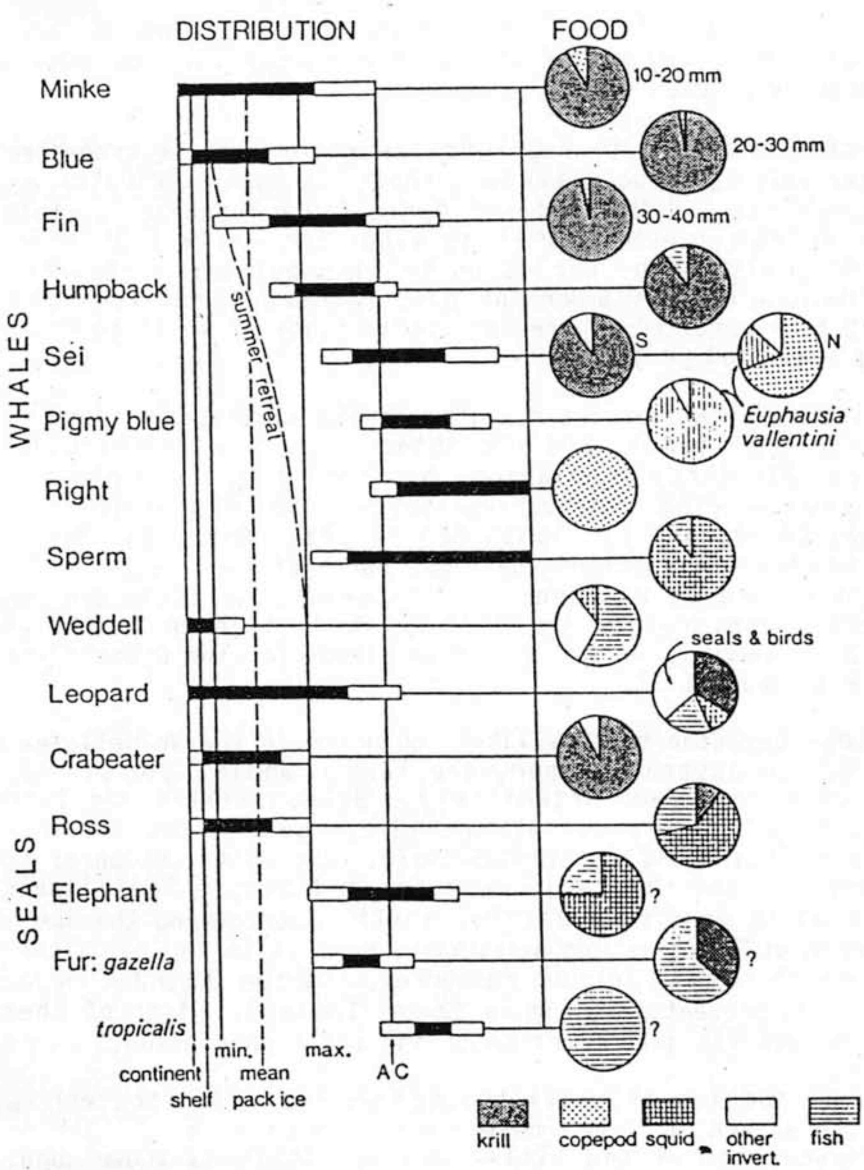
TABLE 8. SEAL SPECIES IN THE WEDDELL SEA REGION

Common Name	Scientific Name	Distribution and Habitat
Crabeater seal	Lobodon carcinophagus	Pack ice with small ice floes, 30-70% ice cover. Feeds on mainly krill. Segregated by age with mature animals at pack ice periphery, younger ones towards the interior. Predation by killer whales and leopard seals is probably significant source of mortality.
Leopard seal	Hydrurga leptonyx	Pack ice. Feeds on krill, fish, other seals (particularly young crabeaters), and occasionally penguins.
Ross seal[a,b]	Omatophoca rossi	Pack ice of 50-70% ice cover. Very rare in Weddell Sea, higher concentrations in Amundsen, Bellingshausen and King Haakon VII seas. Occurs in solitary or small groups. Feeds on mainly cephalopods, also some fish and krill.
Weddell seal[b]	Leptonychotes weddelli	Near Antarctic shore in fast ice. Pupping aggregates found along perennial tide cracks. Feeds on fish, crustaceans (including krill), and cephalopods.
Elephant seal[b]	Mirounga leonina	Pups on Georgia, Sandwich, Orkney, and Shetland Islands. Feeds on fish and cephalopods.
Antarctic fur seal[a,b]	Arctocephalus gazella	South Georgia Island (main population). Breeds on islands south of Antarctic Convergence. Feeds on mainly krill, also some fish and squid.
Sub-Antarctic fur seal[a,b]	Arctocephalus tropicalis	Breeds on islands north of Antarctic Convergence, rarely in Weddell Sea. Feeds on fish, squid, and rock lobster.

[a] Species designated as Specially Protected under the Agreed Measures for the Conservation of Antarctic Fauna and Flora (Public Law 95-541) (NSF 1982).

[b] Species designated as Protected Species pursuant to Article 3 of the Convention for the Conservation of Antarctic Seals.

References: Erickson et al. (1971); Erickson and Hofman (1974); BIOMASS (1977); NSF (1979).



NOTE: THE RELATIVE AREA OF THE SHELF: THE MAXIMUM, MEAN AND MAXIMUM PACK-ICE AREA; AND THE AREA SOUTH OF THE ANTARCTIC CONVERGENCE(AC) ARE INDICATED. EACH SPECIES, EXCEPT THE FUR SEALS, HAS A CIRCUMPOLAR DISTRIBUTION AND THE RANGES INDICATED ARE THE APPROXIMATE AVERAGE LATITUDINAL RANGES IN THE SOUTHERN OCEAN, THE BLACK PART INDICATING HIGHER DENSITIES. PIE DIAGRAM INDICATES THE FOOD COMPOSITION AND MAJOR UNCERTAINTIES ARE SHOWN (?).

REFERENCE: LAWS 1977a

Figure 32. Distributions and food sources of marine mammals in the Weddell Sea.

tration of pack ice or fast ice. With the exception of leopard seals, which occasionally prey on the others, these seal species are rarely seen in the vicinity of each other.

A recent increase in reproductive rates for the crabeater seal, and to a lesser extent, leopard and Ross seals has been attributed to increased prey availability (U.N. Food and Agriculture Organization 1978). Stocks of baleen whales depleted by whaling since the early 1900's has resulted in reduced predation by whales on krill populations (Conroy 1975, Laws 1977b). Release of this important prey resource from its major predator appears to have resulted in greater availability of krill to other predators, including seals and penguins.

Additional seal species residing in the antarctic include the southern elephant seal (a phocid), and the Antarctic and sub-Antarctic fur seals (otarids). All three populations had been heavily exploited by humans and are now recovering from near extinction. Southern elephant seals breed on islands throughout the South Scotia Sea. Antarctic fur seals breed mainly on South Georgia Island and range north of the ice pack to the convergence east of Drakes Passage. Sub-Antarctic fur seals are rare south of the Antarctic Convergence and have not been sighted in the Weddell Sea region. Distribution, habitat, and food items for these seals are indicated in Table 8 and Figure 32.

Whales--Cetacean species likely to occur in the Weddell Sea are listed in Table 9. In austral summer, the larger whales migrate to antarctic waters, where they feed intensively. Baleen whales may increase their body weights up to 50 percent at this time. Lesser increases occur among sperm whales (Laws 1977a; BIOMASS 1977). The distribution of these whales is circumpolar, and the larger species and larger individuals within a species tend to penetrate farther south, approaching the ice edge. This pattern, along with feeding specializations, results in an ecological separation of species with respect to food resources. Species distributions and preferred food items are presented in Figure 32 and Table 9. Most of these species depend on a specific size fraction of the krill population.

Several species of small toothed whales (odontacetes) reside year-round in the antarctic. The more common species are listed in Table 9. With the exception of the killer whale, little is known about the roles of these odontacetes in the ecosystem. The killer whale is a top-order predator, feeding on fish, squid, seals, penguins, and small whales.

Marine Birds--Bird species of the Weddell Sea are listed in Table 10. Six species inhabit and nest on the Antarctic continent proper: the emperor and adelie penguins, Antarctic and snow petrels, Wilson's storm-petrel, and south polar skua. General at-sea distributions and approximate locations of known major nesting areas are shown in Figure 33 (see Watson 1975 for detailed information). These species plus the cape petrel, which nests on South Georgia, South Sandwich, South Orkney, and South Shetland Islands, constitute the principal seabird populations of the representative drilling area.

Numerous less abundant bird species also inhabit the Weddell Sea (Table 10). Four additional penguin species breed near the Weddell Sea, one of

TABLE 9. CETACEAN SPECIES IN THE WEDDELL SEA REGION

Common Name	Scientific Name	Distribution and Habitat
Blue whale[a]	Balaenoptera musculus	Migratory austral summer feeder, averages 4 months in antarctic. Occurs up to the Antarctic shelf. Feeds mostly on krill.
Fin whale[a]	Balaenoptera physalus	Migratory austral summer feeder in antarctic. Feeds mostly on krill from ice edge to north of the Antarctic Convergence.
Sei whale[a]	Balaenoptera borealis	Migratory, with about half the southern stock feeding south of the Antarctic Convergence during austral summer. Feeds in open water away from the ice edge, mainly on krill and other small crustaceans.
Minke whale	Balaenoptera acutorostrata	Spends at least half the year in the antarctic. Occurs from the edge of the continent out to the Antarctic Convergence. Usually feeds in the ice zone, mainly on krill supplemented with copepods and squid.
Humpback[a]	Megaptera novaeangliae	Migratory austral summer feeder in antarctic. Feeds in open waters south of the Antarctic Convergence on krill and small fish.
Southern right[a]	Eubalaena australis	Rare south of the Antarctic Convergence. Feeds mainly on copepods.
Sperm whale[a]	Physeter catodon	Mature males migrate to antarctic during austral summer. Feeds in open, deep waters on squid and some demersal fish.
Pygmy right	Caperea magrinata	Only occasional sightings in the Scotia Sea. Feeds mainly on copepods and other small crustaceans.

TABLE 9. (Continued)

Killer whale	Orcinus orca	Antarctic resident. Occurs mainly in pack ice in all areas south of the Antarctic Convergence, up to the continent. Feeds on seals, penguins, fish, and small whales.
Southern bottlenose	Hyperoondon planifrons	Southern Ocean resident. Occurs in ice-free pelagic regions to north of the Antarctic Convergence. Little known about diet.
Southern giant bottlenose	Berardius arnuxii	Distribution similar to Hyperoodon. Little known about diet.
Cruciger dolphin	Lagenorhynchus cruciger	Southern Ocean resident in both Pacific and Atlantic sectors. Occurs in ice-free pelagic regions north to about 45° S latitude. Little known about diet.
Dusky dolphin	Lagenorhynchus obscurus	Circumpolar distribution, rare south of the Antarctic Convergence. Little known about diet.

a Endangered species as listed under the U.S. Endangered Species Act (16 USC 1531 et seq.) and therefore designated as Specially Protected under the Agreed Measures for the Conservation of Antarctic Fauna and Flora (Public Law 95-541) (NSF 1982).

References: Mackintosh and Brown (1974); BIOMASS (1977); Laws (1977); U.S. Department of State (1979).

TABLE 10. SEABIRD SPECIES IN THE WEDDELL SEA REGION

Regular or Common Occurrence	
Emperor penguin	*Aptenodytes forsteri*
Adelie penguin	*Pygoscelis adeliae*
Chinstrap penguin	*P. antarctica*
Light-mantled sooty albatross	*Phoebetria palpebrata*
Southern giant petrel	*Macronectes giganteus*
Southern fulmar	*Fulmarus glacialoides*
Antarctic petrel	*Thalassoica antarctica*
Cape petrel	*Daption capense*
Blue petrel	*Halobaena caerulea*
Antarctic prion	*Pachyptila desolata*
Snow petrel	*Pagodroma nivea*
Kerguelen petrel	*Pterodroma brevirostris*
Wilson's storm-petrel	*Oceanites oceanicus*
Black-bellied storm-petrel	*Fregatta tropica*
South polar skua	*Catharacta maccormicki*
Arctic tern	*Sterna paradisaea*
Periodic or Possible Occurrence	
King penguin	*Aptenodytes patagonicus*
Gentoo penguin	*Pysgoscelis papua*
Macaroni penguin	*Eudyptes chrysolophus*
Wandering albatross	*Diomedea exulans*
Black-browed albatross	*D. melanophris*
Grey-headed albatross	*D. chrysostoma*
Northern giant petrel	*Macronectes halli*
White-headed petrel	*Pterodroma lessoni*
Soft-plumaged petrel	*P. mollis*
White-chinned petrel	*Procellaria aequinoctialis*
Grey petrel	*P. cinerea*
Sooty shearwater	*Puffinus griseus*
South Georgia diving petrel	*Pelecanoides georgicus*
Blue-eyed shag	*Phalacrocorax albiventer*
American sheathbill	*Chionis alba*
Brown skua	*Catharacta lonnbergi*
Southern black-backed gull	*Larus dominicanus*
Antarctic tern	*Sterna vittata*

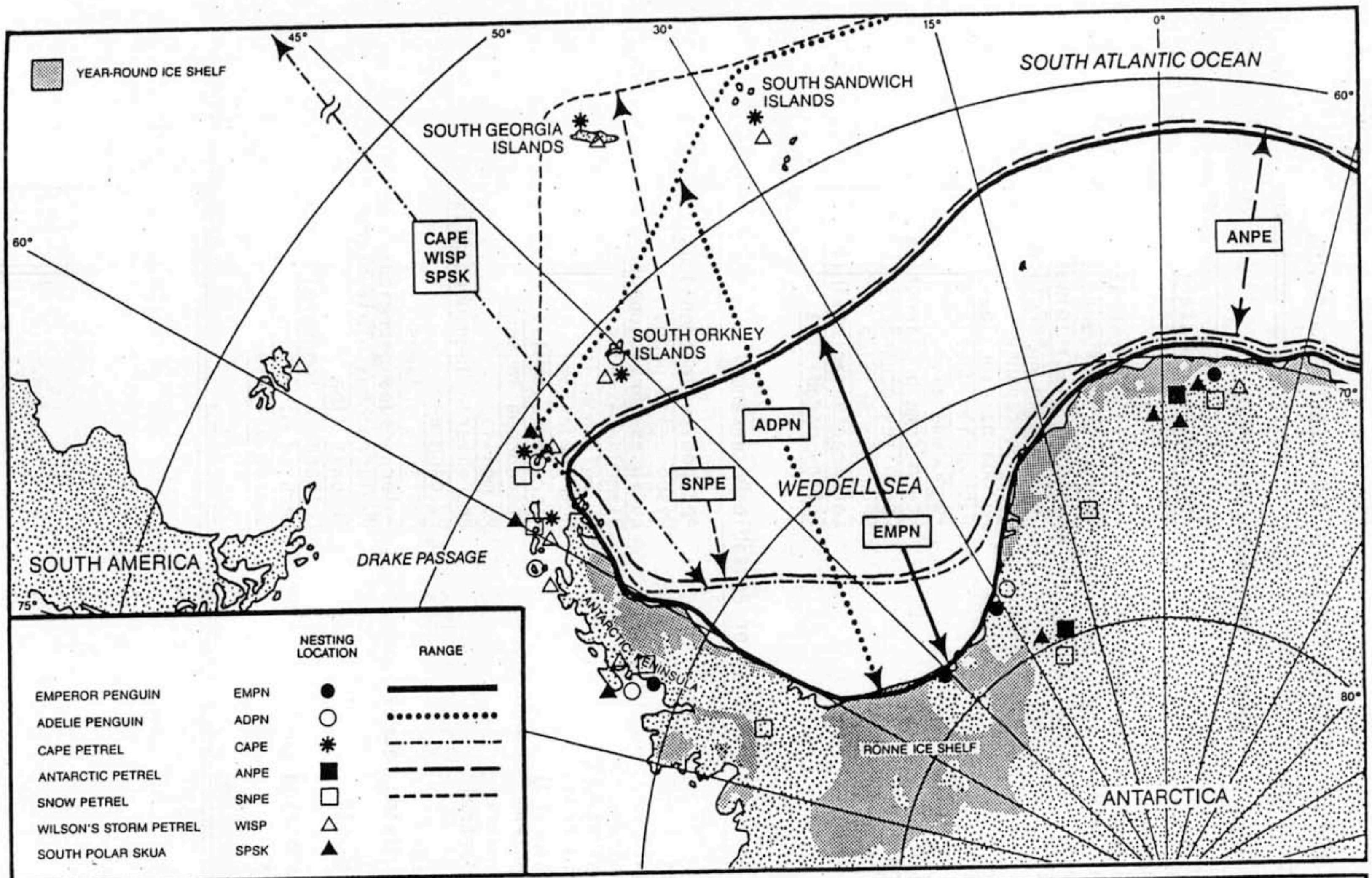


Figure 33. General distribution and nesting areas of seabird species in the vicinity of the Weddell Sea.

which, the chinstrap penguin, ranges regularly into it (Figure 34). Some petrel species that breed outside the Southern Ocean (Figures 35 and 36) forage regularly into the Weddell Sea region. Several additional species of petrels from other subantarctic regions (Table 10) may also forage in the Weddell Sea in small numbers. Other species that may occur in the area include the blue-eyed shag, American sheathbill, kelp gull, brown skua, and Antarctic tern (Figure 37). The Arctic tern also forages throughout the region in austral summer, but returns to the northern hemisphere in austral winter.

Most of the seabirds that occur regularly in the Weddell Sea region during the year (Figures 33-37) (see Cline et al. 1969; Tuck 1975; Watson 1975; Harrison 1983) are present only in ice-free areas. Emperor penguins, adelie penguins, and prions inhabit the shallow areas of the Weddell Sea. The other common species forage in deeper waters of the outer continental shelf and in pelagic waters. Large numbers of offshore-foraging species nest in coastal areas but do not forage in the nearshore habitat. However, due to the narrow shelf within the Weddell Sea, populations of shore-based breeders and offshore-based visitors forage relatively close to shore. Different species forage in different habitats. Important foraging areas include the ice edge, leads, and the shelf edge areas. Birds reportedly concentrate in the area of the Antarctic Convergence, although this feature may not be as important as generally believed (Ainley unpublished manuscript). Overall distribution and abundance vary temporally with ice conditions and extent.

Relative to habitats at lower latitudes, species diversity on the Antarctic continent proper is low. Diversities on the Antarctic Peninsula and on islands throughout the Southern Ocean are slightly higher. Abundances of specific seabird species inhabiting the Weddell Sea are not well-studied, but number of individuals per species is generally high. For example, relatively high densities were found for adelie penguins and a few other species in the Weddell Sea (Cline et al. 1969; Tuck 1975). In addition, Ainley (unpublished manuscript) described bird density in the general antarctic zone as $9.5/km^2$ (SD=7.4). This compares with bird density of $3.4/km^2$ (SD=2.9) in the tropical zone. Biomass in the antarctic was also much greater (e.g., 10 times) than that of the tropics (Ainley unpublished manuscript). Both biomass and numbers of the antarctic seabird population are dominated by penguins (Laws 1985).

Endangered Species--

Five cetacean species listed as endangered under the U.S. Endangered Species Act are known to occur in the antarctic region and one additional endangered cetacean species is a probable resident (SCAR 1977). The endangered species include the fin whale, blue whale, sei whale, humpback whale, right whale, and sperm whale. Baleen whales migrate into antarctic waters during the austral summer to feed and are found south of the Antarctic Convergence from November through March. Right whales are found south of the convergence only occasionally. One-third of the male sperm whale stock is assumed to feed south of the convergence during the summer months. All six species of endangered whales, the pigmy right whale, southern bottlenose, and giant southern bottlenose are listed under Appendix I of the Convention on International Trade of Endangered and Threatened Species of Wild Fauna and Flora

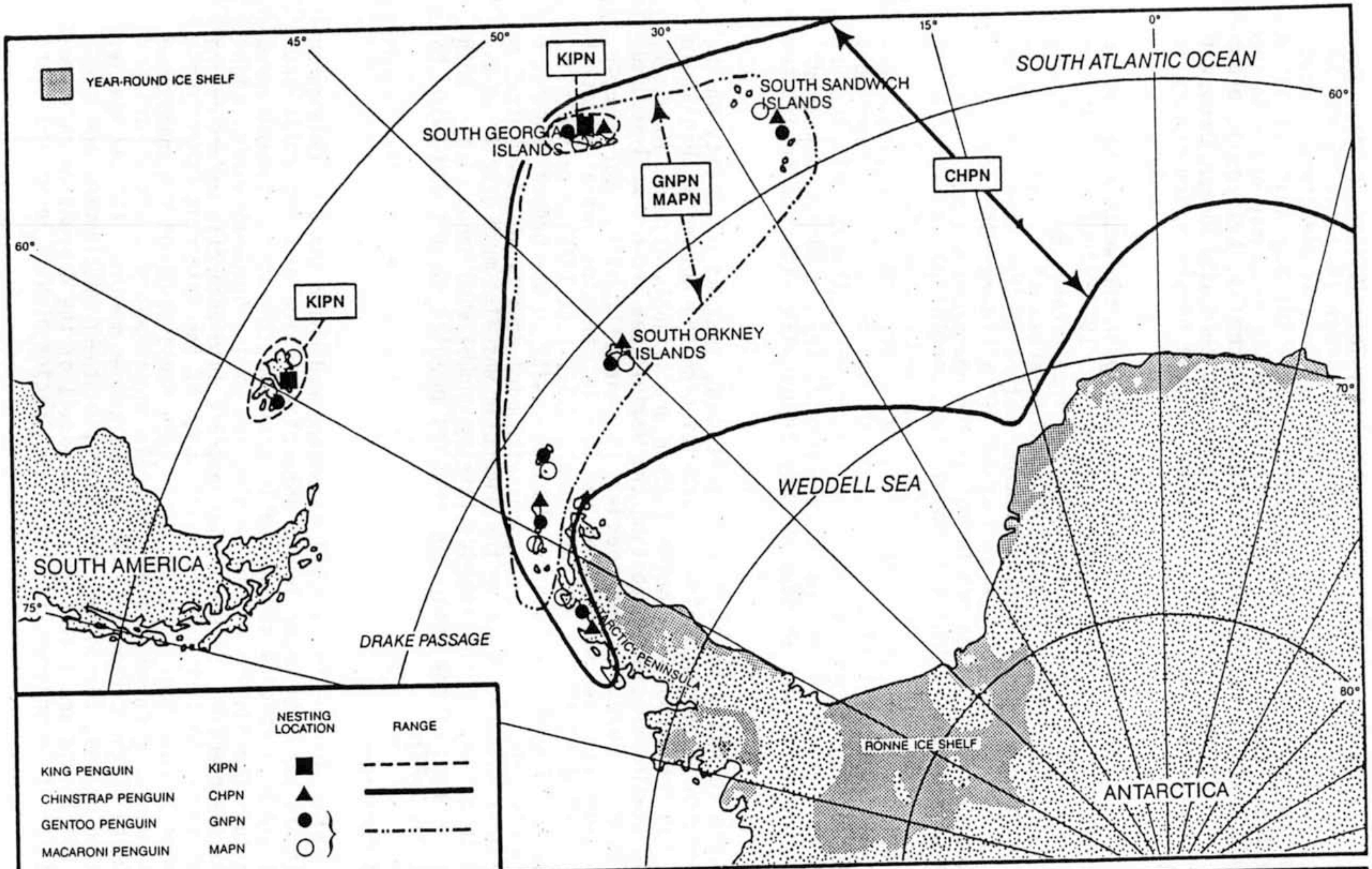


Figure 34. General distributions of penguin species that breed north of the Weddell Sea.

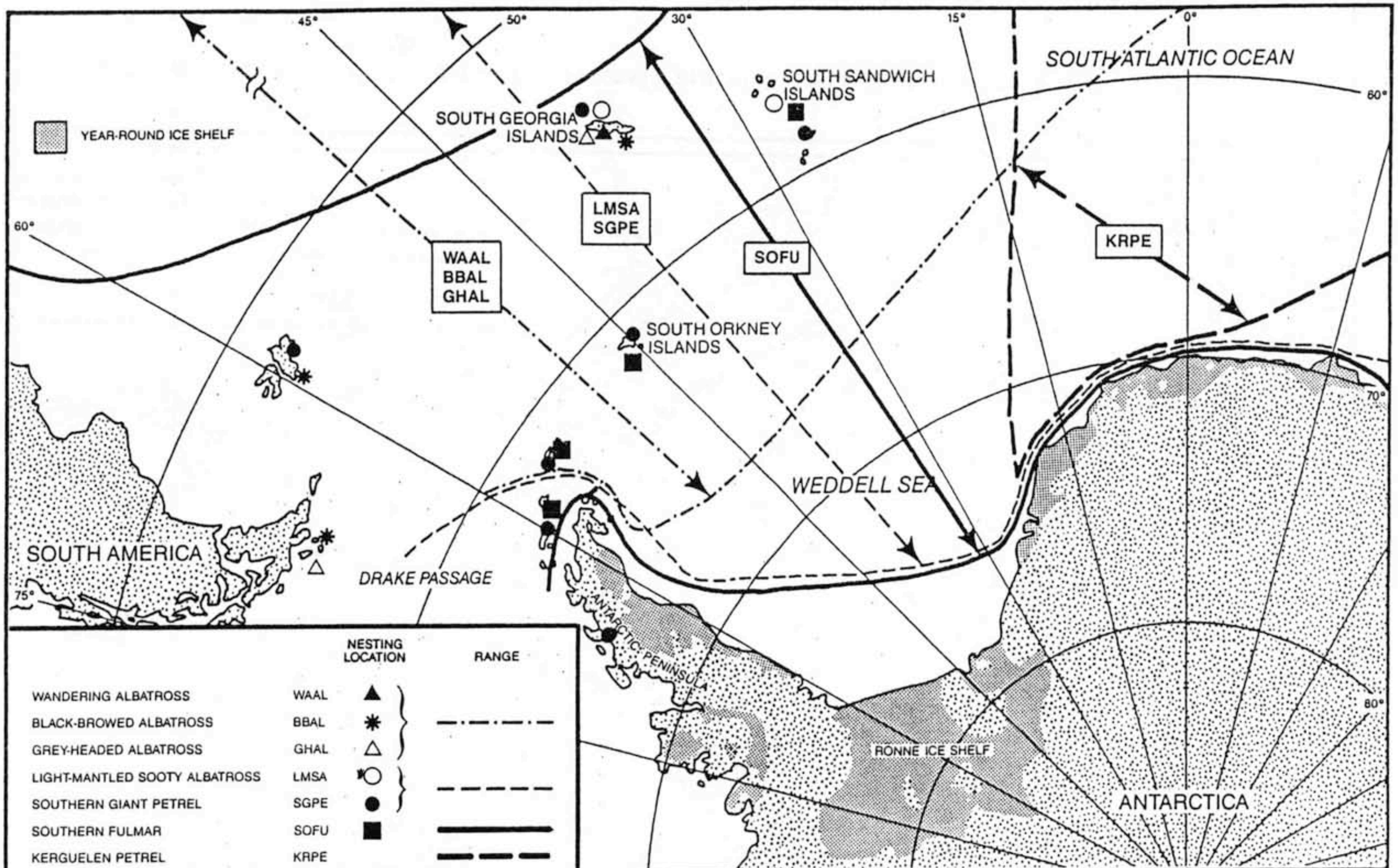


Figure 35. General distributions of large procellarid species that nest north of the Weddell Sea.

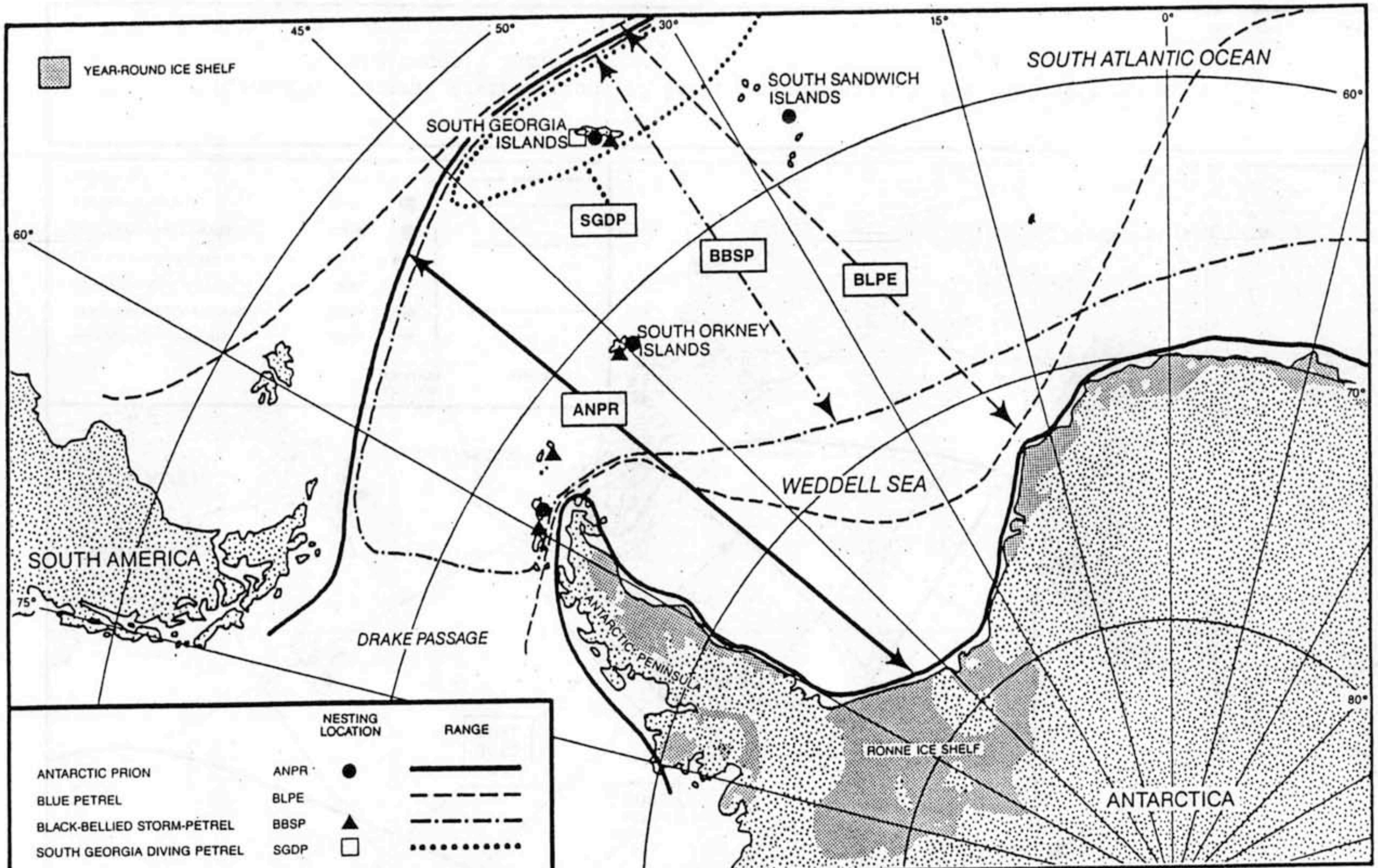


Figure 36. General distributions of small procellarid species that nest north of the Weddell Sea.

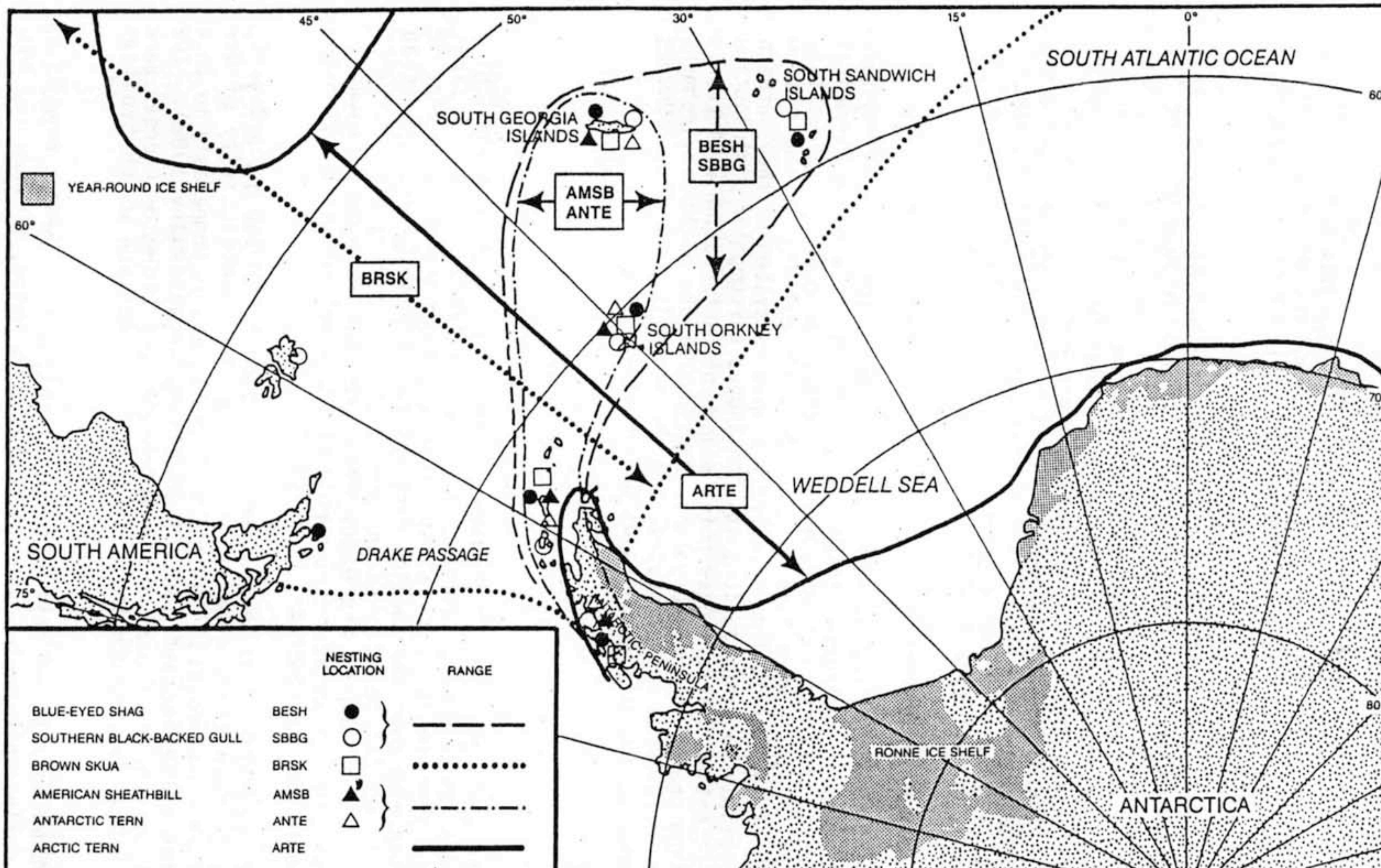


Figure 37. Other seabird species in the vicinity of the Weddell Sea.

(CITES). All cetacean species not included in Appendix I of CITES are listed under Appendix II. The blue whale and humpback whale are listed as endangered, and the fin whale and pigmy right whale are listed as vulnerable in the IUCN Red Data Book.

The Ross seal, the Antarctic fur seal, and the sub-Antarctic fur seal are listed as specially protected species by the Agreed Measures for the Conservation of Antarctic Living Marine Resources (NSF 1979). The Ross seal inhabits the ice pack throughout the Weddell Sea. The Antarctic fur seal is found throughout the Scotia Sea and ranges to the ice edge in the Weddell Sea. The sub-Antarctic fur seal is rare south of the Antarctic Convergence. The three specially protected species, the Weddell seal, and southern elephant seal are listed as protected species under the Convention for the Conservation of Antarctic Seals. The southern elephant seal is also protected under Appendix II of CITES.

Biologically Sensitive Areas--

The major concern in the antarctic is the fragile terrestrial ecosystem. The marine ecosystem is considered to be relatively robust, with environmental conditions that are less extreme, more uniform, and more continuous than those on land. These factors tend to increase the stability of the system (SCAR 1982). Even though the relatively simple ecosystem of the Southern Ocean is susceptible to perturbation, its continuous circumpolar distribution reduces the potential that a single point source of perturbation will result in any long-term change in the ecosystem. Portions of the marine environment that could be considered most sensitive are the ice-edge community, rookeries of marine mammals, and nesting sites of marine birds.

Georges Bank

Phytoplankton--

Two dominant hydrographic features interact to promote extremely high primary production in spring, summer, and fall on Georges Bank. A slow, anticyclonic gyre tends to retain plankters within the euphotic zone of a single water mass over the shallow portions of the bank [i.e., less than 50-80 m (164-262 ft) deep]. In addition, strong, rotary tidal currents lead to vertical mixing of the water mass over the shallow portions of the bank and thus to an abundant supply of dissolved nutrients for phytoplankton growth and reproduction (Riley 1982).

Primary production on Georges Bank is typically 300-500 g $C \cdot m^{-2} \cdot yr^{-1}$. This is two to five times greater than the primary productivity of New England coastal waters (100-150 g $C \cdot m^{-2} \cdot yr^{-1}$), and is comparable to that of productive estuaries and coastal upwelling areas (Riley 1982). The high standing stocks of benthic invertebrates and fishes on Georges Bank (discussed below) demonstrate the high primary production which typifies this area.

The standing crop of phytoplankton is highest in April. Production also peaks during this month, especially in shallow water, although periodic blooms of algae also occur in shallow water during summer and early fall (Riley 1982). Algal blooms may be inhibited by nutrient depletion, declining phytoplankton growth rates, phytoplankton senescence (which leads to their sinking out of the water column), consumption by zooplankton, and reduced light penetration due to high phytoplankton densities (i.e., self-shading) (Riley 1982).

Species composition of the phytoplankton population on Georges Bank varies spatially and temporally. Taxa that may be numerically abundant during one or more times of the year include two dinoflagellate species and numerous species of diatoms (Bigelow 1926).

Zooplankton--

Zooplankton are the major trophic link between the phytoplankton and higher trophic levels (primarily fishes and benthos) on Georges Bank (Figure 38). Standing stocks of zooplankton are slightly higher than standing crops of phytoplankton during most seasons of the year, but secondary production by zooplankton averages only 20 percent of the primary production (Riley 1982). Median standing stocks of <25-130 cc/100 m^3 were reported for the spring, summer, and autumn of 1977 (Sherman et al. 1978).

Both meroplankton and holoplankton are important components of the zooplankton on Georges Bank. For most benthic and demersal species with planktonic young, larvae are released into the water column in the spring or summer, when primary and secondary production are high and larval food supply is adequate. Fish larvae occur on Georges Bank throughout the year, however, since the periods of occurrence for many species tend to be successive rather than simultaneous (Sherman et al. 1978). Larvae released into the highly productive waters of Georges Bank tend to be maintained there by the slow, anticyclonic gyre. When the gyre persists during the warm months, recruitment of larval forms into benthic and demersal habitats may be enhanced.

Successful nurture and recruitment of meroplankters supports the fisheries resources of Georges Bank in two ways. First, many of the meroplankters are species of benthic invertebrates that will later be consumed by fishes. Second, many of the meroplankters are fish larvae. Of the 200 species of fish reported from Georges Bank, 26 are known to spawn there (U.S. Bureau of Land Management 1979), including the commercially valuable cod, haddock, yellowtail flounder, pollock, and silver hake. Most of these species have pelagic eggs and larvae.

Many commercially valuable species of benthic invertebrates, including sea scallops and lobsters, also have pelagic larvae. The unique circulation of Georges Bank may promote rapid growth, development, and settling of lobster larvae that are recruited into the coastal waters of southern Nova Scotia, the Bay of Fundy, and Maine (Harding et al. 1983).

Holoplankton of Georges Bank include copepods, chaetognaths, euphausids, coelenterates, cladocerans, salps, appendicularians, and ostracods (Sherman et al. 1978). Copepods are the most abundant group, accounting for 75 percent or more of the individuals. Of the 36 species collected by Sherman et al. (1978), three are considered numerical dominants.

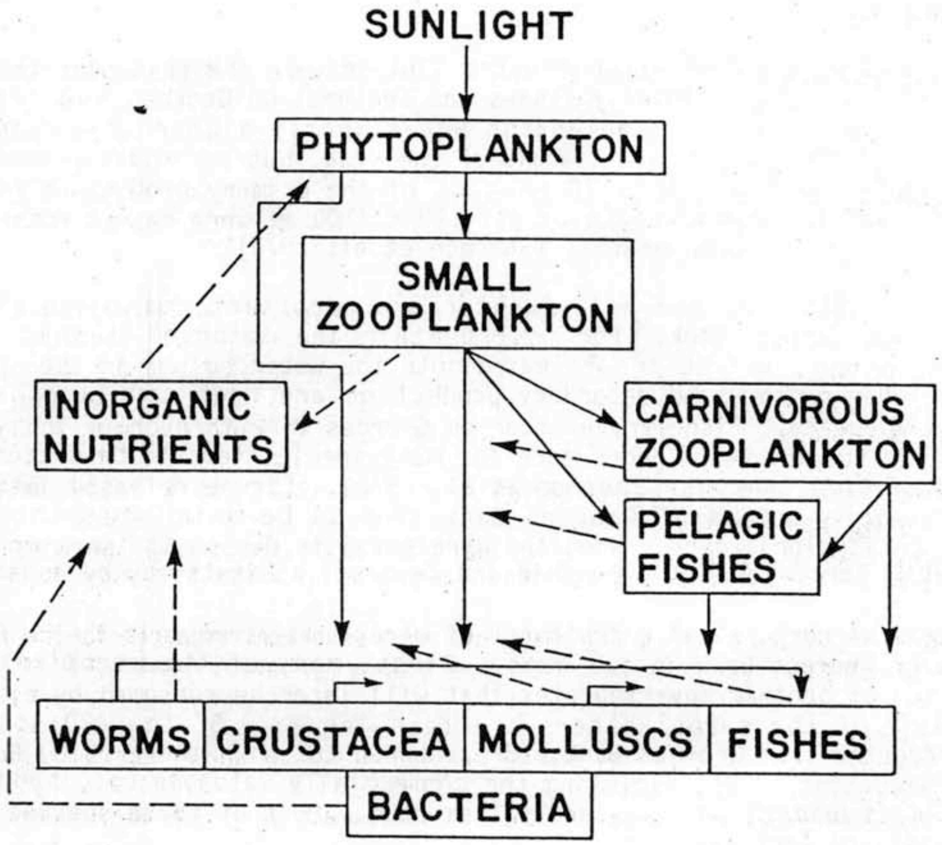


Figure 38. Simplified food web for Georges Bank.

Nekton--

About 200 species of fishes occur on Georges Bank (Bigelow and Schroeder 1953). Together with the squids, these species constitute the nektonic community. Secondary production by nektonic species is very high on Georges Bank due to high primary and secondary production rates by planktonic species.

Important commercial and sport fisheries species are listed in Table 11. Yellowtail flounder, cusk, and winter flounder are essentially non-migratory, while bluefish, butterfish, silver hake, mackerel, halibut, cod, haddock, red hake, pollock, herring, alewives, and shad migrate on and off the bank in an onshore-offshore direction or a north-south direction (U.S. Bureau of Land Management 1979). Eleven of the species in Table 11 spawn on Georges Bank, as do an additional 15 species that are not listed (U.S. Bureau of Land Management 1979).

Georges Bank has supported commercial and recreational fisheries for three centuries. These fisheries may be divided into four resource blocks (Edwards 1982):

- Cods, including cod, hake, and haddock (Table 11). Harvests for 1962-1977 averaged 260,000 mt/yr.
- Herrings, including Atlantic herring, shad, and alewives. Harvests for 1962-1977 averaged 230,000 mt/yr.
- Pelagic species, primarily mackerel, bluefish, and tuna. The target of intensive fisheries only recently, these species have sustained harvests of about 200,000 mt/yr.
- Flounders, principally yellowtail and winter flounders, which are harvested at a rate of about 50,000 mt/yr.

Fisheries stocks in the Middle Atlantic Bight, including Georges Bank, declined drastically during the 1960s and early 1970s (Clark and Brown 1977), primarily due to overfishing by foreign fleets. Environmental conditions and overfishing by the domestic fleet also contributed to the decline. During this 15-year decline, composition of the landings also changed, as fleets shifted from depleted stocks to relatively unharvested stocks. Landings of cods and other groundfish peaked in 1965, landings of herring peaked in 1969, and landings of mackerel peaked in 1973 (Edwards 1982). Declines in traditional fisheries stocks may have triggered changes in species composition, as evidenced by increased abundances of white hake, mackerel, and squids (Clark and Brown 1977). Although restrictions remain in effect for foreign fleets on Georges Bank, continued fishing pressure by domestic and Canadian fleets, coupled with the changed species composition, make it difficult to predict whether species composition and stocks will return to pre-1960 conditions.

Benthos--

Three benthic invertebrate species support major commercial fisheries: the highly prized northern lobster (<u>Homarus americanus</u>), the sea scallop (<u>Placopecter magellanicus</u>) and the deep-sea red crab (<u>Geryon quinquedens</u>)

TABLE 11. PRINCIPAL COMMERCIAL AND SPORT FISHERIES SPECIES ON GEORGES BANK

Common Name	Scientific Name	Commercial	Sport	Spawn On Georges Bank
Cods				
Atlantic cod	Gadus morhua	x	x	x
Haddock	Melanogrammus aeglefinus	x	x	x
Pollock	Pollachius virens	x	x	x
Cusk	Brosme brosme	x	x	x
Red hake	Urophycis chuss	x		x
White hake	Urophycis tenuis	x		
Silver hake	Merluccius bilinearis	x		x
Herrings				
Atlantic herring	Clupea harengus harengus	x		x
Shad	Alosa sapidissima	x	x	
Alewives	Alosa pseudoharengus	x		
Atlantic menhaden	Brevoortia tyrannus	x		
Pelagics				
Atlantic mackerel	Scomber scombrus	x	x	
Bluefish	Pomatomus saltatrix	x	x	
Butterfish	Poronotus triacanthus	x	x	x
Squid	Loligo pealei	x		
Squid	Illex illecebrosus	x		
Flounders				
Yellowtail flounder	Limanda ferruginea	x	x	x
Winter flounder	Hippoglossus hippoglossus	x	x	

Reference: Gusey (1977), Colton et al. (1979), U.S. Bureau of Land Management (1979).

(U.S. Bureau of Land Management 1979). Less important species with commercial value include northern shrimp (Pandalus borealis), surf clams (Spisula solidissima), ocean quahogs (Arctica islandica), and tanner crabs (Chionoecetes opilio) (Gusey 1977). Other benthic invertebrates are preyed upon by fishes and large epifaunal invertebrates (Figure 38).

In contrast to coastal stocks, lobsters inhabiting the outer continental shelf of Georges Bank and adjacent areas undergo extensive seasonal migrations (Cooper and Uzmann 1971). The observed shoreward migration during spring and summer may be required for molting and reproduction, since colder temperatures at the shelf edge may inhibit these activities (Cooper and Uzmann 1971). Because Georges Bank may be a critical spawning habitat for coastal and offshore lobster stocks throughout the Gulf of Maine (Harding et al. 1983), the migrating stocks may be very important to commercial fisheries throughout the region.

A varied and abundant benthic invertebrate fauna is found on Georges Bank. Of the 926 infaunal and epifaunal taxa found in eight surveys during 1982 and 1983 over the southern portion of the bank (Maciolek-Blake et al. 1984), polychaetous annelids (378 species), crustaceans (178 species), and molluscs (148 species) were best represented. Numerically abundant species at depths less than 60 m (197 ft) included tanaid crustaceans, polychaetous annelids, bivalve molluscs, and echinoids. At depths of 70-80 m (230-262 ft), polychaetous annelids, amphipods, and oligochaetes were abundant, while at depths of 100-145 m (329-476 ft), amphipods, and polychaetous annelids were abundant.

Numbers of infaunal species and infaunal abundances at the sampling stations were reasonably consistent at a given station over the eight survey periods, but varied considerably among stations (Maciolek-Blake et al. 1984). Numbers of species generally ranged from 40 to 150 per 0.24 m^2 (2.6 ft^2), while numbers of individuals generally ranged from 300 to 2,000 per 0.04 m^2 (0.43 ft^2). The investigators (Maciolek-Blake et al. 1984) concluded that community structure was reasonably constant through time at a given station, but varied spatially over the survey area. Differences in community structure among stations were highly correlated with depth and sediment type.

Epifaunal communities also varied with depth and sediment type. Stations at depths of 60-80 m (197-262 ft) exhibited sandy substrates and were populated by sand dollars, hydroid colonies, snails, crabs, and sea stars. At depths of about 100 m (328 ft), the sandy-silty sediments were populated by sea stars, sponges, anemones, sea scallops, and hydroids, plus several species of demersal fishes. Asteroids, onuphid polychaetes, crabs, and demersal fishes were abundant at greater depths [140-145 m (459-476 ft)].

Biota of the numerous canyons on the southern flank of Georges Bank has not been sampled extensively. However, several species of corals have been observed (by submersible) at the head of Lydonia Canyon, including sea pens, the yellow gorgonian Paramurcea borealis, the red octocoral Anthomastus agassizi, and the pink solitary coral Desmophyllum cristagalli (U.S. Bureau of Land Management 1979). These species probably occur in other canyons, as well.

Marine Mammals and Birds--

Seals--Seal species likely to inhabit the Georges Bank region are listed in Table 12. Coastal and nearshore waters of the Gulf of Maine and Georges Bank provide habitat for gray, harbor, harp, and hooded seals. Only harbor and gray seals occur in large numbers or with any regularity in this region. While none of these species is on the Federal list of endangered or threatened species, reliable population estimates and trends for neither the harp nor the hooded seal exist.

In general, seals are concentrated along rocky coastlines, which provide remote haulout areas for feeding (all species), resting (all species), and pupping (harbor seal only). Small populations (less than 300 individuals) of gray seal also breed in isolated, rocky island beaches in the Gulf of Maine and the Bay of Fundy. A small group of gray seals inhabit Muskeget Island west of Nantucket Shoals. Harp and hooded seals are irregular visitors to the area. Habitats, distributions, and food items of the four species are listed in Table 12.

Whales--Cetacean species likely to inhabit the Georges Bank region are listed in Table 13. The baleen whales occur throughout the region, but tend to occupy the shallower shelf waters. Feeding specialization results in resource partitioning and reduced competition, allowing different species to feed in common areas (Table 13). The endangered right whale has a small breeding population (less than 100 individuals) in the Bay of Fundy. The sperm whale, (an odontocete) inhabits deeper waters, with concentrations along the shelf break [1,000-m (3,281-ft) depth]. Its range extends offshore into pelagic waters.

Seventeen species of small odontacetes are likely to occur in the Georges Banks region (Table 13). The pilot whale, Atlantic white-sided dolphin, and harbor porpoise are the most common year-round inhabitants. More seasonal in occurrence are the killer whale and dolphins (e.g., bottlenose, common, white-beaked, and striped dolphins). Several species are occasional, irregular, or predominately offshore inhabitants to the region (i.e., Risso's dolphin, pygmy sperm whale, beluga whale, and many species of beaked whales). Species distributions and preferred food items are presented in Table 13.

Marine Birds --Seabird species that nest in coastal areas of the Gulf of Maine and Cape Cod are indicated in Table 14. Only six species that nest in this region forage regularly in offshore areas (e.g., Georges Bank). Two of these species (herring gull and great black-backed gull) also forage in nearshore areas [<20 m (66 ft) depth]. Nine additional species breed in the region, but forage primarily in nearshore habitats. Several species of wading birds (i.e., herons and ibises) also breed in the region and forage in estuarine habitats (see Erwin and Korschgen 1979 for details of locations).

A group of nine bird species visits offshore areas in the region during summer and fall (Table 15). The northern fulmar, which nests in Newfoundland, occurs during summer in small numbers. The other species originate from either the eastern north Atlantic (Cory's, Manx, and Audubon's shearwaters) or from the southern hemisphere (greater and sooty shearwaters, Wilson's and white-faced storm-petrels, south polar skua). While these can be divided

TABLE 12. SEAL SPECIES IN THE GEORGES BANK REGION

Common Name	Scientific Name	Distribution and Habitat
Harbor seal	Phoca vitulina	Common nearshore (even freshwater) and coastal water throughout the region. Haulouts on rocky shores. Juveniles occasionally on sandy beaches and gravel shores. Feeds on pelagic and demersal fish, cephalopods, and crustaceans.
Gray seal	Halichoerus grypus	Small stocks in nearshore and coastal waters in Gulf of Maine and Nantucket shoals. Haulouts and pupping on rocky shores. Feeds on locally abundant coastal fish.
Harp seal	Phoca groenlandica	Common farther north. Individuals occasionally found in Gulf of Maine - Georges Bank region. Feeds on larger zooplankton, pelagic and demersal fish, and crustaceans.
Hooded seal	Cystophora cristata	Common farther north. Strays occasionally found in Gulf of Maine - Georges Bank region during spring or summer. Feeds on bottom invertebrates and fish.

TABLE 13. CETACEAN SPECIES IN THE GEORGES BANK REGION

Common Name	Scientific Name	Distribution and Habitat
Minke whale	Balaenoptera acutorostrata	Subpolar to tropical waters. Most common north of New York. Nearshore northward spring migration and offshore southward fall migration have been noted. Most sitings are nearshore or within the 200-m (656-ft) contour. Feeds on fish (e.g., herring, capelin).
Sei whale[a]	Balaenoptera borealis	Pelagic. Probably winters outside of region and summers from Cape Cod to southern arctic. Feeds on copepods, krill, and small fish by skimming at or below the water surface.
Fin whale[a]	Balaenoptera physalus	Found between shore and the 2,000-m (6,562-ft) contour. Present in all north Atlantic areas throughout the year but concentrated from Cape Cod north in the summer and south in winter. Nearshore northerly spring migration and offshore southerly fall migration probably occur. Possibly breeds in mid-Atlantic. Feeds primarily on sand lance and other available small schooling fish.
Blue whale[a]	Balaenoptera musculus	Pelagic. Remaining individuals appear to be concentrated from the Gulf of St. Lawrence north to Iceland. Limited north/south migrations probably occur. Feeds almost exclusively on krill.
Humpback whale[a]	Megaptera novaengliae	Occurs in shallow coastal waters of the north Atlantic during the spring and summer. Feeding concentrates around Cape Cod, Stellwagen Bank, Jeffreys Ledge, and the Great South Channel. Fall migration to southern breeding grounds in the Caribbean may occur in deeper ocean waters. Feeds primarily on sand lance and other available small schooling fish.
Right whale[a]	Eubalaena glacialis	Remaining individuals found between shore and the 200-m (656-ft) contour. Present around Cape Cod from April to May. By June, most animals are in summer feeding grounds north of Cape Cod. Offshore southern migration from mid-October to early January. Feeds exclusively on plankton by skimming at or below the water surface.
Long fin pilot whale	Globicephala melaena	Pelagic distribution along the shelf edge with spring/summer movement over the shelf. Ranges from Greenland to Cape Hatteras. Prefers northern waters. Feeds on fish and squid.
Killer whale	Orcinus orca	Coastal and over the shelf. Ranges from Florida to the ice pack; infrequent in the U.S. Feeds on a wide variety of foods, including squid, fish, turtles, seabirds, and mammals.
Harbor porpoise	Phocoena phocoena	Most common small cetacean on the shelf and inshore. Normal southern limit of range is Long Island. Strays as far south as Cape Hatteras. Population concentrated north of Cape Cod. Eats mostly fish (e.g., herring, cod, mackerel) and squid.
Beluga whale	Delphinapterus leucas	Shallow coastal waters and estuaries. Normal distribution is from the Gulf of St. Lawrence northward. Belugas from the St. Lawrence stock rarely stray to Cape Cod or Long Island during the warmer months.

TABLE 13. (Continued)

Sperm whale[a]	*Physeter catodon*	Pelagic, but enters shelf waters south of Narragansett Bay. Common along the continental slope and seaward. Ranges from the tropics to the arctic, but females, calves, and juveniles rarely migrate farther north than 40-42° N. North-south migratory pattern, but the mid-Atlantic is always inhabited. Feeds on squid.
Pygmy sperm whale	*Kogia breviceps*	Seldom observed alive. Generally considered pelagic, but stranding incidents indicate it may be coastal also. Occurs from Canada to Florida. Feeds on squid, crab, shrimp.
Bottlenose dolphin	*Tursiops truncatus*	Ranges from Florida through New England. Coastal in southern portion of range but begins to distribute offshore over the shelf north of North Carolina. Inshore and offshore stocks possible. Probably winters in the south Atlantic region. Feeds on fish and shrimp.
Striped dolphin	*Stenella coeruleoalba*	Relatively abundant along the continental slope from Georges Bank and Sable Island, south through the Caribbean and Gulf of Mexico. Feeds mainly on squid.
Common dolphin	*Delphinus delphis*	Primarily pelagic, but also found on the shelf. Found along entire east coast. Seasonal occurrence north of Cape Cod. Appears to follow schools of fish on which it preys.
White-beaked dolphin	*Lagenorhynchus aibirostris*	Ranges from nearshore to offshore. Fairly common April, May, and June near Cape Cod, apparently the southern boundary of its range. Feeds on squid, cod, herring, and capelin.
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	Ranges from nearshore to offshore, generally from Cape Cod, or perhaps Hudson Canyon, northward. Feeds on fish.
Risso's dolphin	*Grampus griseus*	Pelagic, especially along continental slope. Also found on shelf. Found from Florida to Cape Cod and possibly Canada. Feeds on squid and fish.
Goose-beaked whale	*Ziphius cavirostris*	Assumed to be a deep-water, pelagic species. Appears to be sparsely but widely distributed in nonpolar latitudes. Most commonly stranded beaked whale on east coast. Feeds mainly on squid.
North Atlantic bottlenosed whale	*Hyperoodon ampullatus*	Pelagic. Usually found in water deeper than 1,450 m (4,757 ft) from southern New England to the ice pack. Cape Cod is probably the southern extent of the wintering ground. Rare south of Canada. Feeds on squid.
True's beaked whale	*Mesoplodon mirus*	Possibly pelagic. Strandings occur from Nova Scotia to Florida. Little is known.
Antillean beaked whale	*Mesoplodon europaeus*	Possibly a deep-water species. Strandings reported from Florida to New York. Little is known.
North Sea beaked whale	*Mesoplodon bidens*	Strandings reported from Nantucket and Newfoundland. Feeds on squid. Little is known.
Dense-beaked whale	*Mesoplodon densirostris*	Possibly most pelagic of the genus. Probably a warm-water species with northern limit at 45° N. Appears to be widely but sparsely distributed. Feeds on squid. Little is known.

[a] Endangered species as listed under the U.S. Endangered Species Act (16 USC 1531 et seq.).

Reference: Adapted from Minerals Management Service (1983).

TABLE 14. SEABIRDS THAT NEST IN COASTAL AREAS OF THE GULF OF MAINE AND CAPE COD

Species That Forage in Offshore and Pelagic Habitats	
Leach's storm-petrel	*Oceanodroma leucorhoa*
Herring gull	*Larus argentatus*
Great black-backed gull	*L. marinus*
Arctic tern	*Sterna paradisaea*
Razorbill	*Alca torda*
Atlantic puffin	*Fratercula arctica*
Species That Forage in Nearshore Habitats	
Great comorant	*Phalacrocorax carbo*
Double-crested cormorant	*P. auritus*
Common eider	*Somateria mollissima*
Laughing gull	*Larus atricilla*
Herring gull	*Larus argentatus*
Great black-backed gull	*L. marinus*
Roseate tern	*Sterna dougallii*
Common tern	*S. hirundo*
Arctic tern	*S. paradisaea*
Least tern	*S. antillarum*
Black Guillemot	*Cepphus grylle*

TABLE 15. SEABIRD SPECIES THAT OCCUR SEASONALLY IN OFFSHORE HABITATS IN THE GEORGES BANK REGION

Species That Occur in Summer	
Northern fulmar	*Fulmarus glacialis*
Cory's shearwater	*Calonectris diomedea*
Greater shearwater	*Puffinus gravis*
Sooty shearwater	*P. griseus*
Manx shearwater	*P. puffinus*
Audubon's shearwater	*P. lherminieri*
Wilson's storm-petrel	*Oceanites oceanicus*
White-faced storm-petrel	*Pelagodroma marina*
South polar skua	*Catharacta maccormicki*
Species That Occur During Migration Between Northern Nesting Areas and Southern Wintering Areas	
Leach's storm-petrel	*Oceanodroma leucorhoa*
Northern gannet	*Sula bassanus*
Red-necked phalarope	*Phalaropus lobatus*
Red phalarope	*P. fulicaria*
Pomarine jaeger	*Stercorarius pomarinus*
Parasitic jaeger	*S. parasticus*
Long-tailed jaeger	*S. longicaudus*
Great skua	*Catharacta skua*
Sabine's gull	*Xema sabini*
Arctic tern	*Sterna paradisaea*

into "cool" and "warm" water species, their distributions overlap and oceanographic variations result in great variations in annual occurrence (Vickery 1981). Cory's shearwaters, Audubon shearwaters, and white-faced storm petrels are associated with the Gulf Stream. The remaining species generally are not, although they migrate over the Gulf Stream to foraging areas in cool, northern waters.

A group of ten seabird species normally occurs in offshore waters while migrating between nesting areas in the northern hemisphere and wintering areas to the south (Table 15). In the fall, this group coexists with the summer visitors to form the largest seasonal population in the outer areas of Georges Bank.

Seabird species that winter in the Georges Bank region are listed in Table 16, subdivided by habitat (i.e., nearshore, offshore). Many species of divers, waterfowl, and gulls increase species variety during winter.

Figure 39 indicates foraging areas of nesting species listed in Table 14. The figure also shows nesting sites of three species that nest in only a few areas. Atlantic puffins and razorbills, which nest at only a very few sites in the Georges Bank region(Erwin and Korschgen 1979), and Leach's storm-petrel, which breeds at perhaps a dozen sites and probably forages well offshore (i.e., at the edge of the continental shelf or in pelagic waters). Nesting populations of these species are small. Most of the region's nesting population of about 230,000 seabirds consists of gulls and terns that normally forage near shore (Table 14). These species will occasionally range farther to areas of food concentrations (e.g., near fishing vessels on Georges Bank).

Distributions of the offshore summer-fall visitors are characterized in Figure 40. These birds dominate the seasonal populations in numbers and, depending on how oceanographic conditions affect distributions of prey, can be found throughout the Gulf of Maine and Georges Bank. They are relatively uncommon in nearshore waters, but may concentrate at shallow banks near shorelines (e.g., Nantucket Shoals, Stellwagen Bank). Large numbers of birds are found in most seasons in the Gulf of Maine (see Tingley 1983), though recorded densities are low in the deeper waters of the gulf. Species variety in southern New England waters is greater than elsewhere in the Gulf of Maine but numbers are relatively low (U.S. Bureau of Land Management 1979). Low densities of birds have been reported for the crest of Georges Bank. However, sites of commercial fishing activity can attract very large numbers of birds, and large concentrations of greater shearwaters, sooty shearwaters, and Wilson's storm-petrels have been reported at fishing vessels on Georges Bank. Concentrations of seasonal offshore birds (Table 15) have been reported during summer for the shelf break, canyons, and continental slope at the eastern and southern edges of Georges Bank. For example, northern gannets migrating from Canada are reported in large numbers in this area in fall. Red phalaropes are also abundant in the region and concentrate in this area.

During the winter months, additional species inhabit the region (Table 16). The large gulls (herring, lesser black-backed, glaucous, great black-backed), the abundant, pelagically-wintering northern fulmar, and black-legged kittiwake dominate the offshore population in winter. The alcid species

TABLE 16. SEABIRD SPECIES THAT WINTER IN THE GEORGES BANK REGION

Common name	Scientific name
Species That Winter in Offshore Habitats	
Northern fulmar	*Fulmarus glacialis*
Great skua	*Catharacta skua*
Herring gull	*Larus argentatus*
Iceland gull	*L. glaucoides*
Lesser black-backed gull	*L. fuscus*
Glaucous gull	*L. hyperboreus*
Great black-backed gull	*L. marinus*
Black-legged kittiwake	*Rissa tridactyla*
Dovekie	*Alle alle*
Common murre	*Uria aalge*
Thick-billed murre	*U. lomvia*
Razorbill	*Alca torda*
Atlantic puffin	*Fractercula arctica*
Species That Winter in Nearshore Habitats	
Red-throated loon	*Gavia stellata*
Common loon	*G. immer*
Red-necked grebe	*Podiceps griegena*
Horned grebe	*P. auritus*
Great cormorant	*Phalacrocorax carbo*
Double-crested cormorant	*P. auritus*
Brant	*Branta bernicla*
Greater scaup	*Aythya marila*
Common eider	*Somateria mollissima*
King eider	*S. spectabilis*
Harlequin duck	*Histrionicus histrionicus*
Oldsquaw	*Clangula hyemalis*
Black scoter	*Melanitta nigra*
Surf scoter	*M. fusca*
White-winged scoter	*M. perspecillata*
Common goldeneye	*Bucephala clangula*
Barrow's goldeneye	*B. islandica*
Bufflehead	*B. albeola*
Hooded merganser	*Lophodytes cucullatus*
Common merganser	*Mergus merganser*
Red-breasted merganser	*M. serrator*
Little gull	*Larus minutus*
Black-headed gull	*L. ridibundus*
Bonaparte's gull	*L. philadelphia*
Herrring gull	*L. argentatus*
Iceland gull	*L. glaucoides*
Lesser black-backed gull	*L. fuscus*
Glaucous gull	*L. hyperboreus*
Great black-backed gull	*L. marinus*
Black-legged kittiwake	*Rissa tridactyla*
Black guillemot	*Cepphus grylle*

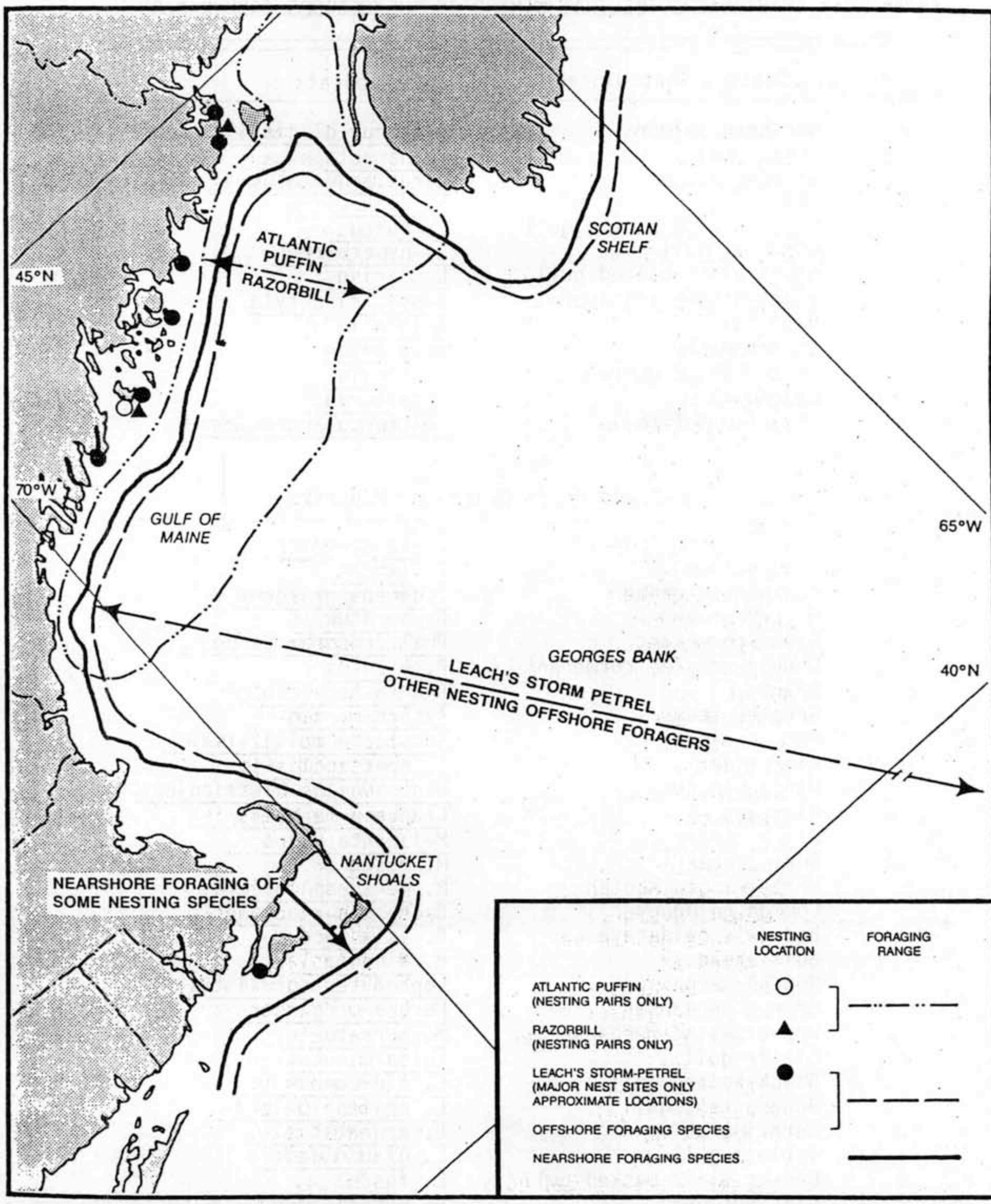


Figure 39. Generalized foraging areas of the nesting species in the Georges Bank region.

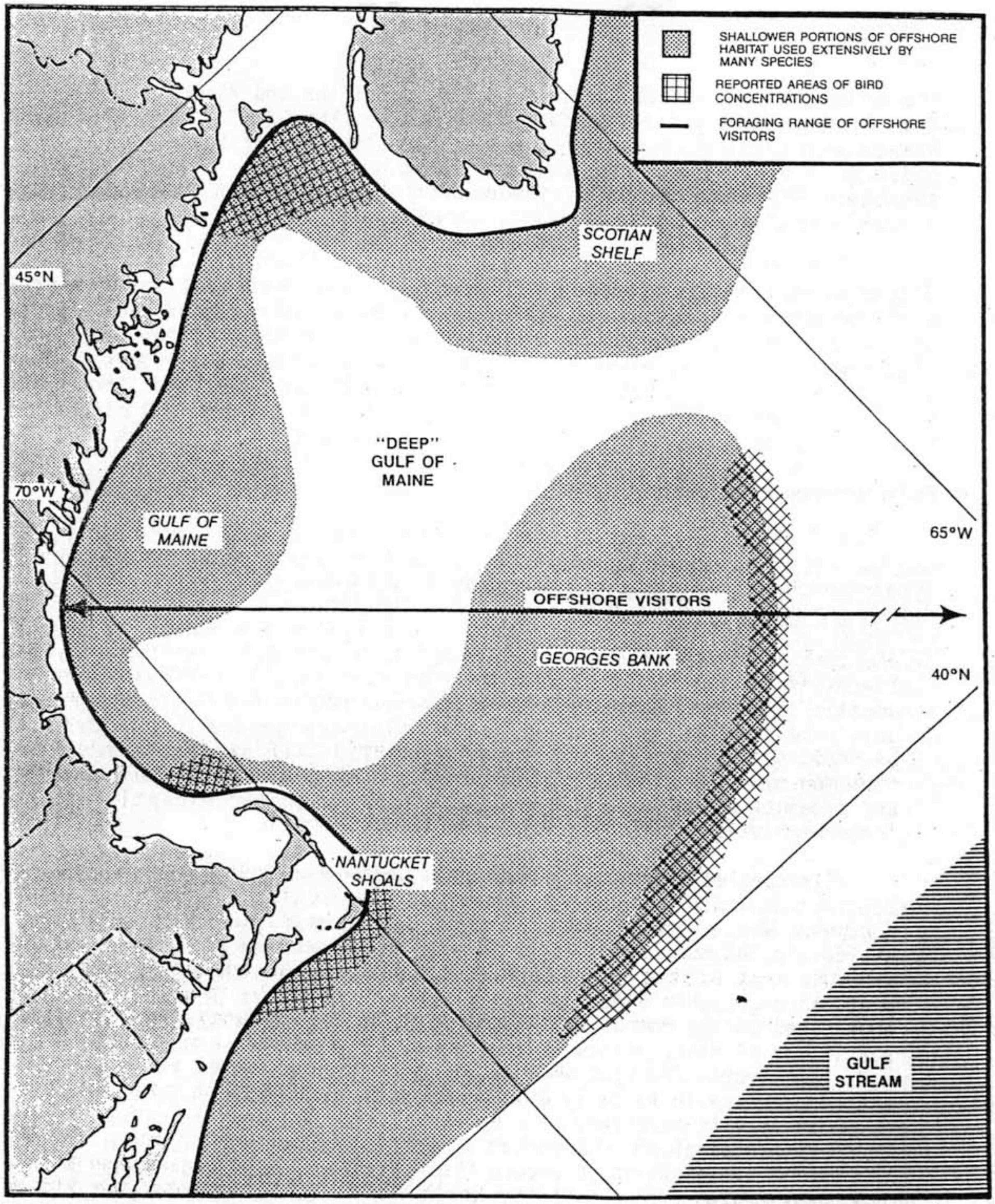


Figure 40. Generalized foraging range of species spending summer and fall in pelagic and offshore habitats.

are rather thinly distributed, with Atlantic puffins and razorbills reported from Georges Bank and the canyons and outer slope (U.S. Bureau of Land Management 1979). In winter the nearshore habitats of the region support populations of loons, grebes, cormorants, ducks, gulls, terns, and other species. Georges Bank is an important foraging region for many birds, including several species of alcids, during winter months.

The greatest species variety and numbers of seabirds occur on outer Georges Bank in summer through fall, when large numbers of shearwaters, storm-petrels, gannets, and gulls are present. The nearshore and shallow offshore habitats are used by birds nesting within the region, including offshore foragers, nearshore foragers (e.g., red-necked phalaropes, gulls, terns, and black guillemots), and estuarine species (e.g., herons). Shorebirds of many species use shoreline habitats during spring and fall migrations between nesting areas to the north and wintering areas to the south.

Endangered Species--

Three endangered and two threatened species of sea turtles (as listed under the U.S. Endangered Species Act) inhabit the north Atlantic. Hawksbill (Eretmochelys imbricata), leatherback (Dermochelys coriacea), and Atlantic Ridley (Lepidochelys kempii) sea turtles are endangered. Loggerhead (Caretta caretta) and green (Chelonia mydas) sea turtles are threatened. Loggerhead sea turtles are the most abundant species in the region, followed by the leatherback, and Atlantic Ridley (the most severely depleted sea turtle species). Green sea turtles prefer southern habitats and visit the region only occasionally. Hawksbill sea turtles are generally considered to be accidental visitors in the north Atlantic. All five endangered and threatened species of sea turtles are listed under Appendix I of CITES and as endangered in the IUCN Red Data Book, with the exception of the loggerhead which is listed as vulnerable by the IUCN.

Six species of cetaceans listed as endangered under the U.S. Endangered Species Act inhabit the north Atlantic region (CETAP 1982): fin whale, humpback whale, right whale, sei whale, sperm whale, and blue whale. Fin whales are the most abundant large whale in the region. Humpback whales are the next most commonly sighted species. Based on its extremely low population (roughly 500 individuals), the right whale is probably the most endangered marine mammal in the region. The Bay of Fundy supports a breeding population of right whales, with the highest frequency of occurrence from July to October. Right whales are also concentrated in the Great South Channel from March to early July and Browns Bank in the southern Scotian Shelf from July to November. The sperm whale is only an occasional visitor on the continental shelf. Areas of concentrated occurrences in feeding and breeding are shown in Figure 41. All six species of endangered whales, the goose-beaked whale, and the North Atlantic bottlenose are listed in Appendix I of CITES. All other cetacean species found in Georges Bank are listed in Appendix II. The blue whale, humpback whale, and right whale are listed as endangered, and the fin whale and North Atlantic bottlenose are listed as vulnerable in the IUCN Red Data Book.

Two species of petrels that forage in the Gulf Stream offshore the Georges Bank region have very small populations. The black-capped petrel (Pterodroma hasitata), has a population of only a few thousand and is rated

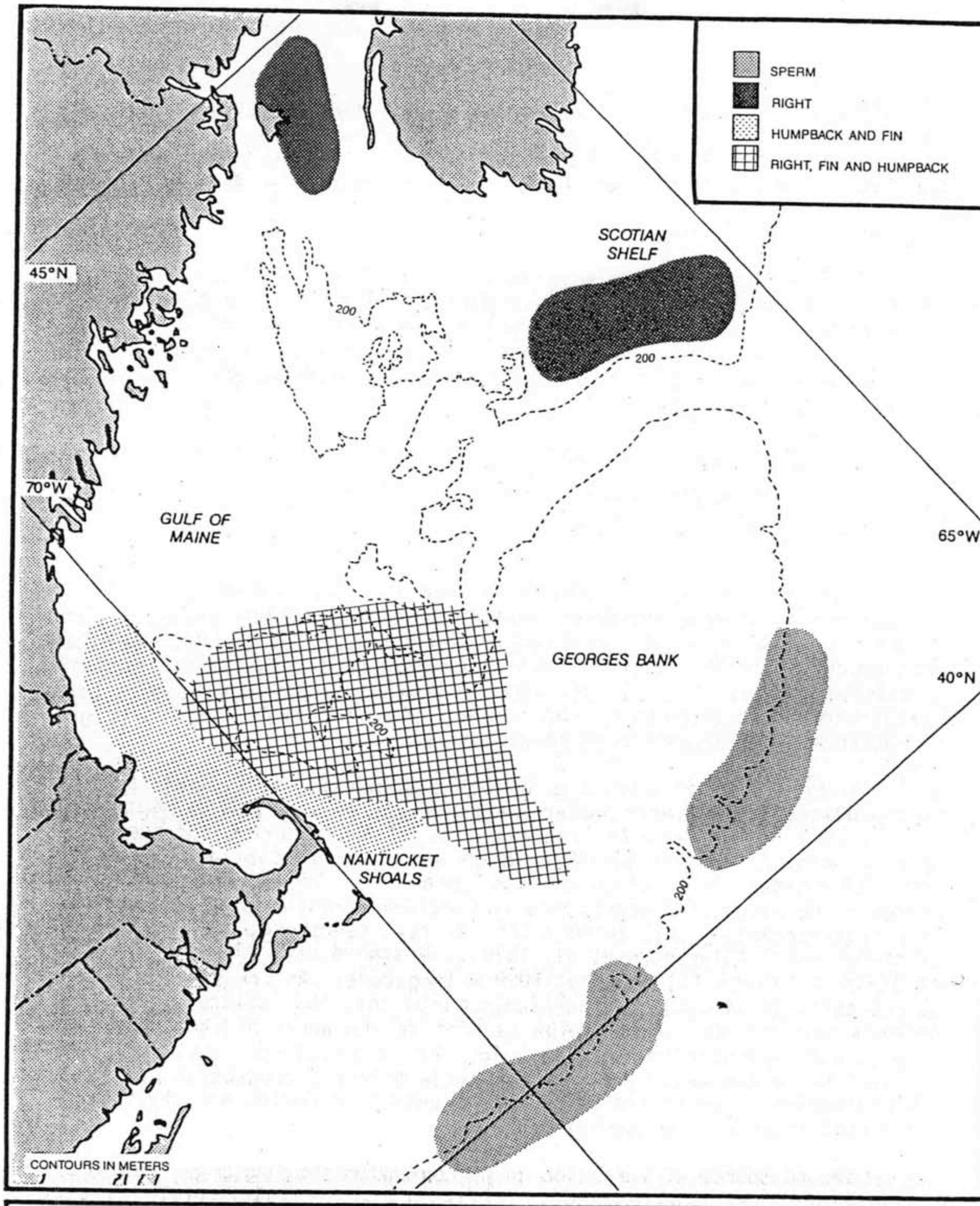


Figure 41. Preferred areas for endangered cetacean species in the Georges Bank region.

vulnerable by the IUCN Red Data Book (King 1981). The Bermuda petrel (P. cahow) has been reduced to a population of about 30 pairs and is endangered (King 1981). The potential that either species will occur in proximity to ODP operations is small, due to small population sizes and large foraging ranges.

Biologically Sensitive Areas--

The entire Georges Bank area is considered biologically sensitive due to its extensive fisheries area. Commercial fishing near Georges Bank represents 13 percent of the total U.S. landings by volume and 15 percent by dollar value. Details on the commercial fisheries are presented below in the discussion of other uses of representative drilling areas. In addition, the high-use habitats for breeding, feeding, and migratory routes utilized by right whales are considered very sensitive areas, especially during seasonal use periods by the right whale and other endangered whale species.

Eastern Tropical Pacific Ocean

Phytoplankton--

Standing crops of phytoplankton are highest in upwelling areas near the coast and decrease westward. Highest primary production also occurs in upwelling areas near the coast, in the vicinity of the Mid-American Trench, and decreases westward. Overall, primary production in the eastern tropical Pacific is relatively high (Holmes et al. 1957) and supports considerable biomass at higher tropic levels. Some of this biomass (e.g., tunas, anchoveta) is harvested commercially.

The east-to-west decrease in primary production is directly related to the upwelling of deeper water near the coast and to the depth of the thermocline relative to the compensation depth offshore. The deeper water upwelled near the coast promotes high standing stocks of phytoplankton and high primary production values (Blackburn 1966), although the exact processes by which this occurs are not well-understood. The thermocline is relatively deep [i.e., 20-40 m (66-131 ft)] nearshore, due to the upwelling of colder water (Blackburn et al. 1970). Westward, the thermocline shoals at 10-20 m (33-66 ft) at about 100° W longitude. As the shoal thermocline is depressed by wind mixing, nutrients mixed into the surface waters promote primary production. Production is high in the areas of shoal thermocline because the compensation depth is below the thermocline. However, as the thermocline to the east of 100° W longitude deepens, production drops because the thermocline is depressed below the compensation depth, and phytoplankters are advected out of the euphotic zone.

A second source of variation in phytoplankton standing crops and production is seasonality. Standing crops, as indicated by chlorophyll a values, are 14-28 mg/m^2 over the upper 150 m (492 ft) (Blackburn et al. 1970), varying annually by a factor of almost two. They are highest from April to September and lowest from October to January (Blackburn et al. 1970). Mean annual primary production in the eastern tropical Pacific Ocean is about 75 g $C \cdot m^{-2} \cdot yr^{-1}$, but there is considerable spatial and temporal variation (Owen and Zeitschel 1970). Depending on the station location and season, values from <100 to >500 mg $C \cdot m^{-2} \cdot day^{-1}$ may be found (average of 127-318 mg $C \cdot m^{-2} \cdot day^{-1}$) (Owen and Zeitschel 1970). Maximum production occurs in the early spring, with a secondary peak in August or September. Minimum production occurs in October or November. Seasonal production cycles appear to vary synchronously over the entire region (Owen and Zeitschel 1970).

Phytoplankton species composition has not been adequately described in the representative drilling areas. However, phytoplankton communities just to the west (i.e., 125-155° W longitude) are dominated by flagellates, monads, coccolithophorids, dinoflagellates, and diatoms.

Zooplankton--

Zooplankton populations in the eastern tropical Pacific Ocean exhibit many of the same characteristics as do the phytoplankton populations. Principally, zooplankton stocks decrease from east to west, with peaks in areas of upwelling areas and in areas of shoal thermocline (Blackburn et al. 1970). In addition, zooplankton stocks decrease greatly below the pycnocline (Beers and Stewart 1971), as do phytoplankton stocks. For the upper 300 m (984 ft) of the water column, about 50 percent of the zooplankton standing stock occurs at depths of 0-70 m (0-230 ft), about 30 percent occurs at depths of 70-140 m (230-459 ft), and about 20 percent occurs at depths of 140-300 m (459-984 ft) (Blackburn 1966). This close association of zooplankton and phytoplankton stocks is due to the thickening of the mixed layer from east to west, and to the dependence of the herbivorous zooplankters on the phytoplankton.

As noted above for phytoplankton, zooplankton standing stocks vary seasonally by a factor of approximately two (Blackburn et al. 1970; Longhurst 1976). Zooplankton volumes offshore (i.e., 10-120° W longitude) range from 80 to 160 ml/1,000 m^3 (Blackburn et al. 1970). In the easternmost part of the region, volumes typically range from 130 to 320 ml/1,000 m^3, but may be greater in coastal upwelling areas (Holmes et al. 1957). Variations in chlorophyll *a* and day zooplankton stocks are "almost indistinguishable in phase" (Blackburn et al. 1970). Moreover, zooplankton stocks appear to be closely associated with the zones of maximum phytoplankton production in the water column (Longhurst 1976; Beers and Stewart 1971). For the eastern tropical Pacific Ocean as a whole, zooplankton standing stocks vary with chlorophyll *a* estimates to the power of approximately 0.7 in all areas for all seasons (Blackburn 1973). Thus, zooplankton biomass does not increase linearly with the standing crop of phytoplankton, and it appears that ecological efficiency decreases between oligotrophic and eutrophic areas within the region.

By volume, the most abundant zooplankton taxa in the eastern tropical Pacific are copepods (20 percent), tunicates (15 percent), chaetognaths (12 percent), siphonophores (8 percent), euphausids (5 percent), medusae (3 percent), decapods (2 percent), amphipods (1 percent), and ostracods (less than 1 percent) (Mais and Jow 1960). These same taxonomic groups are also most important numerically: copepods (63 percent), chaetognaths (15 percent), tunicates (6 percent), euphausids (5 percent), siphonophores (1 percent), ostracods (1 percent), amphipods (less than 1 percent), decapods (less than 1 percent), and medusae (less than 1 percent) (Mais and Jow 1960).

Microzooplankton (i.e., animals passing through a 363-u mesh but retained on a 35-u mesh) contribute an average 24 percent of the macrozooplankton biomass to the total zooplankton standing stock (Beers and Stewart 1971). The most important contributors to microzooplankton abundances are copepods, tintinnid ciliates, radiolarians, acantharians, and foraminifera (Beers and Stewart 1971).

Nekton--

Nekton may be classified into two groups based on motility and size: micronekton [limited motility, 1-10 cm (0.4-4.0 in) long, may be captured in a large, coarse-meshed plankton net] and nekton organisms [high motility, longer than 10 cm (0.4 in), can easily avoid nets and trawls]. Micronekton in the eastern tropical Pacific Ocean are primarily fish, crustaceans, and cephalopods. Some species are permanent members of the micronekton, while others are temporary members (i.e., during only their larval and juvenile stages). Ten families and one suborder constitute over 90 percent of the micronekton by volume in the eastern tropical Pacific Ocean: the fish families Myctophidae (lanternfishes) and Gonostomatidae (lightfishes); the crustacean families Euphausiidae (krill), Penaeidae (shrimps), Squillidae (mantis shrimps), Portunidae (crabs), and Sergestidae (shrimps); and the caphalopod family Enoploteuthidae (squids) (Blackburn 1968). However, the remaining 10 percent by volume consists of many other taxonomic groups, including 51 families and three orders of fishes (Ahlstrom 1972). Many of these are larval forms, the most abundant of which are the myctophid lanternfishes (47 percent), gonostomatid lightfishes (23 percent), sternoptychid hatchetfishes (6 percent), bathylagid smelts (5 percent), and scrombrid tunas and mackerels (2 percent) (Ahlstrom 1971). Most micronektonic taxa are probably carnivorous, except for the micronektonic crustaceans, which are probably a mixture of herbivores, primary carnivores, and some secondary carnivores (Blackburn et al. 1970).

The distribution of micronekton standing stocks is similar to that of phytoplankton and zooplankton: stocks are highest in the coastal zone and decrease gradually to the west (Blackburn et al. 1970). Standing stocks of micronektonic fish range from 27-81 ml/1,000 m^3 in nearshore areas to 0.3-1.0 ml/1,000 m^3 (or less) in the vicinity of the offshore drilling sites. Similarly, stocks of micronektonic crustaceans and cephalopods each range from 3.1-9.0 ml/1,000 m^3 nearshore to less than 0.3 ml/1,000 m^3 offshore (Blackburn 1968). Seasonal variations in the standing stocks of micronektonic crustaceans are apparently not statistically significant ($P>0.05$). However, seasonal variations in the standing stocks of micronektonic fish plus cephalopods are significant ($P<0.05$) and are nearly opposite in phase to variations in plankton stocks (Blackburn et al. 1970).

Tunas are the most important large nektonic species because they are harvested commercially. Yellowfin (Thunnus albacares) and skipjack (Euthynnus pelamis) tunas constitute most of the catch in the vicinity of the Mid-American Trench, but bigeye tunas (T. obesus) are also harvested (Mais and Jow 1960). The yellowfin tuna fishery in the vicinity of the Mid-American Trench is especially productive due to the shallowing of the thermocline in that region (Mais and Jow 1960). Other tunas in the area in low abundances include bullet mackerel (Auxis rochei), black skipjack tuna (E. lineatus), and albacore tuna (T. alalunga) (Mais and Jow 1960; Shingu et al. 1974).

Billfishes are also harvested in the representative drilling areas, principally by the Japanese. The most important species are the sailfish (Istiophorus platypterus), shortbill spearfish (Tetrapturus angustirostris), and striped marlin (Tetrapturus audax). Swordfish (Xiphias gladius), black marlin (Makaira indica), and blue marlin (M. nigricans) are also caught.

Other abundant large nektonic organisms in the eastern tropical Pacific are sharks, lancet fishes, flying fishes, dolphinfish (Coryphaena hippurus), wahoo, ocean sunfish, and squids (Mais and Jow 1960; Office of Ocean Minerals and Energy 1981). Dolphinfish and sharks are very abundant, contributing roughly half of the longline catch (Mais and Jow 1960). The most common shark species are the requiems and the threshers.

Benthos--

Benthos have not been sampled in the eastern tropical Pacific Ocean within the representative drilling areas (see Rowe 1983). However, using studies in nearby regions, benthic communities expected to occur in the representative drilling areas can be characterized in general. Two types of benthic communities are expected: soft-bottom communities and hydrothermal vent communities. Soft-bottom communities were surveyed west of the representative drilling areas (i.e., 8-16° N latitude and 125-152° W longitude) as part of the Deep Ocean Mining Environmental Study (DOMES). Benthic organisms at three sites were surveyed by photography, free-fall baited traps, and box cores. Photographs documented that more than 90 percent of the larger, epifaunal organisms were sea stars (Cl. Asteriodea), brittle stars (Cl. Ophiuroidea), sea anemones (Cl. Anthozoa), sea cucumbers (Cl. Holothuroidea), and sponges (Phy. Porifera) (Office of Ocean Minerals and Energy 1981). Sea spiders (Phy. Pycnogonida), crabs (Cl. Decapoda), isopod crustaceans, and sea urchins (Cl. Echinoidea) were also observed. Amphipod crustaceans and two families of fishes [rattails (Fam. Macrouridae) and sea snails (Fam. Liparidae)] were collected in baited traps. These scavenging organisms may be considered bentho-pelagic because of their close association with the bottom.

Benthic macrofaunal communities sampled by box corer were characterized by low abundances ($\bar{x}$ = 121 organisms/m^2; range = 36-268 organisms/m^2) and high diversities (i.e., species richness), as is typical of abyssal environments (Hecker and Paul 1979). Among the 381 species collected in the 80 0.25-m^2 box core samples, 131 were represented by a single specimen, 58 by two specimens, 51 by three specimens, and 36 by four specimens. Plots of the expected numbers of species per numbers of individuals revealed that the fauna was greatly undersampled. Hence, only a fraction of the resident species were represented in the large box core samples.

The most abundant species were polychaetous annelids (40.1 percent), tanaid crustaceans (19.5 percent), isopod crustaceans (11.7 percent), bivalve molluscs (8.4 percent), ectoprocts (5.4 percent), gastropod molluscs (2.5 percent), and brachiopods (2.1 percent). An additional 20 taxonomic groups were represented at densities less than 1 percent of the total infauna. About 81 percent of all macrofaunal organisms were characterized by Hecker and Paul (1979) as deposit feeders. The remaining 19 percent were characterized as suspension feeders.

Meiofaunal organisms retained on a 300-u mesh sieve were also collected and analyzed by Hecker and Paul (1979). Nematodes, ostracods, and copepods were the most abundant meiofaunal taxa, accounting for 82.5 percent, 9.6 percent, and 7.5 percent of the total numbers of meiofaunal organisms, respectively.

Hecker and Paul (1979) also conducted classification analyses that strongly suggest that benthic communities vary in species composition over the eastern tropical Pacific region. Hence, it is unrealistic to expect the same benthic species at the same proportions in the representative drilling areas as were observed by Hecker and Paul (1979) in the DOMES survey area. Macrofaunal densities may also differ (i.e., be higher) in the representative drilling areas because of the higher levels of primary production which occur near the coast. Benthic communities are largely dependent on organic "rain" from the surface layers of the ocean for nutrients, and higher primary production is often reflected in higher benthic standing stocks and secondary production. The composition and quantity of the organic "rain" also greatly influences the character of the sediments within a given region. Therefore, sediments may differ somewhat in the representative drilling areas from the pelagic clays, siliceous oozes, and calcareous sediments found in the DOMES survey area.

The second type of benthic community expected in the eastern tropical Pacific is associated with hydrothermal vents. Hydrothermal vents have been documented on the Galapagos Rift at 0° 47.5' N latitude and on the East Pacific Rise at 21° N latitude (Corliss et al. 1979, Spiess et al. 1980). They have not been documented on the East Pacific Rise in the vicinity of the representative drilling site, but they probably occur there also. Hydrothermal vents occur in association with active spreading centers. Cold sea water is entrained into the fissure system along the ridge axis, flows through the warm (sometimes hot) oceanic crust, and exits at warm water vents. Temperatures as high as 380° ± 30° C have been recorded for the exiting waters, which are rich in hydrogen sulfide (Corliss et al. 1979). High densities of sulphur-oxidizing and heterotrophic bacteria have been observed in water samples collected at two vent orifices (Corliss et al. 1979). The bacteria which oxidize hydrogen sulfide are the primary producers which support extensive epifaunal communities along the mid-ocean ridges (Edmond and Von Damm 1983; Jannasch 1984; Somero 1984).

The extensive epifaunal communities live in close association with the vents. Species composition varies somewhat among the vents in each area and between areas (Corliss et al. 1979; Spiess et al. 1980). However, bivalve molluscs, crabs, pogonophorans, shrimps, gastropods, copepods, six families of polychaetous annelids, and one species of brotulid fish appear to be common in vent habitats (Jones 1981b). Serpulid and terebellid polychaetous annelids formed dense tube masses on the East Pacific Rise (Spiess et al. 1980), while aggregations of mytilid mussels and anemones were observed on the Galapagos Rift (Corliss et al. 1979).

Hydrothermal vent habitats are unique and their ecology (e.g., energy and nutrient sources, recruitment of organisms into newly generated vent systems) is not well-known. Yet it appears that growth rates of the bivalve molluscs in these vent communities are high, being comparable with those for shallow water species. Such high growth rates are in contrast with the extremely low growth rates estimated for a non-vent deep-sea bivalve mollusc (Turner and Lutz 1984). Perhaps the most intriguing of the vent organisms is the pogonophoran Rifia pachyptila, which grows in dense assemblages of tubes, each 2-3 cm (0.8-1.2 in) in diameter and up to 3 m (10 ft) tall. Remarkably, this large animal lacks a functional gut. It is postulated that R. pachyptila is an autotroph capable of generating energy through the reduction of hydrogen sulfide, or that it derives its energy and nutrients from symbiotic sulfur-oxidizing bacteria (Cavanaugh et al. 1981; Felbeck 1981; Jones 1981a; Rau 1981). The latter hypothesis is supported by the finding of large numbers of symbiotic bacteria within the trophosome of the organism. It is postulated that these bacteria form organic carbon compounds using carbon dioxide and energy from the reduction of hydrogen sulfide (Jones 1984).

Marine Mammals and Birds--

Seals--Three species of otarids that could range into the two representative site areas inhabit the eastern tropical Pacific Ocean. The Galapagos fur seal (Arctocephalus galapagoensis) and a subspecies of the California sea lion [the Galapagos sea lion (Zalophous californianus wollebaeki)] breed in the Galapagos Islands. The Guadalupe fur seal (Arctocephalus townsendi) breeds on Guadalupe Island off of Baja California and ranges south to near the East Pacific Rise. All three species prefer inaccessible rocky beaches for haulouts. The two fur seals also use sea caves. Both fur seal populations number only about 1,000 individuals and are recovering from near extinction due to exploitation. The Galapagos sea lion has a more stable population of around 20,000. All three species apparently feed on fish and cephalopods.

Whales--Cetacean species likely to inhabit the eastern tropical Pacific are listed in Table 17. Baleen whales in the region include blue, fin, sei, Bryde's, minke, grey, and humpback whales. All baleen whales, except Bryde's whale, are transient in the region. These transients migrate to lower latitudes to breed during winter months and feed little, if at all, during their stay. Many toothed cetaceans also inhabit the region. Species that occur individually or in small groups, and that feed mainly on squid or large fish include sperm, pygmy sperm, pygmy killer, false killer, pilot, melon-headed, and goose-beaked whales; various beaked whales of the genus Mesplodon; and Risso's dolphin. Distributions and preferred food items are presented in Table 17.

Small delphinids in the eastern tropical Pacific Ocean occur mainly in large interspecific herds. They feed mostly on squids and small, schooling, surface and mesopelagic fish. In order of estimated abundances, these species are spotted, spinner, common, bottlenose, stripped, Frazer's, and rough-toothed dolphins (U.N. Food and Agriculture Organization 1978). These large interspecific (or occasionally single-species) herds are associated with schools of yellowfin tuna that drive prey (e.g., small fish and squid) to the surface. The delphinids, flocks of birds, tuna, and even sharks will feed in this aggregation. The delphinids' association with tuna has also resulted in drastic reductions in the stocks of several species, including

TABLE 17. CETACEAN SPECIES IN THE EASTERN TROPICAL PACIFIC REGION

Common Name	Scientific Name	Distribution and Habitat
Blue whale[a]	Balaenoptera musculus	Pelagic. Northern Pacific stock migrates south for breeding during northern winter. Apparently does not feed while in region.
Fin whale[a]	Balaenoptera physalus	Migration pattern, behavior, and distribution resemble those of the blue whale. Stock size is larger.
Sei whale[a]	Balaenoptera borealis	Similar migration pattern for breeding. Inhabits both shallow coastal waters and deep ocean areas. May feed occasionally while in the region on large zooplankton and small shoaling fish.
Bryde's whale	Balaenoptera edeni	Only baleen whale that resides year-round in the region. May breed throughout the year. Usually found in pelagic waters. Feeds on small shoaling fish (e.g., sardine and mackerel) and squid.
Minke whale	Balaenoptera acutorostrata	Part of the northern population migrate this far south in winter. Breeds in early spring. Probably feeds in southern waters on zooplankton, small fish, and squid.
Humpback whale[a]	Megaptera novaeangliae	Northern population migrates south in winter. Inhabits shallow nearshore and coastal regions. Apparently feeds seldom, if at all, in wintering grounds.
Gray whale[a]	Eschrichtius robustus	Migrates south along the coast to breed in winter. Only small portion of population travels farther south than Baja California. Apparently does not feed in breeding lagoons. Feeds on benthic invertebrates on northward migrations.
Sperm whale[a]	Physeter catodon	Pelagic. Mainly females, calves, and juveniles in the region. Females migrate to subtropics to mate. Feeds on squid.
Pygmy sperm whale	Kogia breviceps	Seldom observed alive. Individual strandings on islands in the Pacific and along Baja California. Feeds on squid and large crustacea.
Pygmy killer whale	Feresa attenuata	Pelagic. Distributed in tropical and subtropical Pacific waters. Little known about population or feeding.
False killer whale	Pseudorca crassidens	Pelagic. Rarely seen alive. Strandings throughout eastern tropical Pacific. Breeding apparently not seasonal. Feeds on large pelagic fish and squid.
Melon-headed whale	Peponocephala electra	Pelagic, usually far offshore. Little known about this species. Apparently feeds on squid.
Spotted dolphin	Stenella attenuata	Pelagic and coastal throughout eastern tropical Pacific. Possibly two or three stocks. Herds in large (up to 1,000) interspecific groups. Feeds on small schooling fish.
Spinner dolphin	Stenella longirostris	Mainly pelagic. Costa Rican subspecies inhabits coastal region of Mid-American Trench. Possibly three offshore stocks. Herds in large interspecific groups. Feeds on small schooling fish.

TABLE 17. (Continued)

Common dolphin	*Delphinus delphis*	Two stocks concentrated in coastal waters around Baja California and southern Central America. Sighted frequently in pelagic waters. Common in herds up to 200. Feeds on small schooling fish, squid, and crustaceans.
Bottlenose dolphin	*Tursiops truncatus*	Found throughout tropical Pacific. Common in continental shelf, although occurs in pelagic waters. Some researchers divide population into separate stocks or even species. Common in herds up to several hundred. Feeds primarily on fish.
Stripped dolphin	*Stenella coeruleoalba*	Mainly pelagic. Possibly three separate stocks in eastern tropical Pacific. Occurs in large interspecific groups. Feed on schooling fish and squid.
Fraser's dolphin	*Lagenodelphis hosei*	Occurs farther offshore in smaller groups. Little known about this species. Apparently feeds on pelagic fish and squid.
Rough toothed dolphin	*Steno bredanensis*	Pelagic. Little known about this species. Occasionally found in association with interspecific herds. Apparently feeds on schooling fish and squid.
Risso's dolphin	*Grampus griseus*	Pelagic. Also common on slope and shelf in region. Feeds on squid and fish.
Goose-beaked whale	*Ziphius cavirotrus*	Widely distributed in tropical to temperate waters. Most common of beaked whales. Feeds on squid, fish, and occasionally crustaceans.
Beaked whales	*Mesoplodon* spp.	Rare pelagic sightings, usually solitary. Feeds on squid. Little is known.

a Endangered species as listed under the U.S. Endangered Species Act (16 USC 1531 et seq.).

References: Coffey (1977), U.N. Food and Agriculture Organization (1978), Evans (1982), Hammond and Laake (1983).

spinner and spotted dolphins, from incidental takes by the tuna fishery. Distribution and food items for these delphinid species are presented in Table 17.

Marine Birds--Marine birds that may be affected by drilling activities in the two representative drilling sites may be divided into three groups: species occurring in nearshore, offshore, and pelagic waters of the representative sites (Figure 42, Table 18), species occurring in shoreline habitats (Figure 42, Table 18), and pelagic species that might be affected only by drilling at the East Pacific Rise site (Figure 42, Table 19). Two additional groups inhabit the eastern tropical Pacific, but they occur several hundred kilometers from the representative drilling sites: species inhabiting the region of the Peru and Humboldt Currents (Figure 42, Table 19) and species found primarily in the Galapagos Islands (Figure 42, Table 19).

The total number of marine birds species in the eastern tropical Pacific throughout the year is high. However, most species are present for only part of the year and few species breed in the area (e.g., only eight species breed near the representative drilling sites) (Murphy 1936; de Schauensee 1970; Harris 1974; American Ornithological Union 1983). Resident species show few seasonal changes in distribution, and some species have variable or staggered nesting seasons.

Generalized at-sea distributions of marine birds, as synthesized from Love (1971), King (1974), Harrison (1983), and others, are shown in Figures 43-48. However, the distribution of many pelagic species in the region is poorly documented.

Pelagic ranges of large petrels and shearwaters are shown in Figure 43. Four species breed in the eastern tropical Pacific and at least four others migrate through or spend their non-breeding season within the region. Eleven species of storm-petrels inhabit the region (Figure 44), although several of these are associated primarily with the Peru Current system. Storm-petrels in the vicinity of the representative drilling sites include black and least storm-petrels from colonies north of the region, wedge-rumped and band-rumped storm-petrels from the Galapagos Islands, Wilson's storm-petrel from the antarctic, and Leach's storm-petrel. Storm-petrels are occasionally abundant in pelagic areas.

Five larger-sized marine bird species occur in the eastern tropical Pacific, as shown in Figure 45. Except for the waved albatross, which is endemic to the Galapagos and forages in the northern Peru Current, these large birds inhabit the representative drilling sites. Red-billed tropicbirds breed in several locations and forage over wide areas of the Pacific Ocean. Brown pelicans are abundant and widespread, principally along shorelines and nearshore habitats. The two frigatebirds breed in the region and have pelagic distributions during the non-breeding season.

Boobies (Figure 46) are abundant in the region. Although they are considered pelagic, booby populations are concentrated along the continental shelves. They are one of the dominant species in nearshore habitats, such as the Mid-American Trench, but may also be found widely at sea, often feeding in large flocks where prey is abundant (e.g., in fronts, upwelling areas).

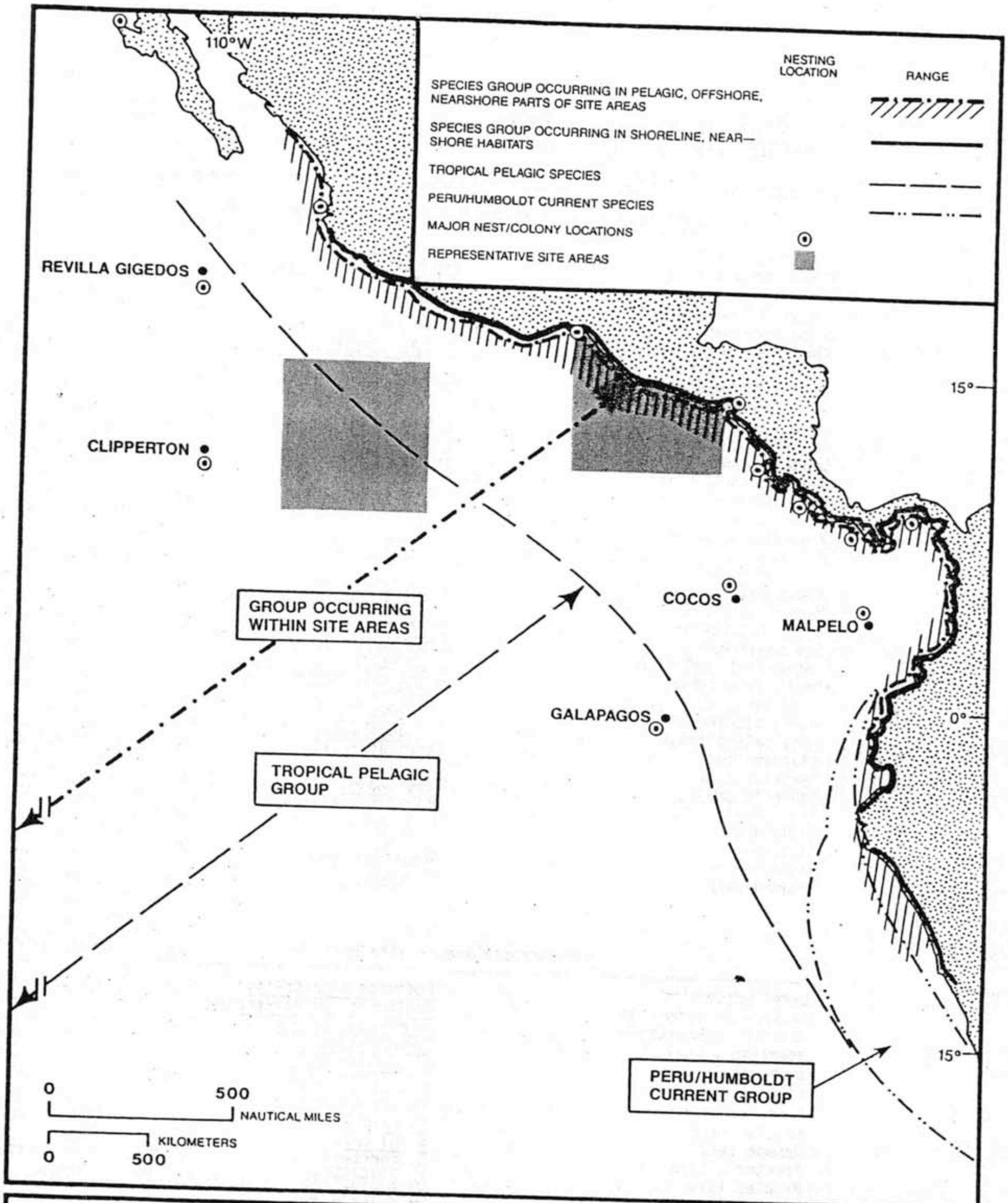


Figure 42. General distributions of seabird species groups in the eastern tropical Pacific Ocean.

TABLE 18. SEABIRD SPECIES OF REGULAR OR COMMON OCCURRENCE IN THE REPRESENTATIVE SITES, EASTERN TROPICAL PACIFIC REGION

Both East Pacific Rise Site and Mid-American Trench Site	
Dark-rumped petrel	Pterodroma phaeopygia
Parkinson's petrel	Procellaria parkinsoni
Pink-footed shearwater	Puffinus creatopus
Wedge-tailed shearwater	P. pacificus
Sooty shearwater	P. griseus
Black-vented shearwater	P. opisthomelas
Audubon's shearwater	P. lherminieri
Wilson's storm-petrel	Oceanites oceanicus
Least storm-petrel	Halocyptena microsoma
Wedge-rumped storm-petrel	Oceanodroma tethys
Band-rumped storm-petrel	O. castro
Leach's storm-petrel	O. leucorhoa
Black storm-petrel	O. melania
Red-billed tropicbird	Phaethon aethereus
Brown pelican	Pelecanus occidentalis
Blue-footed booby	Sula nebouxi
Masked booby	S. dactylatra
Red-footed booby	S. sula
Brown booby	S. leucogaster
Magnificent frigatebird	Fregata magnificens
Great frigatebird	F. minor
Red phalarope	Phalaropus fulicaria
Red-necked phalarope	P. lobatus
South polar skua	Catharacta maccormicki
Pomarine jaeger	Stercorarius pomarinus
Parasitic jaeger	S. parasiticus
Long-tailed jaeger	S. longicaudus
Laughing gull	Larus atricilla
Franklin's gull	L. pipixcan
Sabine's gull	Xema sabini
Arctic tern	Sterna paradisaea
Sooty tern	S. fuscata
Royal tern	S. maxima
Brown noddy	Anous stolidus
Black noddy	A. minutus
Mid-American Trench Site Only	
Eared grebe	Podiceps nigricollis
Olivaceous cormorant	Phalacrocorax olivaceus
American oystercatcher	Haematopus palliatus
Heermann's gull	Larus heermanni
Bonaparte's gull	L. philadelphia
Black tern	Chlidonias niger
Gull-billed tern	Sterna nilotica
Caspian tern	S. caspia
Common tern	S. hirundo
Forster's tern	S. forsteri
Bridled tern	S. anaethetus
Least tern	S. antillarum
Elegant tern	S. elegans
Sandwich tern	S. sandvicensis
Black skimmer	Rynchops niger

Plus many other wading and shorebird species, both resident and migrant, that use exposed shoreline and protected estuarine habitats.

TABLE 19. SEABIRD SPECIES OF PERIODIC OR POSSIBLE OCCURRENCE IN THE REPRESENTATIVE SITES, EASTERN TROPICAL PACIFIC REGION

Species from Offshore and Northern Areas	
Kermadec petrel	*Pterodroma neglecta*
White-necked petrel	*P. externa*
Cook's petrel	*P. cooki*
Stejneger's petrel	*P. longirostris*
Buller's shearwater	*Puffinus bulleri*
Townsend's shearwater	*P. auricularis*
Black-bellied storm-petrel	*Fregatta tropica*
White-faced storm-petrel	*Pelagodroma marina*
Markham's storm-petrel	*Oceanodroma markhami*
Ashy storm-petrel	*O. homochroa*
Wilson's phalarope	*Phalaropus tricolor*
Craveri's murrelet	*Synthliboramphus craveri*
Species from the Vicinity of the Northern Peru Current	
Humboldt penguin	*Spheniscus humboldti*
Waved albatross	*Diomedea irrorata*
Black-browed albatross	*D. melanophris*
Buller's albatross	*D. bulleri*
Shy albatross	*D. cauta salvini*
Light-mantled sooty albatross	*Phoebetria palpebrata*
Southern giant petrel	*Macronectes giganteus*
Southern fulmar	*Fulmarus glacialoides*
Cape petrel	*Daption capense*
Gray petrel	*Procellaria cinerea*
White-chinned petrel	*P. aequinoctialis*
Elliott's storm-petrel	*Oceanites gracilis*
White-bellied storm-petrel	*Fregatta grallaria*
Hornby's storm-petrel	*Oceanodroma hornbyi*
Peruvian diving petrel	*Pelecanoides garnoti*
Peruvian pelican	*Pelecanus occidentalis*
Peruvian booby	*Sula variegata*
Guanay cormorant	*Phalacrocorax bougainvillii*
Red-legged shag	*P. gaimardi*
Grey gull	*Larus modestus*
Band-tailed gull	*L. belcheri*
Southern black-backed gull	*L. dominicanus*
Grey-headed gull	*L. cirrocephalus*
Andean gull	*L. serranus*
Swallow-tailed gull	*L. furcatus*
South American tern	*Sterna hirundinacea*
Peruvian tern	*S. lorata*
Inca tern	*Larosterna inca*

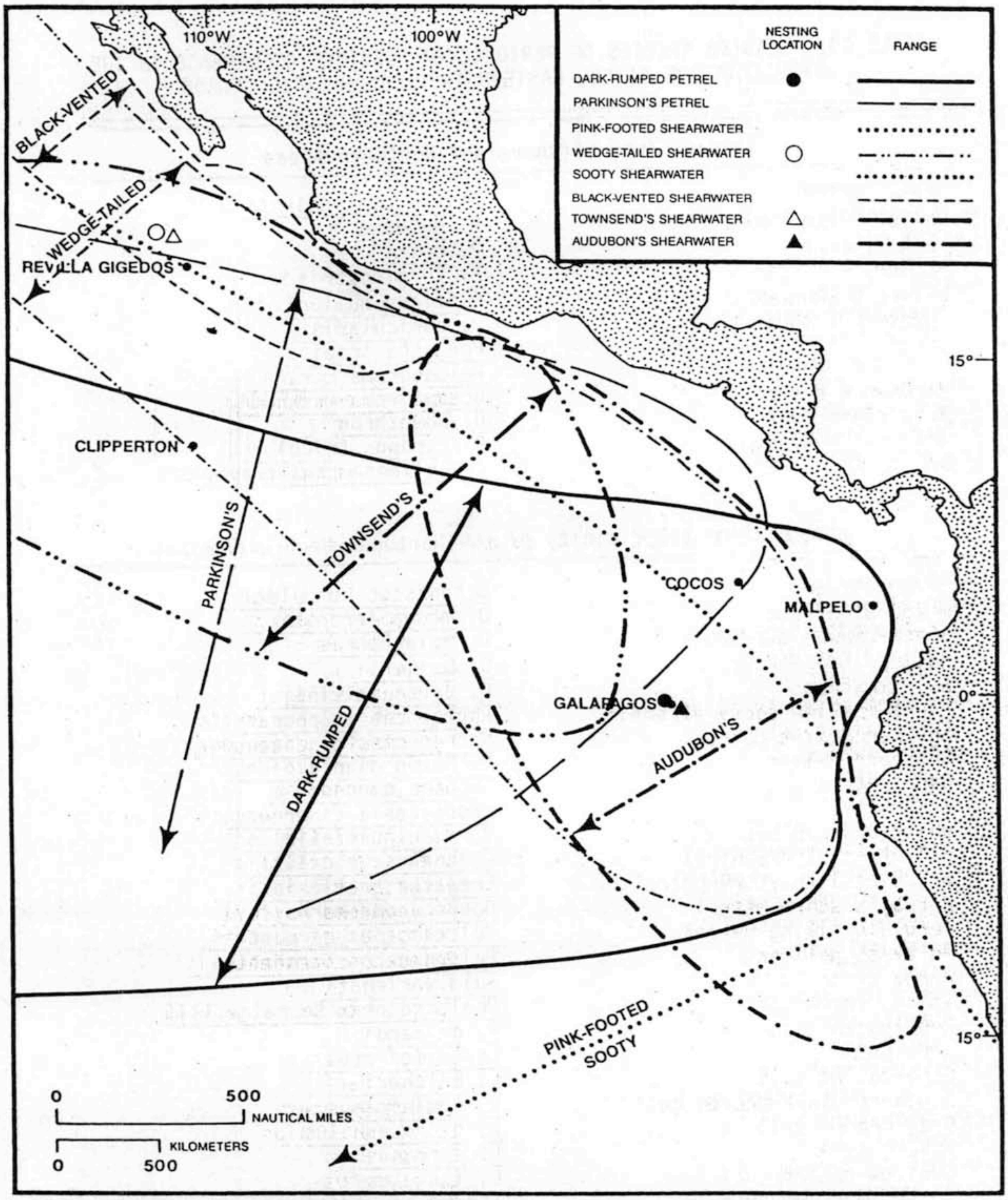


Figure 43. General distributions of petrels and shearwaters in the eastern tropical Pacific Ocean.

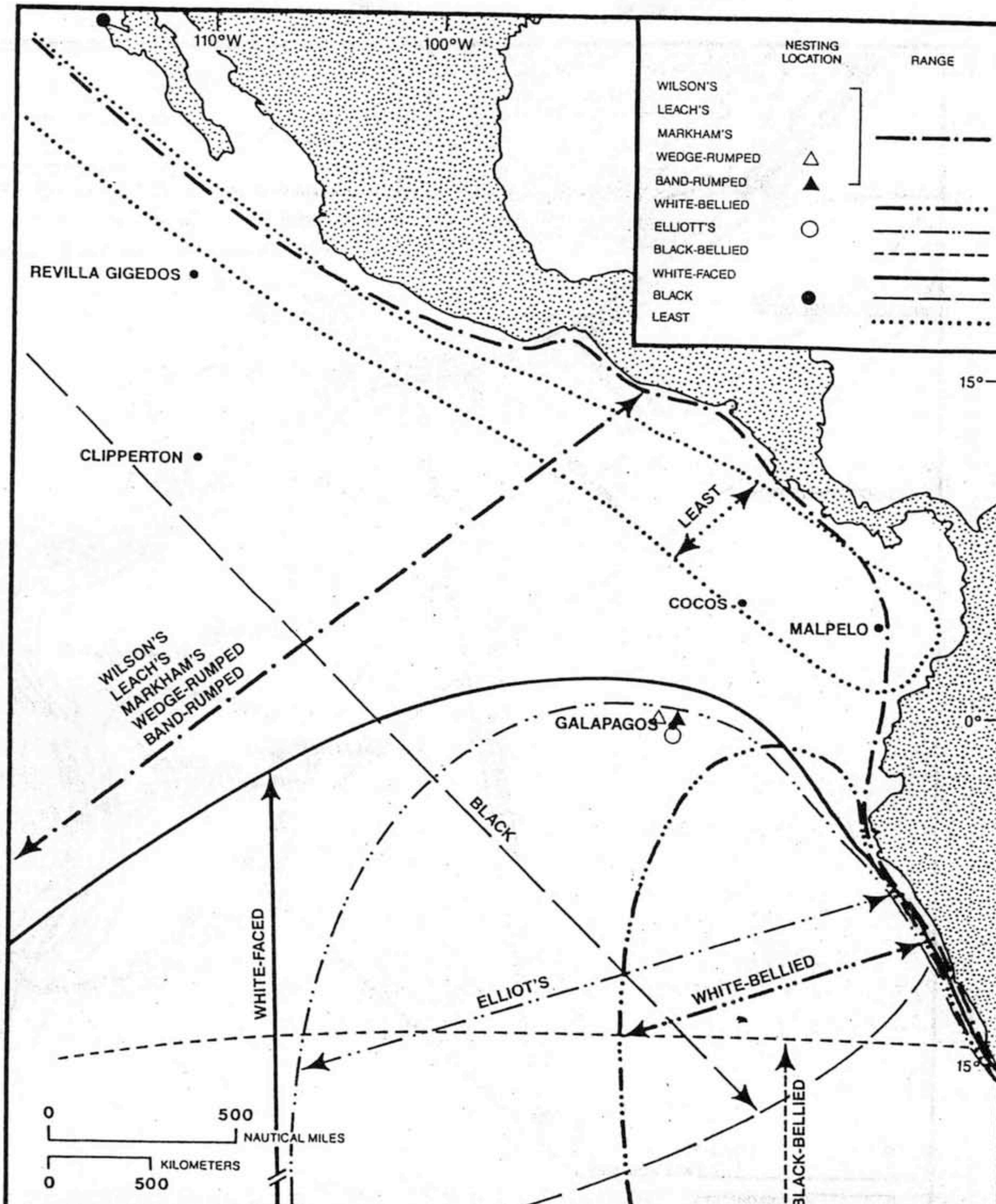


Figure 44. General distributions of storm-petrels in the eastern tropical Pacific Ocean.

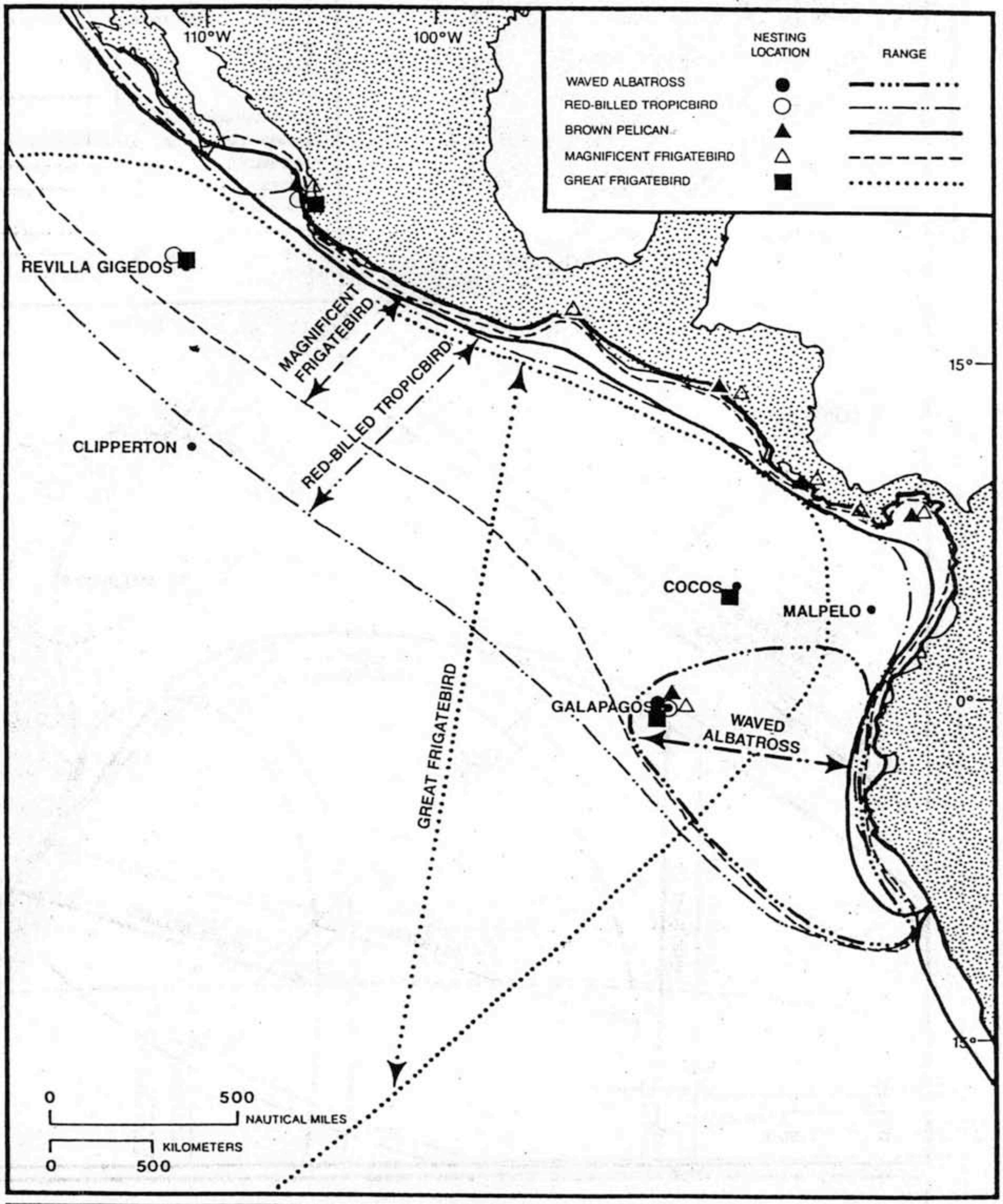


Figure 45. General distribution of several large seabird species in the eastern tropical Pacific Ocean.

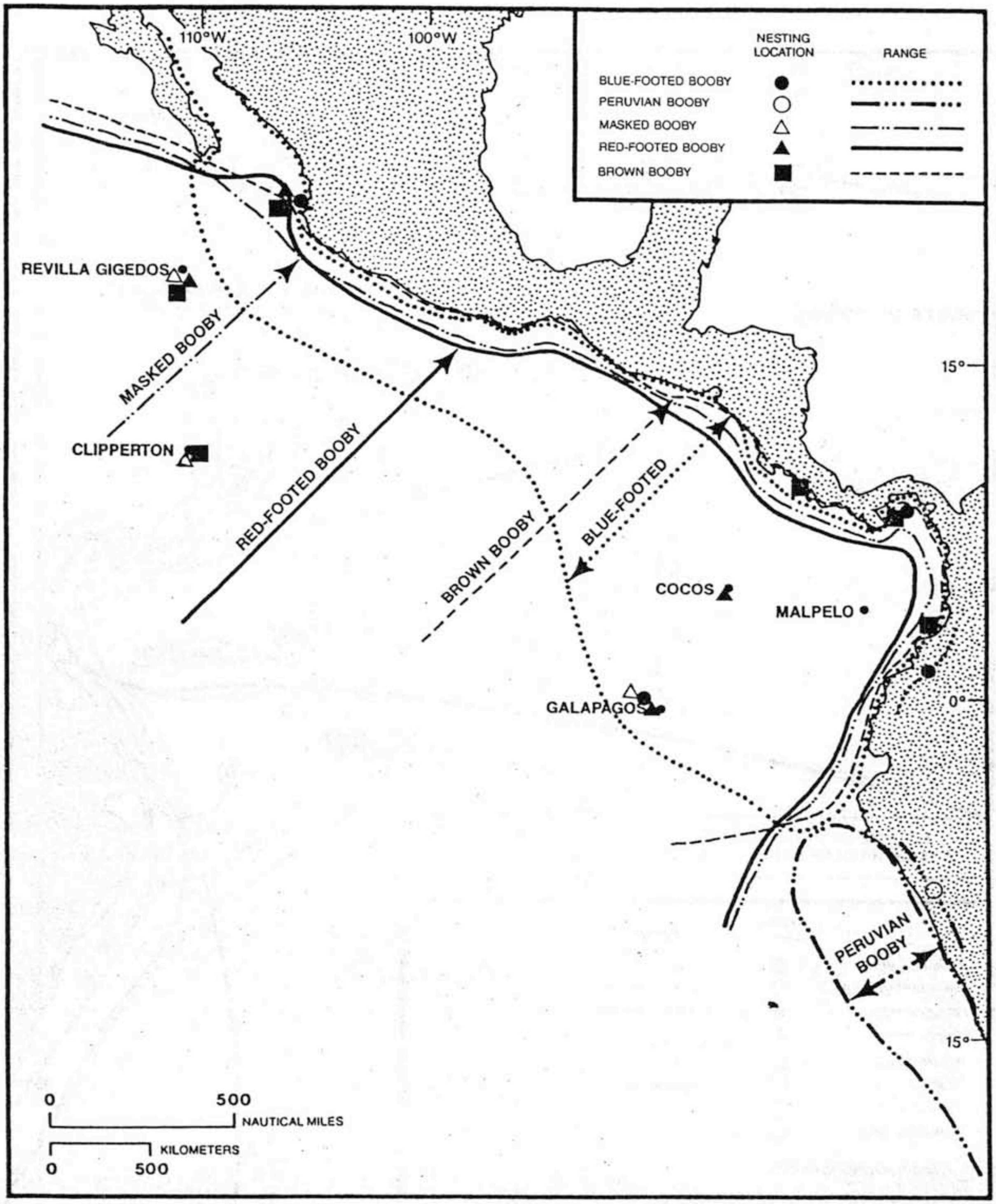


Figure 46. General distributions of boobies in the eastern tropical Pacific Ocean.

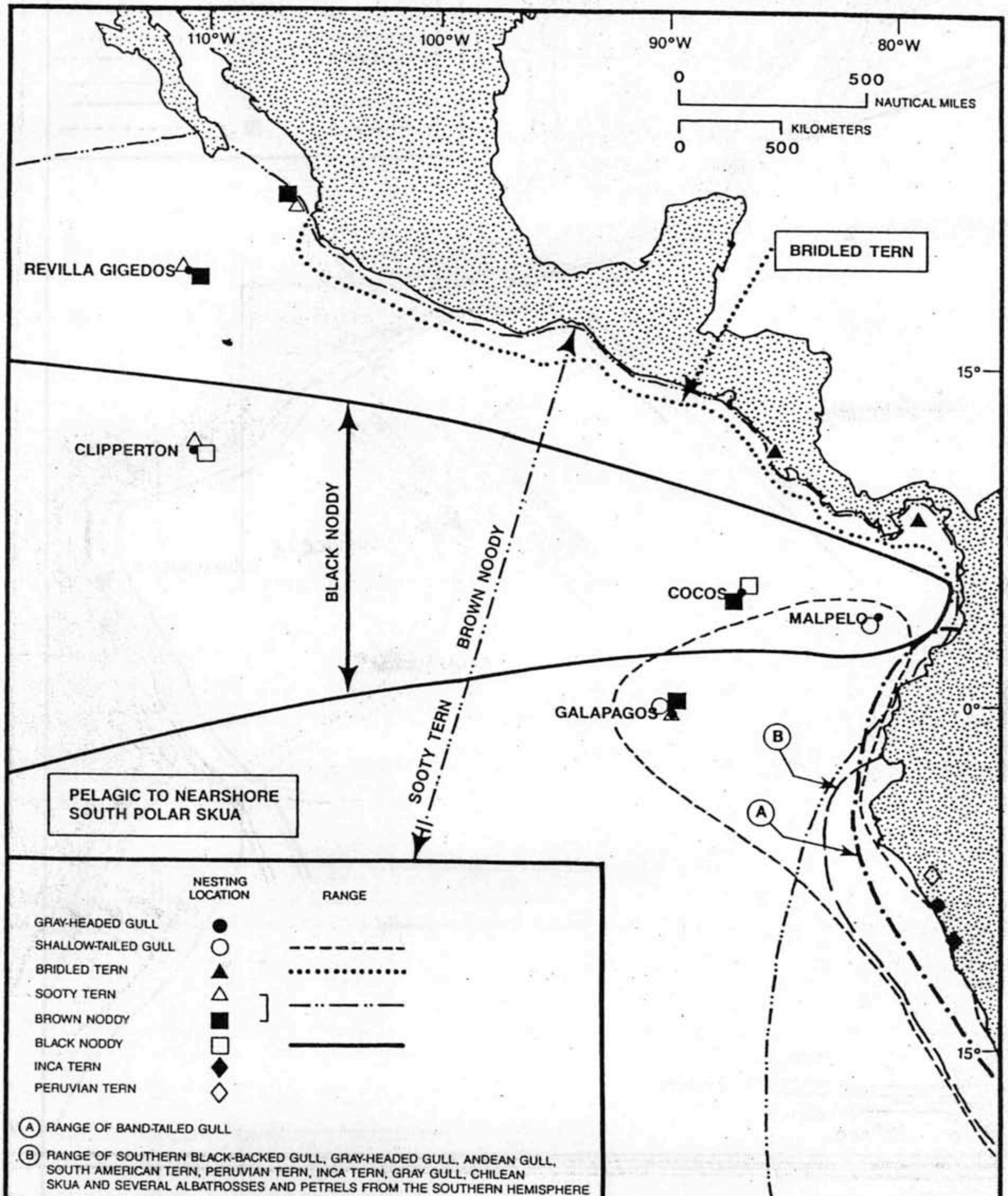


Figure 47. General distributions of skuas, gulls, and terns in the eastern tropical Pacific Ocean.

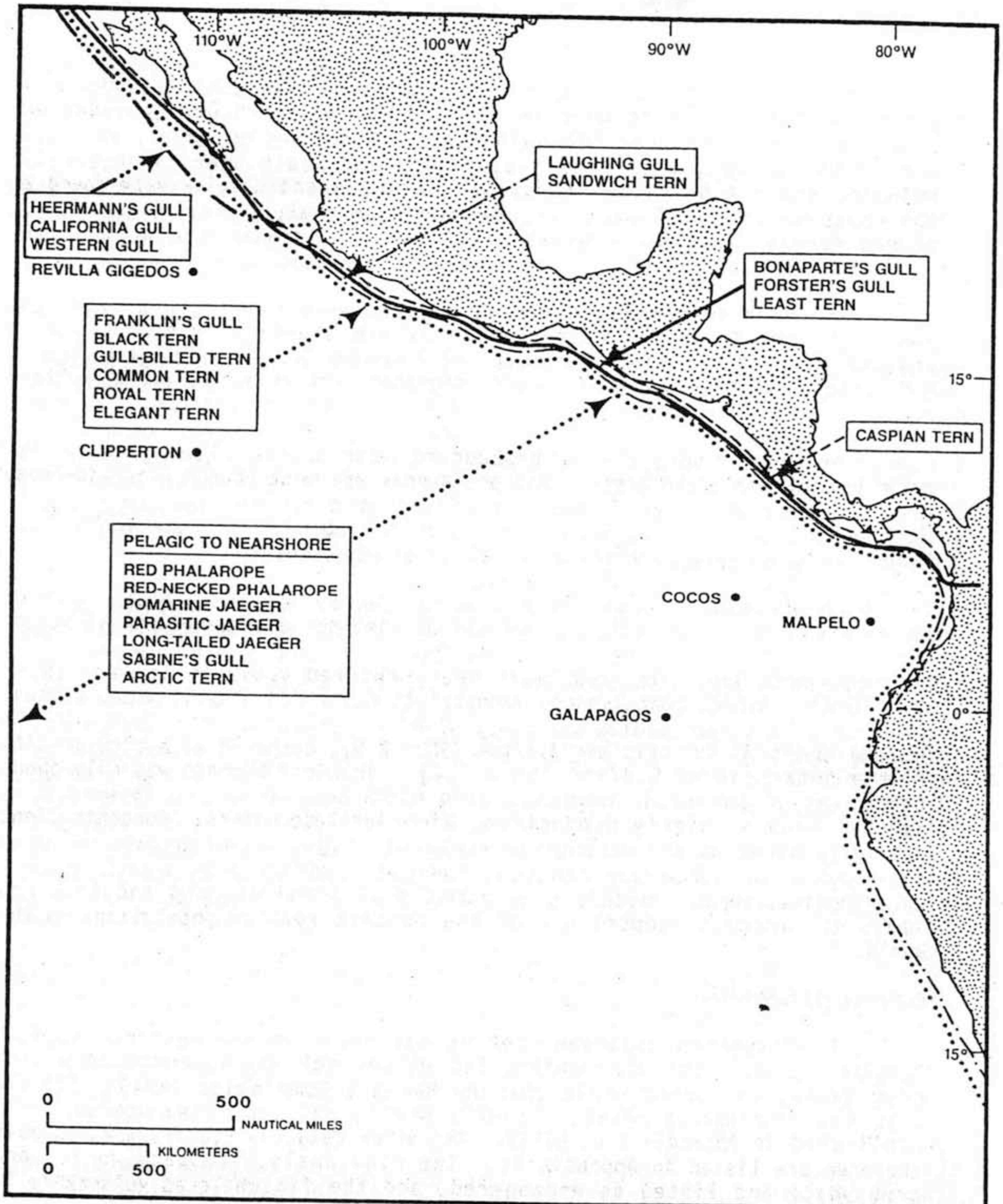


Figure 48. General distribution of migrant boreal seabird species in the eastern tropical Pacific Ocean.

Species of gulls and terns that nest in the region are shown in Figure 47. Species that reside in or migrate to the northern Peru Current area are also shown in Figure 47, including abundant species associated with cold water habitats (e.g., albatrosses, petrels, and South American gulls). Bridled, sooty and the two noddy tern species are likely to be found at the representative drilling sites. The south polar skua, a pelagic migrant, occurs rarely. The swallow-tailed gull has a limited population, nests at just two areas, and forages essentially in the northern Peru Current.

Many North American species also migrate through or winter in the region (Figure 48). Some of these species are abundant, particularly in nearshore habitats within or near the Mid-American Trench (i.e., gulls and terns). Another group of species migrates far offshore between northern nesting areas and wintering areas as far south as Antarctica (e.g., Arctic tern). Phalaropes may occur in large flocks throughout the region. Generally, red-necked phalaropes are most abundant near shore, although they also occur in many mid-ocean areas. Red phalaropes are most abundant in mid-ocean areas. Jaegers are very sparsely distributed in the region. Sabine's gull and Arctic terns may occur in flocks during migration, but few have been sighted near representative drilling sites (Jehl 1974).

Abundances and densities of seabird species in pelagic tropical areas are generally very low, and long periods of time may elapse between sightings of even individual birds. However, concentrations of seabirds within the two representatives site areas have been reported (Love 1971; Jehl 1974; King 1974). Ainley (unpublished manuscript) described densities and biomass for four generalized ecological zones of bird distribution. Bird density in the tropical Pacific was $3.4/km^2$ (SD = 2.9), compared with bird density in the antarctic of $9.5/km^2$ (SD = 7.4). Tropical biomass was only about 10 percent of antarctic biomass. Bird distribution at sea is generally patchy, even in highly productive, high-latitude waters. Concentrations typically occur at oceanographic features (e.g., areas of upwelling at shelf edges or submarine canyons, current boundaries or fronts). Cold water regimes support much higher numbers of seabirds, and the Peru and Humboldt Currents support one of the densest seabird populations in the world.

Endangered Species--

Six endangered cetacean species may occur in the eastern tropical Pacific region: the blue whale, fin whale, sei whale, humpback whale, gray whale, and sperm whale (Marine Mammals Commission 1984). All six species of endangered whales, Bryde's whale, and the goose-beaked whale are listed in Appendix I of CITES. All other cetacean species that inhabit the area are listed in Appendix II. The blue whale, humpback whale, and gray whale are listed as endangered, and the fin whale as vulnerable in the IUCN Red Data Book.

Two endangered species of sea turtles inhabit the waters of the eastern tropical Pacific: the green sea turtle (*Chelonia mydas*) and the Pacific Ridley sea turtle (*Lepidochelys olivacea*) (U.S. Fish and Wildlife Service 1982). The Pacific Ridley sea turtle is listed as endangered and the subspecies of the green sea turtle in the eastern pacific is listed as vulnerable in the IUCN Red Data Book.

Two otarid seal species that inhabit the eastern tropical Pacific have protected status. The Guadalupe fur seal, which can range south to near the east Pacific Rise, is protected by the Fur Seal Act of 1966, listed as vulnerable in the IUCN Red Data Book, and listed in Appendix I of CITES. The Galapagos fur seal in listed in Appendix II of CITES.

Two marine bird species are classified as endangered by the IUCN: the dark-rumped petrel and Parkinson's petrel (King 1981). The dark-rumped petrel breeds in the Galapagos and the Hawaiian Islands and its population of about 4,000 pairs is considered endangered in both locations. Parkinson's petrel breeds off New Zealand and may forage in both representative eastern tropic Pacific drilling sites.

Biologically Sensitive Areas--

Biologically sensitive areas in the eastern tropical Pacific include the Pacific coast of Mexico, which supports breeding populations of the endangered green and Pacific Ridley sea turtles; the Galapagos Islands, which support many endemic species; and other islands (e.g., Clipperton Island, Reville Gigedos), which support important seabird nesting habitat and, in places, entire seabird populations. Hydrothermal vent communities found along the spreading center of the East Pacific Rise are rare and sensitive areas which support species endemic to these vents.

OTHER USES OF REPRESENTATIVE DRILLING AREAS

Weddell Sea

Commercial Fisheries--

Fish are relatively unimportant in the Southern Ocean ecosystem. Though small commercial fishing operations exist, mostly off South Georgia Island in the Scotia Sea and around Iles de Kerguelen (SCAR 1982), no commercial fishing occurs in the Weddell Sea. Krill are harvested commercially in Antarctic waters on a small scale at present, but could become more heavily exploited. Minke whales and some small odontacetes are taken from antarctic waters. This harvest is expected to cease in 1986, when the International Whaling Commission ban on commercial whaling takes effect. Sealing is restricted under the regulations of the Convention for the Conservation of Antarctic Seals. An international treaty establishes a regime for Conservation of Antarctic Living Marine Resources (U.S. Department of State 1978) and regulates harvesting of Antarctic species.

Military Uses--

The Antarctic Treaty states that it is in the interest of all persons that Antarctica shall continue forever to be used exclusively for peaceful purposes and shall not become the scene or object of international discord. As a result, this area is not used for any military purposes.

Resource Development--

Presently, there is no resource development in the Weddell Sea region other than the specific fisheries discussed earlier. In two reports on the antarctic environmental implications of possible mineral exploration and exploitation, SCAR (1981, 1982) suggested that offshore hydrocarbons could be the first mineral resource in Antarctica to be developed. Initial efforts are expected to take place either in the Ross Sea embayment or adjacent to the Antarctic Peninsula, but not before the year 2000.

Other Scientific Research--

Scientific research is the principal activity on the continent of Antarctica and in its surrounding waters. Most research is conducted in glaciology, biological and medical sciences, earth sciences, upper atmosphere physics, meteorology, and ocean sciences. Most programs focus on environmental and resource-related research.

Scientific expeditions in the Weddell Sea have produced a substantial body of oceanographic data from the ice-free portion of the Weddell Sea, and interdisciplinary programs have defined relationships among a variety of processes in the Weddell Sea region.

Georges Bank

Commercial Fisheries--

The New England region, including the Georges Bank, supports a large commercial fishery representing 13 percent of total U.S. landings in terms of pounds and 15 percent in terms of dollars. In both weight and value, it is the third most important region in the U.S. (Minerals Management Service 1983c). Although the entire Georges Bank area is important for commercial fisheries, the Northeast Peak shelf break zone and the Georges Bank crest, bounded by the 60-m isobath, are the areas of greatest biological and economic importance.

Commercially important species on Georges Bank include cod, haddock, pollock, hake, herring, flounder, mackerel, lobster, crab, and sea scallop (see Table 11). In 1983, the National Oceanic and Atmospheric Administration (NOAA) estimated a maximum sustainable yield for Georges Bank stocks of cod, haddock, and yellowtail flounder to be 35,000 mt, 22,750 mt, and 5,000 mt, respectively (Minerals Management Service 1983c). These yields are much lower than comparable annual landings from 1962 to 1977 reported by Edwards (1982) and emphasize the depletion of these stocks.

Military Uses--

Portions of the water and air space of the Georges Bank area are used for training, readiness, and support of U.S. national defense and security interests. These activities normally occur in areas specifically designated for such purposes. The controlling authorities for each operating area are responsible for directing oceanic and air maneuvers and for coordinating them with other endeavors, such as oil exploration activities or the ODP. Overall responsibility for the Offshore Military Activities Program is vested in the Assistant Secretary of Defense (Manpower Reserve Affairs and Logistics). Under the policy specified in 32 CFR 252, the Department of Defense will accommodate the joint use of such areas with other agencies and with the public to the maximum extent feasible. Currently designated areas in the vicinity of Georges Bank are the Boston Operating Area, along the New England coast, and the Air Force Warning Area W-506, encompassing the southern portions of Georges Bank.

Transportation--

There are four major ports in New England: Boston (Massachusetts), Portland (Maine), New Haven (Connecticut), and Providence (Rhode Island). Traffic Separation Schemes (TSSs) and Precautionary Areas (PAs) have been established by the U.S. Coast Guard and adopted by the International Maritime Organization (IMO) to reduce the possibility of collision between vessels entering and exiting major port areas. Mariners are advised to exercise extreme caution when crossing traffic lanes and separation zones, and when navigating within precautionary areas. All TSSs and PAs are closer to the coastline than to Georges Bank. The precautionary area in the Great South Channel southwest of Georges Bank is closest to potential ODP drilling activities.

Resource Development--

In addition to the fishery resources discussed above, the Georges Bank area has substantial reserves of oil and gas. The Minerals Management Service (1983c) estimated that conditional mean resource levels of 210 million barrels of oil and 4.9 trillion ft^3 of gas may be present in the outer continental shelf area offshore the North Atlantic states. Georges Bank covers the major portion of this offshore area. The first lease sale by the U.S. Department of the Interior in this area was held in 1979 and resulted in 62 executed leases. Since then, two other lease sales have been proposed but later postponed due to Congressional action. Eight exploratory wells were drilled on Georges Bank as a result of the first lease sale, but commercial discoveries have not yet been made.

Other Scientific Research--

The controversy over oil and gas development in the Georges Bank area has resulted in a number of scientific studies to assess the environmental impacts of potential oil spills. For example, the Minerals Management Service is sponsoring studies on the fate of drill muds and cuttings on Georges Bank, the affects of these discharges on marine benthos, the effects of oil on marine benthos, the effects of oil on marine mammals, physical and biological processes of canyons and the continental slope in the North and Mid-Atlantic OCS, physical oceanographic and geologic investigations, and an environmental summary of the U.S. Atlantic continental rise.

Eastern Tropical Pacific

Eastern Pacific Rise--

Commercial Fisheries--Commercial fishing in the international waters of the East Pacific Rise representative region is conducted mainly by large fishing fleets from the developed countries of the Pacific Rim. In the eastern central Pacific region, which consists largely of the Eastern Pacific Rise area, the annual catch of fish (mainly tunas), crustaceans, molluscs, and other species has increased steadily (U.N. Food and Agriculture Organization 1983). The annual catch increased from 1.5 million mt in 1976 to 2.6 million mt in 1982, but still forms a very small part of the total world catch.

Other Uses--The East Pacific Rise region is not among the heavily travelled ocean routes in the world. Regularly scheduled military exercises or scientific research are not carried out on the open seas. Interest in the seafloor mining of manganese nodules in this region is increasing. However, only exploration has been conducted to date and no commercial activities are planned for the near future. Since none of these activities is expected to interfere with or be affected by the ODP, no further discussion is provided.

Mid-American Trench--

Commercial Fisheries--Commercial fishing is expanding in almost all Central American countries bordering the Mid-American Trench representative region (Panama, Costa Rica, Nicaragua, El Salvador, Guatemala, Honduras, and Mexico). These fisheries earn foreign exchange and supply an important component of the local diet. Waters offshore Central America support smaller populations of numerous species rather than large schools of just a few species. Shrimps, lobsters, croakers, albacore, skipjacks, and anchovies are the most important commercial species. In Guatemala, Honduras, and Nicaragua, shrimp and lobster are the principal species caught for export.

Most local fishermen operate within the 19-km (12-mi) territorial limit. Fishing on the open seas is carried out mostly by international companies. Mexico claims a 322-km (200 mi) EEZ and reserves mineral and marine resources within this zone to itself. Foreign vessels may be licensed to fish in the EEZ if Mexican citizens constitute at least half the crew.

Other Uses--Coastal waters are used for transportation, military activities, and scientific research, but the level of such activities is low due to general economic conditions in Central America. None of these activities is expected to interfere with or be affected by the ODP, and no further discussion is provided.

Section 3.4
FEATURES OF THE TERRESTRIAL ENVIRONMENT WHICH MAY BE IMPACTED BY ODP

Land use and air quality may be impacted by specific ODP activities. Onshore tasks involve program planning and management, conversion of the drilling vessel, design and fabrication of the drilling systems, and development and use of land staging areas, particularly at TAMU.

Major U.S. sites of onshore activities include Washington D.C.; College Station, Texas; Palisades, New York; and Pascagoula, Mississippi. JOI's overall planning, management, operations, and data dissemination activities are located in Washington, D.C. Direction of science and shipboard operations, design and maintenance of permanent laboratories and support facilities, and curation and dissemination of scientific information occur at TAMU. This major university is located in College Station, a city of approximately 37,000 people in southwest Texas. Logging analysis and data dissemination will occur in L-DGO's facility at Palisades, New York. L-DGO, TAMU, and Scripps Institution of Oceanography in La Jolla, California will serve as core repositories. Detailed procedures for offloading cores at ports, transport to repositories, and curation are described in the Shipboard Scientist Handbook (ODP 1985). Ship conversion, fabrication, and construction of drilling systems and equipment occured in Pascagoula, Mississippi, a port city of approximately 29,000 people. An industrial and fishing center, Pascagoula is located on the Gulf of Mexico.

The drillship will visit various ports throughout the world between operational legs for core transfer, fueling, routine maintenance, special repairs, and stocking of consumables and materials. These established ports have in-place facilities to accommodate calls by vessels like the JOIDES RESOLUTION. Transportation of personnel and supplies to these various locations will use existing carriers.

CHAPTER 4

ENVIRONMENTAL CONSEQUENCES

Section 4.1
INTRODUCTION

Results of comparing the environmental impacts of the proposed action with those of its alternatives are presented in this chapter. Environment has been broadly defined to include physical, biological, social, legal, and economic considerations. Both direct and secondary impacts have been analyzed, whether positive or negative. Subjects are discussed at a level of detail appropriate to the relative significance of each topic.

TREATMENT OF DRILLING LOCATIONS

As discussed in Chapter 2, the impact assessment focuses on four drilling sites that represent the range of scientific goals, geographic locations, and ecological conditions expected during of the ODP and that allow analysis of the range of potential impacts. Subject categories that were reviewed under each representative site in Chapter 3 are retained in this chapter for impact analysis. Environmental conditions from all four sites are considered in the determination of impacts on or to each subject category. This allows assessment of potential impacts that may be ignored under a more generalized approach.

TREATMENT OF ALTERNATIVES

The Council on Environmental Quality (CEQ) regulations implementing NEPA (40 CFR 1500-1508) state that all reasonable alternatives to a proposed action must be "rigorously explored and objectively evaluated." Such careful analyses occurred during the OMDP period of planning and evaluation and throughout the subsequent development of the AODP and transition to the ODP. Initially, alternatives external to ocean drilling were discussed (that is, activities that could be implemented in lieu of drilling to achieve some, but not all, of the objectives of deep-sea scientific drilling). These options primarily involved extensive geophysical surveys and/or other seismic studies. Continued CHALLENGER-type drilling was also considered (in essence a continuation of the DSDP). Impacts of these alternatives have been addressed in the DSDP/IPOD EIS (NSF 1975), which is still applicable to the program. However, assessment throughout program development indicated that only through an expanded program of deep-sea drilling, which the ODP represents, could the important objectives be realized. Other alternatives were judged inadequate for meeting the objectives (Committee on Post-IPOD Science 1979; JOIDES 1981, 1982).

Alternative operational programs, which were mentioned in Chapter 2 of this EIS, are evaluated in this chapter. Internal programmatic alternatives are appropriate to evaluate in the EIS. During program development, many decisions were made to improve cost and technical efficiency. Decisions lacking influence on environmental considerations do not receive detailed discussion in this EIS. However, some aspects of the program do have bearing on environmental considerations (e.g., operational decisions such as site locations, well planning, drilling procedures, and drilling schedules). These subjects are addressed with the necessary detail. Many of these alternatives are still under evaluation.

Section 4.2
BASIC ASSUMPTIONS USED IN THE ANALYSIS OF ENVIRONMENTAL IMPACTS

In this section, program elements are categorized by their site of potential influence (i.e., whether on land or at sea). Then, processes and procedures constituting the program elements are described in enough detail to support the discussions of impacts appearing later in the chapter.

ASPECTS OF ODP PRIMARILY AFFECTING THE TERRESTRIAL ENVIRONMENT

The first years of effort in the ODP have taken place onshore, primarily for the tasks of program design, planning and management, conversion of the drilling vessel, and design and fabrication of the drilling systems. The primary impact of these activities was to create jobs. For most of the activities, this was a temporary effect that ended with the commencement of at-sea operations. Land-based activities continuing throughout the program were discussed in Section 3.4.

Conversion of JOIDES RESOLUTION for ODP operations required shipyard construction work on the hull and superstructure. The U.S. Department of Commerce, Maritime Administration discussed impacts of shipyard construction in the Final EIS on Title XI, Vessels Engaged in Offshore Oil and Gas Drilling Operations (MarAd 1975), which were applicable during conversion. Similar impacts are expected from future conversion to riser drilling capability and are addressed in MarAd (1975).

ASPECTS OF ODP PRIMARILY AFFECTING THE OCEAN ENVIRONMENT

Most potential impacts of the ODP will occur in the ocean, the site of most of the program activity. These activities are described in this section. Assessments of impacts appear later in the chapter (Sections 4.4-4.6.)

Presence of the Ship and Drill String

Various materials are released to the environment during routine ship operations, whether in transit or drilling on station. During riserless drilling activities, the maximum length of time the ship would occupy a single location is limited to the duration of one sea leg (usually less than 60 days). For any riser drill sites, this stay is lengthened by the time required to assemble the riser before drilling commences (typically 3 weeks), and to achieve the deeper penetration of most riser holes.

The major discharges expected from riserless drilling activities are drilling fluids (seawater) and cuttings. These will be discharged to the seafloor, and will accumulate in the immediate vicinity of the hole. Surface discharges are also expected, including sanitary and domestic wastes, desalination unit discharge, boiler blowdown, deck drainage, cooling water, uncontaminated ballast and bilge water, burn box waste, and excess cement slurry.

The volume of sanitary waste which consists of masserated hypochlorinated effluent is expected to reach 1,000 to 5,000 gallons per day (GPD). Dissolved oxygen depression resulting from this treated discharge is not expected to affect organisms when ambient dissolved oxygen concentrations are at least 6 mg/L. Dissolved oxygen concentrations of surface waters in most of the world's oceans are generally much greater than 6 mg/L. Domestic wastes (shower and sink drainage) are not expected to produce a significant pollutant loading and will only raise particulate concentration temporarily in a localized area. Any drainage from the laboratories will have been acid neutralized in limestone media and milk of magnesia before addition to the domestic waste holding tank for eventual discharge.

Desalination units may discharge on the order of 20,000 GPD of seawater at a salinity twice that of ambient seawater. Boiler blowdown may be discharged once or twice per year and is not expected to be a significant source of pollutant loading.

Deck drainage consisting of rain and wash water from the deck and drilling floor is conveyed by gutters to a settling tank. Solids are separated before the water is discharged. Oil is the primary pollutant in deck drainage, but these discharges may also contain smaller concentrations of detergents.

Bilge and engine room drainage will be treated to remove oil prior to discharge. An International Maritime Organization (IMO) rule requires all Liberian-registered ships to meet a 15 ppm oil concentration limit on these discharges by January 1, 1986. Noncontact cooling water discharge is not expected to be an important pollutant source. Except for the elevated temperature, the composition of noncontact cooling water will not differ significantly from ambient seawater. Ballast waters will not be treated.

All refuse and combustible waste material generated while at sea is burned in a high temperature burn box over the side of the vessel. After burning, the combusted burn box waste is discharged into the ocean. The discharge will not have any measurable dissolved oxygen demand and is not expected to produce significant pollutant loading. Particulate concentrations will be raised temporarily in a localized area.

Cement will also be discharged on the ocean floor during the early phases of drilling (i.e., during setting of surface casing), and during well abandonment and plugging. According to the ODP policy on well abandonment, when plugging is necessary, the hole should be cemented up to the first competent formation. This reduces the amount of cement introduced into the marine environment on the seafloor. Excess cement slurry resulting from equipment washdown after cementing operations will be discharged with deck drainage. The composition of the cement is not documented, but is not expected to be a significant pollutant source.

Release of Cuttings and Drilling Fluids

Drilling procedures and equipment vary significantly between riserless and riser drilling, as discussed in Section 2.2. In addition, the composition of drilling fluids and the location of release are different for the two drilling procedures. Therefore, environmemtal affects of drilling muds and cuttings are discussed separately for the two drilling procedures.

Riserless Drilling Operations--

Riserless drilling procedures used aboard CHALLENGER during the DSDP will also be used for the ODP. Surface seawater, used as the drilling fluid, is pumped through the drill string to the bottom of the hole. This cools the bit and washes the cuttings up the annular space between the drill string and the wall of the drilled hole. At CHALLENGER's average pumping rate (350 gal/min) and operational time (aggregate 150 days/year) 75.3 million gal/year or 285,000 m^3/year (372,780 yd^3/year) of surface seawater were discharged at the seafloor. Minor amounts may invade sub-bottom formations. However, pump pressure sufficient to cause this would be avoided because of the deleterious effect on hole stability and the potential loss of the down-hole drill assembly and other subsea equipment.

If laden with drilling particulates (very fine cuttings), this sea water/solid suspension will spread laterally downcurrent. Particulates will settle out and the fluid will mix with the local bottom water. If generally particulate-free (as might be the case when pumping but not drilling or when drilling produces only very coarse cuttings that will not stay in suspension), the fluid will probably retain some coherence and buoyance, having been warmed while in the drill hole. The warmer, less-dense fluid will entrain ambient water on its rise through the deeper water masses. Eventually, this mixture will reach a level of neutral bouyancy, at which point it will spread laterally, mixing with the ambient waters.

Based on figures compiled during the DSDP, an average of 20,000 m/year (65,600 ft/year) of sediment and basalt will be penetrated. Assuming a 25-cm (10-in) diameter hole and about 30 percent hole enlargement, approximately 1,350 m^3/year (1,766 yd^3/year) of drill hole cuttings will be produced and discharged at the seafloor, along with the drilling fluid. The maximum particle size that can be washed out at present pumping velocities is approximately 2 mm diameter. Particle-size distribution in the cuttings will vary with the material being drilled and the variety of bit. In soft sediments, the original particle size will dominate the size distribution of cuttings. Diamond bits, if used in consolidated sediments or solid rock, will produce finer cuttings than the more coarsely toothed roller bits.

Drilling muds are occasionally used to clean, spot, or lubricate the drill hole. For example, in preparation for logging and casing, 20-50 bbl of drilling mud may be injected to remove coarse cuttings that the seawater drilling fluid did not remove [volume of 2.3-8 m^3 (4.2-105 yd^3) based on average mud weight of 17 lb/bbl and average water content of 50 percent]. When the drill string is being pinched by a formation, 10-bbl [1.6 m^3 (2.1-yd^3)] shots may be used for lubrication. Estimated total usage of drilling mud is 3,000 m^3/year (3,924 yd^3/year), based on the DSDP mud use rates for similar riserless drilling. As with cuttings, muds will exit the hole at the seafloor. Areas of accumulation will depend on bottom currents.

Volumes of drilling muds and cuttings introduced into the environment at a single drill site can be estimated based on hole depth. Assuming a penetration of 1,700 m (5,576 ft) (a worst-case scenario for riserless drilling based on the deepest penetration obtained during the DSDP), 115 m^3 (88 yd^3) of cuttings and 255 m^3 (195 yd^3) of drilling muds will be discharged from the hole at the seafloor. For purposes of impact analyses on benthic communities, solids deposited in even thicknesses of 1 cm and 1 mm would result in coverage of 0.04 km^2 (0.01 mi^2) and 37 km^2 (14 mi^2), respectively. This is equivalent to circles of 220 m (662 ft) and 6,900 m (22,632 ft) in diameter. In reality, coverage is much less, with most of the deposition in the immediate vicinity of the borehole. The coarser fraction will accumulate near the hole, while the finer fractions will accumulate progressively farther downcurrent. The total area covered by cuttings will depend on bottom current velocities and the size distribution of cuttings.

Riser Drilling Operations--

Riser drilling procedures, materials, and equipment are similar to those used in offshore oil drilling. Drilling mud instead of seawater is used as the drilling fluid. The muds leave the drill bit nozzle, sustain the drill cuttings in suspension, and carry them to the drillship between the drill pipe and the walls of the bore hole, casing, and riser. On board the ship, cuttings are separated from the muds by screening and washing techniques and then discharged at the sea surface. Muds are returned to the mud tank for recirculation down the hole. Drilling muds that are not separated from the drill cuttings are discharged with the cuttings to the ocean.

The volume of mud used per riser drilling site depends on water and hole depth. The volume of mud discharged will vary from a few bbl to over 1,000 bbl, depending on downhole formations and the condition and composition of the mud in use at the time. For purposes of impact analyses, the worst-case situation would involve discharge of the four mud tanks on board JOIDES RESOLUTION, which combined hold 2,150 bbl. This could occur if the reserve tanks were full and a mud change was necessary to meet conditions downhole or if the mud was beyond reconditioning. This would result in the discharge of 342 m^3 (447 yd^3) of drilling mud to the surface waters over the drill site.

Although riser drilling holes are deeper, and more cuttings will be discharged per hole, fewer boreholes can be drilled per year. The net effect will be to reduce the annual volume of cuttings discharged. In addition, the cuttings will be released at the surface, resulting in greater dispersion and thinner initial accumulations on the seafloor.

Dilution of Drilling Mud Discharges--The Offshore Operations Committee (OOC) model has been used to estimate the dilution of drilling mud discharges from the JOIDES RESOLUTION. A complete description of model formulations, concepts, required inputs, output options, and model limitations is given in the user's manual (Brandsma et al. 1983). The OOC model was developed to describe the fate of offshore drilling mud discharges. The model simulates the effluent plume (commonly known as the lower plume) through three phases: the jet phase (convective descent, dynamic collapse, and passive diffusion). The model also simulates an upper plume, which appears to form when particles of mud separate from the main plume during the convective descent phase. The upper plume may represent up to 10 percent of the dischaged mud.

OOC model simulations for various oceanographic and drilling conditions were conducted by Tetra Tech (Bigham et al. 1984). Results of these simulations indicate that dilution increases with water depth. The case closest to conditions that will be encountered during most ODP drilling is an open ocean site characterized by a deep, well-mixed surface layer. Parameters include a 120 m (394 ft) water depth, a 1,000 bbl/h mud discharge rate, a 17.4 lb/gal mud bulk density, and a 10 cm/sec current speed. The shallower depth of this case compared to ODP drill sites should conservatively represent ODP conditions. Minimum particulate and dissolved dilutions at 100 m (328 ft) from the discharge were calculated to be 1,440:1 and 2,500:1, respectively. Similarly, at 300 m (984 ft) distance, the particulate and dissolved dilutions were calculated to be 5,440:1 and 7,290:1, respectively. At 500 m (1,640 ft) from the discharge, both particulate and dissolved fraction dilutions were well over 10,000:1. Since lower discharge rates are more typical of offshore drilling activity and higher current speeds may be encountered in the surface waters of many proposed drilling sites, dilutions achieved during actual ODP drilling should be much greater than those calculated.

Deposition of Drilling Discharges--Accumulation of drilling muds and cuttings on the seafloor is expected to be minimal for discharges to water depths as great as those of most sites to be drilled with a riser during the ODP (several hundred meters minimum). No field studies and few modeling efforts have been conducted at these depths to determine characteristics of seafloor deposition.

The OOC model has been used to simulate drilling mud solids accumulation in water depths from 5 to 750 m (16 to 2,460 ft) (Bigham et al. 1984; Continental Shelf Associates 1984). While the majority of these simulations were run for shallow water conditions, the results indicate that minimal seafloor solids accumulation (much less than 0.1 mm) occurs for depths greater than 100 m (328 ft) and that accumulation decreases as water depth or current increases.

Simulations conducted by Continental Shelf Associates (1984) represented typical drilling and oceanographic conditions offshore southern California. Current speed, density stratification, bulk mud density, and water depth were varied to determine deposition patterns under various conditions. Four water depths greater than 100 m (328 ft) were considered in this analysis: 190 m (623 ft), 200 m (656 ft), 480 m (1,574 ft), and 750 m (2,460 ft). The maximum drilling mud deposition thickness calculated for these cases [190 m (623 ft) depth, 480 bbl discharge] was 0.01 mm. The bottom area affected by deposition greater than 0.001 mm was calculated to be 0.43 km^2 (0.17 mi^2) for this case. Even a worst-case discharge (2,150 bbl) should result in maximum accumulations of less than 0.05 mm. Cuttings deposition was simulated for the 480 m (1,574 ft) depth case only (480 bbl of cuttings). The maximum deposition thickness for this case was calculated to be 0.007 mm. The bottom area affected by cuttings deposition greater than 0.001 mm was calculated to be 107 km^2 (41 mi^2). Cuttings volumes in the simulation are on the order of those expected discharged from a deep hole.

Composition of Drilling Mud--

Drilling muds are complex mixtures of clays, barite, and several specialty additives used primarily to remove rock particles from the hole created by the drill bit. The composition of drilling mud can vary over a wide range from one hole to the next, as well as with depth during the drilling of a single hole.

Drilling muds serve several other functions in addition to removing solids. These include creating back pressure to counteract formation pressure at depth, lubricating the drill bit, and controlling the flow of fluids between the formation and the hole. As the hole becomes deeper and encounters different formations, the type of mud may need to be changed or the composition altered.

Eight generic mud types were evaluated by the U.S. EPA during discharge permit development for drilling muds and cuttings in offshore drilling. Basic components of each mud and their maximum authorized concentrations are listed in Table 20 . These guidelines will be followed by the ODP. Each mud differs in its basic components, and a single mud type can vary substantially in composition. For example, the amount of barite in seawater/lignosulfonate mud can vary from 25 to 450 lb/bbl.

The presence of potentially toxic trace elements in drilling muds and cuttings is of primary concern. Metals including lead, zinc, mercury, arsenic, and cadmium can be present as impurities in barite; chromium is present in chrome lignosulfonates and chrome-treated lignite (Crippen et al. 1980; Kramer et al. 1980). Drill pipe dope (15 percent copper, 7 percent lead) and drill collar dope (35 percent zinc, 20 percent lead, 7 percent copper) may also contribute trace metals to the muds and cuttings discharge (Ayers et al. 1980; Ecomar 1978).

An estimate of trace metal concentrations in the drilling muds and cuttings discharged from ODP drilling operations is made here for subsequent impact evaluation. Because only limited data are available on the trace metal content of drilling muds and cuttings, maximum values for generic muds (Table 20) were compared from all the OCS regions and used to produce the maximum expected trace metal concentration values presented in Table 21.

In the absence of detailed information on the partitioning of metals between the dissolved and particulate phases of drilling muds and cuttings, the metals partitioning characteristics of dredged material are used here to estimate dissolved metals concentrations associated with drilling muds and cuttings. This is believed to be a reasonable approach because of the physical similarities of the two materials. Dredged materials are naturally-occurring sediments, sometimes contaminated, that are mechanically or hydraulically picked up and transported to another site for disposal. The important similarity to drilling muds and cuttings is that the majority of the bulk metals are incorporated into the crystalline lattice of inorganic particles.

Concentrations of metals observed in the solid and dissolved fraction of samples of dredged material dumped at sea in 1978 and 1979 (Bigham et al. 1982) are presented in Table 22. The data represent approximately

TABLE 20. APPROVED DRILLING MUD TYPES

COMPONENTS	MAXIMUM AUTHORIZED CONCENTRATION (pounds per barrel)
Seawater/Freshwater/Potassium/Polymer Mud	
KCL	50
Starch	12
Cellulose polymer	5
XC polymer	2
Drilled solids	100
Caustic	3
Barite	450
Seawater or freshwater	As needed
Seawater/Lignosulfonate Mud	
Attapulgite or Bentonite	50
Lignosulfonate	15
Lignite	10
Caustic	5
Barite	450
Drilled solids	100
Soda ash/Sodium bicarbonate	2
Cellulose polymer	5
Seawater	As needed
Lime Mud	
Lime	20
Bentonite	50
Lignosulfonate	15
Lignite	10
Caustic	5
Barite	180
Drilled solids	100
Soda ash/Sodium bicarbonate	2
Seawater or freshwater	As needed
Nondispersed Mud	
Bentonite	15
Acrylic polymer	2
Barite	180
Drilled solids	70
Seawater or freshwater	As needed

COMPONENTS	MAXIMUM AUTHORIZED CONCENTRATION (pounds per barrel)
Spud Mud	
Lime	1
Attapulgite or Bentonite	50
Caustic	2
Barite	50
Soda ash/Sodium bicarbonate	2
Seawater	As needed
Seawater/Freshwater Gel Mud	
Lime	2
Attapulgite or Bentonite	50
Caustic	3
Barite	50
Drilled solids	100
Soda ash/Sodium bicarbonate	2
Cellulose polymer	2
Seawater or freshwater	As needed
Lightly Treated Lignosulfonate Freshwater/Seawater Mud	
Lime	2
Bentonite	50
Lignosulfonate	6
Lignite	4
Caustic	3
Barite	180
Drilled solids	100
Soda ash/Sodium bicarbonate	2
Cellulose polymer	2
Seawater to freshwater ratio	1:1-approximately
Lignosulfonate Freshwater Mud	
Lime	2
Bentonite	50
Lignosulfonate	15
Lignite	10
Caustic	5
Barite	450
Drilled solids	100
Cellulose polymer	2
Soda ash/Sodium bicarbonate	2
Freshwater	As needed

TABLE 21. MAXIMUM TRACE METAL CONCENTRATIONS MEASURED IN DRILLING MUD DISCHARGES

Metal	Concentration (mg/kg)	Reference
Arsenic	24	a
Barium	398,000	b
Cadmium	19.2	c
Cromium	1,300	d
Copper	127	c
Lead	915	c
Mercury	2.8	e
Nickel	88	d
Vanadium	235	d
Zinc	1,350	b

[a] Crippen et al. (1980). Reported as ug/g drilling fluid.

[b] Data derived from end-of-well chemical analyses reported to U.S. EPA Region X in discharge monitoring reports (mg/kg dry weight).

[c] McCulloch et al. (1980) (mg/kg dry weight).

[d] Northern Technical Services (1981) (ppm drilling fluid) and Northern Technical Services (1982) (mg/kg solid phase).

[e] EG&G (1980b) (mg/kg dry weight).

TABLE 22. SOLUBLE AND SOLIDS METAL CONCENTRATIONS IN DREDGED MATERIALS DUMPED AT SEA, 1978 AND 1979

Metal	Average Concentration Solid Phase mg/kg	Average Concentration Liquid Phase[a] ppm	Dissolved Constituent Concentration Ratio[b]
Arsenic	4.0	0.0049	0.0012
Cadmium	1.2	0.0016	0.0013
Chromium	33.0	0.0048	0.0001
Copper	30.4	0.0027	0.0001
Mercury	0.3	0.0003	0.0010
Nickel	15.0	0.0068	0.0005
Lead	29.6	0.0068	0.0002
Zinc	68.8	0.0325	0.0005

[a] From results of elutriate test.

[b] Liquid phase:solid phase (mg/l:mg/kg).

Reference: Bigham et al. (1982, pp. 292-294).

50 separate analyses of sediments from the east and Gulf coasts of the U.S. The data in Table 22 indicate that the partitioning varies from one metal to the next but, in general, the dissolved fraction in mg/L is approximately 0.1 percent of the solid fraction in mg/kg.

Potential Oil and Gas Spills and Blowouts

Safety procedures and mitigating measures to reduce encounters with hydrocarbon reserves and prevent their release into the environment are discussed in Section 4.8. While the probability of an oil spill or an oil or gas blowout is very low, it is not zero. Impacts associated with these events are discussed under Mishaps and Accidents (Section 4.7).

Transportation of Supplies and Personnel

The drillship and its operation require supply of consumables and materials. Additionally, replacement of crew members and scientific personnel is involved. Supplies and personnel are transported by existing carriers to the various ports of call throughout the world. Occasionally, transport of supplies and personnel from shore-based facilities to the ship while at sea is accomplished by helicopter and other support vessels.

Noise from Drillship and Drilling Operations

Noise from ODP operations are generated by operation of the vessel, drilling rig, dynamic positioning system, helicopter, other support vessels and seismic geophysical surveying. Primary sources are machinery noise and diesel engines. Shipboard personnel are required to wear hearing protection devices where appropriate. Attenuation of airborne sound under light wind conditions and calm seas would reduce noise from normal drilling operations to below ambient levels after 3.2 km (2 mi). Under higher sea states, attenuation would occur within less distance (Minerals Management Service 1983a). Noise impacts to terrestrial areas are not expected, due to the distance of drill sites from land. However, sound waves travel underwater for far greater distances than they travel in air. Under the right conditions, noise from drilling operations can be elevated above ambient conditions for over 100 km (62 mi) from the drill site (Gales 1982). Impacts on the acoustical environment are detailed in Section 4.4.

Section 4.3
IMPACT OF THE ENVIRONMENT ON THE ODP

The environment will exert considerable influence on several aspects of the ODP, particularly in the areas of design and field operations (Table 23). Principal components of the environment that are addressed in this discussion include weather, ice, sea conditions, and geological conditions. The relevance of each of these topics will be discussed in turn. The discussions will overlap because many of these environmental features are interrelated and therefore tend to have cumulative effects.

WEATHER

Familiarity with climate of an area and some predictive ability are essential to:

- Ensure the vessel is capable of operating in conditions that are normal to each drill site and can safely withstand occasional extreme conditions

- Ensure adequate design of the riser and drill string systems to withstand the forces translated to the water column from the atmosphere

- Schedule the drill sites to avoid period of likely extreme conditions

- Determine prevailing working conditions on board the ship so that personnel may be outfitted and trained adequately to ensure peak safety and efficiency

- Develop drilling procedures that respond adequately to the prevailing weather and develop emergency procedures for extreme conditions.

Winds are the most significant weather condition affecting the program. Winds in the general location of a proposed drill site are important for two reasons. First, they can force the drillship off station and damage the drilling system, or, if sufficiently strong, can force abandonment of the drilling operation. Second, winds act upon the surface of the ocean, generating waves, swell, and surface currents that can impede or endanger operations. JOIDES RESOLUTION is designed to keep station and drill in winds up to 45 kn, swells up to 8 m (26 ft), and currents up to 2.5 kn.

On-site weather data are essential during operations. Sufficient advance warning of approaching weather systems is necessary to permit operations to be modified or curtailed and the ship secured. Accordingly, weather will be monitored on board the ship with a full-time meteorologist and state-of-the-art instrumentation staffed by the ODP.

TABLE 23. IMPACT OF THE ENVIRONMENT ON THE ODP

Parameter	Areas of Impact
Climate and Weather	
Wind	Dynamic positioning, supply vessel operations
Fog	Supply vessel operations, ice encounter, safety
Extreme events (e.g., storms, hurricanes, typhoons, tornadoes, gales)	Dynamic positioning, supply vessel operations, scheduling, shipboard analyses, training, drilling systems, riser and drill string design and handling, drilling/coring, safety
Precipitation	Supply vessel operations, safety
Ice	Scheduling, training, supply vessel operations, drilling/coring, safety
Sea Conditions	
Waves	Dynamic positioning, shipboard analyses, training, supply vessel operations, drilling equipment handling, drilling/coring, safety
Currents	Dynamic positioning, riser and drill string design, drilling systems drilling/coring
Physical anomalies (e.g., internal waves, turbidity currents, tsunamis)	Dynamic positioning, riser and and drill string design, training, drilling/coring, safety
Geologic Conditions	
Ambient temperature	Well design[a], subsea equipment,[b] well control
Formation pressures	Well design, subsea equipment, drilling/coring, well control
Fracture gradients	Well design, subsea equipment, drilling/coring, well control
Geologic anomalies (clathrates, overpressure zones, faults, slides and slumps)	Subsea equipment, drilling/coring, well design, well control, safety
General characteristics (e.g., sediment types, depth of basement rock, surface conditions, sediment stability)	Well design, drilling/coring, well control

[a] Includes casing, hydraulics, cement, bit, and mud programs.

[b] Includes all downhole equipment and logging tools.

ICE

Sea ice at some of the drilling locations will impact the program. JOIDES RESOLUTION was designed and constructed for work in cold weather and is capable of operating in air temperatures as low as -18° C and sea temperatures as low as -2° C. However, drilling in the high latitudes, where sea conditions can be extreme and air temperatures are commonly below freezing, increases the possibility that ice build-up on the vessel superstructure will affect vessel stability. Eventually, ice build-up could force curtailment of drilling operations and abandonment of the area.

Operations may also be impacted by the presence of ice in the water, perhaps resulting in standby or drive-off conditions. JOIDES RESOLUTION is ice-strengthened to a rating of ABS Ice Class 1B for "navigation in medium ice conditions". However, there are no plans to continue site operations when an immediate threat of contact with icebergs or pack ice exists. While the ship has the capability to transit through pack ice, it cannot drill under any ice-flow conditions because of station-keeping difficulties.

SEA CONDITIONS

Sea conditions, represented primarily by waves and currents, are largely a product of meteorological conditions occurring over a broad area. This is especially true of waves, which are caused by the interaction between wind and the water surface. Currents are the product of winds and a variety of other forces acting on the column of water (e.g., gravity, tides, surface pressure, and differences in seawater density.)

Sea conditions will have an important impact on design and implementation of the ODP. Waves and currents exert a direct influence on vessel motion through forces directed against the ship and the riser or drill string. These forces affect the ship's position relative to the well bore and necessitate a dynamic positioning system capable of compensating for prevailing conditions. In addition, waves will impact working conditions on board the ship. If the sea is sufficiently rough, work will be suspended.

Data on the ranges of magnitude, direction, and duration of surface and subsurface currents at potential drill sites were necessary to design the drill string and riser system. Waves, currents, buoyancy, and gravity all contribute to the total forces acting on the drill string or riser. Data on surface currents are particularly important because the forces of concern are those imposed on the union between the ship hull and drill string. Lift and drag forces may be significant for extremely long drill strings in a current flow. The drill string and load-handling equipment on JOIDES RESOLUTION have been redesigned to handle extreme conditions.

Physical features such as strong internal waves and turbidity currents may also impact drilling operations. Little is known of the forces that could be generated by either of these physical phenomena so it is difficult to account for them in the design of the drilling systems. The likelihood of these phenomena affecting drilling is thought to be low, given the low frequency of observation.

GEOLOGICAL CONDITIONS

General geology of the representative drill sites was described in Chapter 3. Geological conditions of the formations to be drilled influence the program, primarily in site selection and well planning. Data gathering will continue during drilling operations through use of downhole logging with in situ measuring devices and coring, which permit real-time analysis of the formations being drilled. Site-specific information is essential in planning to maximize data recovery and minimize operation risks. As indicated earlier, sites must be located away from geological structures where significant amounts of hydrocarbons are possible or where other geological hazards and safety problems may occur. Strict procedures followed by the ODP during the site selection process are reviewed in detail in Section 4.8.

The ODP will engage in several data-gathering activities. Seismic surveys will be conducted before drilling to provide data on formation dip and strike, slumping, faulting, bright spots (which may indicate abnormal pressures), stratigraphy, and other aspects of the geology. This information will be confined mainly to the upper few kilometers.

Data collection will continue during drilling, primarily through downhole logging and coring. Logging activities which consist of electrical surveys run in the hole and through the drill string or casing, will provide data on thickness and sequence of formations penetrated, porosity, fluid content, pore pressure, natural and induced radioactivity, electrical conductivity, and sound wave conductivity. In most coring activities, a hydraulic piston core developed during the DSDP will be used to retrieve relatively undisturbed cores from below the drill bit in the top 100 m (328 ft) of unconsolidated sediment. Normal drilling activities utilizing a rotary coring system will be used during the remainder of the drilling. This will allow visual confirmation of formations being drilled and analyses for hydrocarbon or hydrogen sulfide accumulations. Mudlogging during riser drilling can provide additional geological information. In some cases, mudlogging can yield data on hydrocarbon analysis and lithology before cores can be brought to the surface.

Ambient temperature of the sediments will also affect drilling procedures. At the depths and latitudes to be drilled, the ambient water temperature can reach -1° C. Temperatures at the bottom of the hole typically reach 120° C or greater, and returning seawater drilling fluid or drilling mud may reach 80° C upon circulating up to the seafloor. Subsea equipment and drilling mud must therefore operate over a wide temperature range: -1 to 80° C. The bit and lower drill string must operate over an even wider range: -1 to 120° C. Riserless drilling will also occur in hydrothermally active regions near active spreading centers, where downhole temperatures may reach 300° C or higher.

Geological features in the vicinity of the drill sites could result in the decision not to drill, cause early abandonment, or lead to damage and/or loss of subsea equipment. Geological constraints and hazards that could impact the ODP include:

- Deep or shallow faulting and related seismicity
- Mass movements of sediments (i.e., slides and slumps)
- Gasified sediments

These features and processes are normal in the marine environment and are considered here for their impact on the ODP. Other geologic features and processes that could result in the release of substances into the marine environment are discussed in Section 4.7.

Faulting generally indicates present or historic seismic activity. Shallow faults indicate the potential for movement due to either gravitational forces or to seismic activity. Deep faults overlain by recent unfaulted sediments indicate the potential for reactivation. In all cases, movement will affect sediment stability and could result in loss of the hole and damage or loss of the drill string and subsea equipment. In addition, fault planes can act as conduits for deeper hydrocarbons or high pressure gas that could result in a blowout. Both shallow and deep faults are detectable with modern geophysical techniques.

Mass movements of sediments can be induced in a number of ways, including:

- Cyclic loading by storm waves or breaking internal waves
- Dynamic loading by ground acceleration during earthquakes
- Overloading by deposition
- Oversteepening by erosion (Aaron et al. 1980).

Without shear strength analysis from actual cores, it is difficult to predict if a slope will fail and cause a slump or slide. However, seismic surveys can determine if slumps or slides have previously taken place.

Gasified sediments can occur in unconsolidated surface sedimentary layers where in situ biogenic gas forms. Under certain load-bearing capacities and given sufficient amounts of gas with associated critical values of solubility and sediment characteristics, spontaneous liquefaction of gasified sediments may occur (Minerals Management Service 1983c). This loss of sediment stability can result in the loss of the hole and damage or loss of the drill string and subsea equipment. Gas-charged sediments can be identified by analysis of surface cores or by acoustically turbid zones or "wash outs" on high-resolution seismic records.

Each geologic feature indicating these hazards can be detected with the modern seismic profiling methods required by the ODP. Since the standard ODP site selection process eliminates locations that indicate potential occurrence of these features from further consideration, it is unlikely that geologic hazards will be encountered during the ODP.

Section 4.4
IMPACT OF THE ODP ON THE PHYSICAL ENVIRONMENT

IMPACT ON LAND

Conversion of the ship, and fabrication and construction of drilling systems and equipment were performed on land areas. Because these activities took place in existing shipyards, additional land resources were not depleted. Waste disposal activities were conducted in accordance with applicable regulations and no significant impact occurred.

IMPACT ON AIR QUALITY

Onshore conversion of the ship, and fabrication and construction of drilling systems and equipment generated fugitive dust. Insignificant quantities were added to the ambient air, because the quantity of emissions involved was small and many of the activities were done indoors.

Through fuel consumption, operation of the drilling ship, airplanes, and helicopters will locally increase emissions of nitrogen oxides, sulfur oxides, hydrocarbons, carbon monoxide, and particulate matter emission. Use of the burn box will also release carbon monoxide and particulate matter. Solvents used in the laboratories are collected by hoods and vented to the air at very low concentrations. There will be a temporary, minor impact on local ambient air quality during these operations.

IMPACT ON WATER QUALITY

Water quality in the vicinity of ODP drilling activities may be impacted by a wide range of waste discharges related to the drilling process, equipment maintenance, and personnel housing. Discharges include drilling muds and cuttings, sanitary and domestic wastes, desalination unit discharges, boiler blowdown, deck drainage, cooling water, uncontaminated ballast and bilge water, burn box wastes, and excess cement slurry. As described in Section 4.2 of this document, the discharge of sanitary and domestic wastes, desalination unit wastes, deck drainage, bilge and ballast waters, and excess cement slurry will not significantly impact water quality due to the low volume and low pollutant loading of these wastes.

The major discharges expected from riserless drilling activities are those of surface seawater (drilling fluid), drilling mud, and cuttings at the seafloor. Discharges at the ocean floor are discussed in Section 4.2. The quality of bottom water would be impacted by localized, slight increases in temperature, oxygen, nutrients, dissolved gases from the atmosphere, and suspended particulates. Coarser drill cuttings will accumulate in the immediate vicinity of the borehole. No increase in suspended particulates in the water column is expected.

The major discharges expected from riser drilling activities are those of drilling mud and cuttings to surface waters. The components of typical drilling mud and the expected dilutions with distance from the discharge are discussed in Section 4.2. Although no studies have addressed dilution of drill cuttings in the water column directly, these materials are expected to act similar to the particulate fraction of the drilling mud.

Impact on water quality from drilling mud and cuttings discharges is expected to be limited to the immediate vicinity of the discharge. Maximum expected trace metals concentrations in the dissolved fraction of the drilling mud, the U.S. Environmental Protection Agency (EPA) marine water quality criteria, and typical seawater concentrations (background) for specific metals of concern are summarized in Table 24. Using these values, a maximum dilution of only 44:1 is needed to comply with EPA criteria, and of approximately 11,000:1 to approach background metals concentrations. As discussed in Section 4.2, predicted minimum drilling mud dilutions (dissolved fraction) of approximately 2,500:1 and 11,000:1 are reached within 100 and 500 m (328 and 1,640 ft), respectively. Not only are EPA criteria for metals met well within 100 m (328 ft) of the drillship, but background levels are approached within 500 m (1,640 ft). Therefore, negligible water quality impacts from dissolved drilling mud components are expected outside of a 100-m (328-ft) radius from the drillship.

Drilling mud discharges will cause increases in receiving water suspended solids concentrations. Using the particulate dilutions discussed in Section 4.2, estimated suspended solids concentrations at 100 and 500 m (328 and 1,640 ft) from the discharge are 1,000 mg/L and 110 mg/L, respectively. These results indicate that there will be substantial increases in receiving water turbidity within 500 m (1,640 ft) of the discharge. However, the suspended solids concentration within the plume decreases very rapidly with distance. Based on this trend, background suspended solids concentrations (less than 10 mg/L) should be approached within approximately 1,000 m (3,280 ft) of the discharge. Impacts associated with temporarily increased turbidity are negligible outside a 1,000-m (3,280-ft) radius from the drillship.

IMPACT ON THE SEA BOTTOM

The seafloor will be impacted by the deposition of drilling mud and cuttings, surface casing and reentry cone assemblies, and dynamic positioning beacons. Metal components will deteriorate eventually, mainly to hydrated oxides. Impacts from these structures or their breakdown products will be minor.

Accumulations of drilling mud and cuttings are discussed in Section 4.2. For riserless drilling, worst-case accumulations of 255 m^3 (195 yd^3) in the immediate vicinity of the borehole were estimated. This would cover a circle of diameter 220 m (662 ft) to the depth of 1 cm. Impacts would include local alteration of sediment characteristics and modification of bottom topography. Deposition from surface discharges of drilling mud and cuttings from riser drilling is expected to be minimal at the depths of most sites to be drilled during the ODP. While area of impact will be increased by dispersion in the water column, maximum accumulations should be less than 0.02 mm. Negligible impacts to the sea bottom should occur from these accumulations during the riser drilling phase.

TABLE 24. TRACE METAL CONCENTRATIONS OF THE WHOLE MUD AND DISSOLVED FRACTION COMPARED TO WATER QUALITY STANDARDS

Metal	Concentration: Whole Mud[a] (mg/kg)	Concentration: Dissolved Fraction[b] (ug/L)	EPA 1-hour Average Saltwater Criteria[c] (ug/L)	Background Concentration in Seawater[d] (ug/L)
Arsenic	24	24	69 (trivalent)	1.04 ± 0.07
Barium	398,800	398,800	No criteria	NA
Cadmium	19.2	19.2	43	0.026 ± 0.005
Chromium	1,300	1,300	1,100 (hexavalent)	0.118 ± 0.021
Copper	127	127	2.9	0.291 ± 0.027
Lead	915	915	140	0.251 ± 0.027
Mercury	2.8	2.8	2.1	NA
Nickel	88	88	140[e]	0.290 ± 0.031
Vanadium	235	235	No criteria	NA
Zinc	1,350	1,350	170[e]	0.980 ± 0.099

[a] Whole mud concentrations from Table 21.

[b] Estimated as 0.001 times the maximum whole mud concentration (see Table 22).

[c] From 50 Federal Register 30784.

[d] Concentrations measured in nearshore seawater reference sample (CASS-1) by the National Research Council of Canada. NA means not available.

[e] Maximum Allowable Federal Saltwater Criteria (45 FR 79318) because there is no U.S. EPA 1-hour average criteria for this metal.

IMPACT ON THE ACOUSTICAL ENVIRONMENT

ODP operations produce noise above ambient levels in the ocean. Underwater noise levels may be elevated over ambient as far as 160 km (100 mi) under certain conditions (Gales 1982). Noise levels are significantly greater when the vessel is underway than when drilling. Most of this noise is produced by propeller cavitation (Ross 1981), although at lower speeds this falls below noise levels from propulsion machinery (Brown 1982). Noise measurements of JOIDES RESOLUTION or other dynamically positioned drillships underway or while drilling apparently have not been made. Ships of similar size produce various tones while in transit of 170 to 200 dB between 10 and 150 Hz, with levels falling off at the higher frequencies (Buck and Chalfant 1972; Ross 1981; Brown 1982). Dominant tones produced from drilling operations on various drillships and semi-submersibles ranged from 130 to 160 dB over a larger bandwidth of 10 to 250 Hz (Buerkle 1975; Gales 1982; Greene 1982; Turl 1982; and Stewert et al. 1983). Dynamic positioning by thrusters could significantly raise noise levels while drilling. Echo sounding equipment used in dynamic positioning produces tones slightly elevated over ambient levels at 3.5 and 12 kHz.

Other significant sources of noise generated during ODP operations result from use of the heliport on the fantail of the ship and seismic surveying. Dominant tone levels of about 150 dB at 22 Hz have been measured below the surface from helicopters (Greene 1982). Noise will only be detectable under water for about 16 to 26 sec during helicopter flyover. Seismic surveys can produce the most intense noise levels with dominant tones of 220 to 250 dB over a large bandwidth. However, most are at lower frequencies (Johnston and Cain 1981). Levels have been recorded between 115 and 153 dB for frequencies around 150 Hz at distances ranging between 8 and 28.7 km (5 and 17.8 mi) (Greene 1982). Seismic profiling from JOIDES RESOLUTION is run with a single channel system employing a 80 in^3 water gun and a 400 in^3 air gun which should produce lower noise levels.

Ambient noise levels in the ocean seldom exceed 80 dB in the frequency range that most ODP related noise is produced (see Figure 18). Noise in the vicinity of operations will be significantly elevated, similar to any region that has moderate ocean vessel traffic. Seismic profiling is only run on one line starting 16 to 19 km (10 to 12 mi) from the drill site until reaching station resulting in a short-term significant increase in noise over ambient levels. Noise levels will not be raised significantly at any terrestrial areas from ODP operations, resulting in negligible impact to the terrestrial acoustical environment.

Section 4.5
IMPACT OF THE ODP ON THE BIOLOGICAL ENVIRONMENT

IMPACT ON PHYTOPLANKTON AND ZOOPLANKTON

Presence of Drillship

Surface discharges from the ship will include sanitary and domestic wastes, desalination unit discharges, boiler blowdown, deck drainage, cooling water, uncontaminated ballast and bilge water, burn box waste, and excess cement slurry.

The largest volume of ship discharge will be high-salinity water from the desalination unit, up to 20,000 gallons per day (GPD). It will not contain appreciable quantities of organic materials, metals, or toxic substances, and will be diluted rapidly in the water column. Because of their innocuous nature and rapid dilution by ambient seawater, discharges from the desalination unit are expected to have negligible impacts on phytoplankton and zooplankton.

Sanitary and domestic wastes will be discharged at a rate of 1,000 to 5,000 GPD. Nutrients introduced into the water column by these wastes may enhance phytoplankton growth. However, because of the small volumes of sewage effluent, rapid dilution in the receiving waters, and dispersion of the waste field by currents, impacts are expected to be negligible.

The suspended solids portion of the sewage and domestic waste discharges may affect zooplankton populations by interfering with feeding or respiratory activities. However, such impacts are expected to be negligible because of the short periods of time during which zooplankters will be exposed to the wastes. It is expected that the sewage and domestic wastes will be diluted and dispersed rapidly in the water column. The rapid dilution and dispersion of sewage and domestic wastes should also preclude indirect effects on zooplankton populations through alteration of phytoplankton communities, as there will be insufficient time for phytoplankton community changes to occur. Finally, as was discussed earlier in Section 4.2, dissolved oxygen depression resulting from the discharge of sewage and domestic wastes is not expected to affect marine organisms, including zooplankton.

The remaining surface discharges (i.e., boiler blowdown, deck drainage, cooling water, uncontaminated ballast and bilge water, burn box waste, and excess cement slurry) are considered innocuous, or are discharged only occasionally and in small volumes. They should be diluted rapidly in the water column, and dispersed quickly by surface currents. Impacts from these discharges are also expected to be negligible.

Riserless Drilling Operations

Riserless drilling operations will result in the discharge of seawater, cuttings, and some drilling muds on the seafloor. Because drilling muds and cuttings will not be discharged into the water column, no impacts on phytoplankton or zooplankton populations are expected as a result of drilling operations themselves.

Riser Drilling Operations

Riser drilling operations may generate impacts due to the presence of the drillship, and the surface discharge of drilling muds and cuttings. Possible impacts of surface discharges of drilling muds and cuttings on phytoplankton include:

- Decreased primary production and/or increased mortality due to acute or sublethal toxic effects of trace metals

- Decreased primary production due to light reduction and increased turbidity

- Stimulation of primary production by trace nutrients in the discharge.

Since phytoplankton species exhibit differential sensitivities to light, nutrients, and toxic materials, any or a combination of these effects could cause changes in relative species abundance, diversity, and species composition.

Of the three possible impacts listed above, the toxic effects of metals are of greatest concern because of the potential for metals to bioaccumulate within organisms and to biomagnify within the ecosystem. Few bioassay data are available concerning the effects of drilling muds on phytoplankton (see Petrazzuolo 1983). However, several factors suggest that the discharge of drilling muds and cuttings will have little (if any) impact on phytoplankton. First, suspended solids and dissolved particulate metals will be diluted rapidly to background levels, usually within 100 to 1,000 m (328 to 3,281 ft) downcurrent of drilling mud discharges (Neff 1981; Duke and Parrish 1984). Second, residence times of suspended solids and toxic materials in the water column are expected to be short. Drilling muds, will be discharged briefly and intermittently. It is unlikely that pelagic organisms in the vicinity of the mud discharge would be exposed continuously to high concentrations of drilling fluids for long periods of time. Third, most metals in the discharge will not be available for uptake by organisms because they are bound to particulates in the mud itself. Lastly, if the mud and cuttings discharges affect phytoplankton populations that contact the plume, mixing of impacted phytoplankton with adjacent unaffected populations, should occur rapidly and promote recovery of the impacted populations.

Possible impacts of surface discharges of drilling muds and cuttings on zooplankton include:

- Decreased growth, altered behavior, and/or increased mortality due to acute or chronic effects of toxic materials in drilling muds

- Interference with feeding or respiratory activities due to increased suspended solids concentrations

- Indirect enhancement or inhibition of zooplankton populations resulting from impacts on phytoplankton.

Since zooplankton species exhibit differential sensitivities to toxic materials, suspended solids, and altered phytoplankton communities, any or a combination of these effects could cause changes in species composition and abundance.

Of the three possible impacts listed above, the toxic effects of metals are of greatest concern because of the potential for metals to bioaccumulate within organisms and to biomagnify within the ecosystem. Bioassay data concerning the effects of drilling muds on zooplankton are limited. Available data indicate that crustacean larvae are relatively more sensitive to mud/water mixtures than other species tested (Carls and Rice 1984). This sensitivity may be due to an inability to tolerate high concentrations of suspended particles rather than to toxicants in the drilling fluids (Neff 1981). The single species of copepod that has been tested was also found to be relatively sensitive to drilling muds (see Petrazzuolo 1983). Results of tests on phytoplankton and zooplankton using drilling muds and cuttings represent the sum of the additive, synergistic, and antagonistic effects of individual pollutants on the species tested. At present, these additive, synergistic, and antagonistic interactions are poorly understood.

Although some zooplankters appear to be sensitive to discharges of drilling muds and cuttings, little or no impact on zooplankton is expected under field conditions. The reasons for this are the same as those discussed above for phytoplankton populations: 1) suspended solids and dissolved particulate metals will be diluted rapidly to background levels; 2) the residence times of suspended solids and toxic materials in the water column are expected to be short; 3) drilling muds will be discharged briefly and intermittently, precluding continuous, long-term exposure to high concentrations of muds and cuttings; and 4) impacted populations will be mixed rapidly with adjacent unaffected populations, promoting rapid recovery.

IMPACT ON NEKTON

Presence of Drillship--

As was discussed above, ship discharges are expected to be innocuous, rapidly diluted in the water column, and dispersed quickly by surface currents. Rapid dilution and dispersion should minimize contact, and hence impacts, to nektonic organisms.

Riserless Drilling Operations

Because seawater, cuttings, and drilling muds will be discharged on the sediment surface, pelagic nektonic organisms (i.e., fishes, squids, and other motile forms) should not be exposed to these discharges. Demersal nektonic organisms may be exposed to these discharges, however, since they live in close association with the sediment-water interface and often consume benthic organisms. The area affected by the discharge will vary with the volume of the discharge, the discharge rate, and the current velocity at the sediment-water interface. Persistence of the discharge pile will depend on its composition, periodic storms (at continental shelf depths), and current velocities (at all depths). Potential impacts to demersal nektonic organisms include the smothering of demersal eggs, acute and chronic toxicity, bioaccumulation, and indirect effects through food supply reduction.

Smothering of Demersal Eggs--

Demersal eggs of a number of species could be smothered or otherwise affected if a discharge coincides with spawning or the presence of eggs on the bottom. Eggs of fishes (and invertebrates) require oxygen exchange across the egg membrane and may require exchanges of metabolites, salts, and nutrients. Little is known of the sensitivities of the eggs of most fish species to burial. The potential for smothering would be greatest in continental shelf and upper continental slope areas, particularly in areas where spawning is known to occur (e.g., Georges Bank). If one assumes that demersal eggs would be smothered when the thickness of deposited muds and cuttings exceeds 1 cm (0.4 in), then the worst-case analysis presented in Section 4.2 indicates that demersal eggs would be smothered over an area of 0.4 km^2 (0.15 mi). This area is equivalent to a circle 220 m (722 ft) in diameter.

Acute and Chronic Toxicity--

Whereas drill cuttings are largely inert, drilling muds often contain metals and other potentially toxic substances. Metals content of drilling muds can vary considerably. However, the following five components constitute at least 90 percent of the substances in most water-based drilling muds: barite, bentonite, lignite, chrome lignosulfonate, and sodium hydroxide. The most toxic of these components are the chrome and ferrochrome lignosulfonates, which are "moderately toxic" to all but the most sensitive species and life stages (National Research Council 1983). Typical 96-hour LC_{50} values for these substances are 100-1,000 ppm. Other metals of concern are barium, cadmium, copper, iron, mercury, lead, and zinc (Neff 1981).

Acute toxicities of a variety of drilling muds have been determined for a number of fish species (see Neff 1981; National Research Council 1983; Petrazzuolo 1983; Duke and Parrish 1984). With few exceptions, acute toxicities of drilling muds to fish species were low. That is, 96-hour LC_{50} values exceeded 10,000 ppm of drilling mud added (Neff 1981). For those few species that were relatively intolerant of drilling muds, test results often suggested that damage was caused by abrasion or clogging of respiratory surfaces by particulates rather than by chemical toxicity of the mud. Larval and juvenile fishes may be more sensitive to drilling muds than are adult fishes, as is generally true of invertebrate species. A study using embryos of the killifish Fundulus heteroclitus documented retarded development at mud concentrations of 1,000 ppm (see Neff 1981). However, the available data are insufficient to fully evaluate this hypothesis.

Sublethal effects of drilling muds and cuttings have received little study. Therefore, it is not possible to determine whether such impacts would occur at lower concentrations of muds and cuttings than those at which acute toxicities have been documented.

Demersal species (i.e., primarily demersal fishes) may be in contact with drilling muds and cuttings on the seafloor during and after the period of discharges. The potential for contact will remain until the mud and cuttings are thoroughly dispersed. Because drilling muds and cuttings apparently have a low toxicity potential for most fishes, and because fishes may actively avoid the discharged materials, acute and chronic impacts to demersal fishes should be negligible. Moreover, if such impacts occur, they should be very localized, occurring only where the muds and cuttings are not yet dispersed.

Bioaccumulation--

Lead, mercury, zinc, arsenic, cadmium, chromium, and barium are the primary constituents of drilling muds with potential for bioaccumulation. The presence or absence and concentrations of each metal will vary with the specific type of drilling mud and the quantities used. Most of these metals will be associated with solids. However, reducing conditions in the sedimentary environment could release some bound forms into the interstitial water or overlaying water column.

Fish can bioaccumulate metals by direct absorption from the water or by ingestion of contaminated food. Because of the low concentrations of metals in dissolved form, the small area of the bottom affected, and the mobility of fish, it is unlikely that direct absorption will be an important pathway for the bioaccumulation of metals.

Benthic invertebrates in the vicinity of the discharge, or benthic organisms that later settle on discharged materials, may bioaccumulate metals (discussed below in Impact on Benthos). By consuming these organisms, fish may also bioaccumulate the metals. When the metals ingestion rate exceeds the metals excretion rate in a given fish, biomagnification occurs.

At present, insufficient information is available to:

- Predict the degree to which benthic organisms will bioaccumulate metals
- Predict the degree to which fish will consume benthic organisms containing metals, accumulate those metals in their tissues
- Predict the amount of contact a fish will have with discharged materials.

However, the bioaccumulation of metals in demersal fish tissues should be negligible because of the limited area of bottom over which muds and cuttings would be deposited and the mobility of fish.

Indirect Effects through Food Supply Reduction--

The disposal of drilling muds and cuttings may indirectly affect demersal fish populations by causing changes in benthic communities upon which they feed. Benthic commmunities may be affected by smothering, changes in substrate characteristics, and alterations in the recruitment patterns of larval forms (discussed below in the Impacts to Benthos). The areal extent and magnitude of such impacts to benthic communities will depend on the volume of discharged muds and cuttings, the dispersion of those materials by storms and currents, and the sensitivity of the benthic community to changes in the benthic habitat. Impacts to demersal fishes because of reduced benthic prey populations should be negligible because the area of impact will be extremely small compared with the total benthic resources available to fish populations within a given ecosystem. If one assumes that benthic communities will be smothered in areas where muds and cuttings exceed 1 cm (0.4 in) depth of accumulation (see "Impacts on Benthos" below), the area over which prey organism abundances would be reduced would be 0.4 km^2 (0.15 mi^2). This area is equivalent to a circle 200 m (722 ft) in diameter. Benthic conditions should return to a "normal" state as the muds and cuttings are dispersed through time.

Riser Drilling Operations

Because riser drilling operations discharge muds and cuttings at the surface, these materials may impact both pelagic and demersal nektonic forms. Pelagic species have the potential to be impacted by toxic materials in the drilling muds as the discharged materials settle through the water column. Such impacts should be negligible for two reasons. First, drilling muds and cuttings will be diluted and dispersed quickly. Exposure time to the discharged materials will, therefore, be of very short duration. Second, pelagic species should be able to avoid the waste field easily.

Demersal nektonic species may be impacted through the same mechanisms discussed above for riserless drilling operations: smothering of demersal eggs, acute and chronic toxicities, bioaccumulation, and reduced food supplies. But since the discharged muds and cuttings will settle through the water column before being deposited on the sea floor, they will be much more dispersed on the bottom compared with riserless drilling discharges. The area of bottom upon which they settle will be determined by the volume of discharged materials, the rate at which they are discharged, the water depth, and the surface and subsurface currents at the time of discharge. In water depths typical of the ODP [i.e, water depths well in excess of 200 m (656 ft)], the drilling muds and cuttings will be greatly dispersed upon reaching the bottom (see Section 4.2). The greater the area over which the muds and cuttings are dispersed, the thinner the deposits will be. Based on the worst-case analysis presented in Section 4.2, the maximum expected thickness of muds and cuttings deposited on the bottom is <0.01 mm at a water depth of 190 m (623 ft). Water depths at most ODP drill sites are expected to result in yet smaller deposition thicknesses for drilling muds and cuttings. Accumulations of muds and cuttings less than 1 mm (0.04 in) are expected to have negligible impacts on benthic communities (see "Impacts on Benthos" below). Hence, impacts to demersal fishes through reductions on prey populations and the other mechanisms listed above are expected to be negligible.

IMPACT ON BENTHOS

Presence of Drillship

The presence of the drillship should have no impact on benthic communities, since the small quantities of wastes discharged from the ship should be diluted to undetectable levels before reaching the seafloor.

Riserless Drilling Operations

Seawater, drill cuttings, and some drilling muds will be discharged on the sediment surface. The area affected by the discharge will vary with the volume of the discharge, the discharge rate, and the current velocity at the sediment-water interface. Persistence of the discharge pile will depend on periodic storms (at continental shelf depths) and currents (at all depths). Drilling muds and cuttings could impact benthic communities through smothering, changes in substrate characteristics, toxic effects, and bioaccumulation.

Smothering--

Because nearly all cuttings and muds are expected to be deposited in the immediate vicinity of the well site, smothering of the resident infaunal and epifaunal biota is expected in this area. Smothering will extend farthest from the well site in the mean downcurrent direction. The deposition depths at which various species may be smothered is not well known. Experiments with large clams indicate that critical depths of burial occurred at 5-10 cm (2-4 in) (Armstrong 1965) and were, possibly, related to siphon length. Large clams with long siphons could reasonably be expected to tolerate greater burial depths than many other infaunal organisms (i.e., polychaetes, small molluscs, crustaceans). Smothering of a substantial portion of the infaunal biota will probably occur at burial depths >1 cm (0.4 in). Based on the worst-case analysis presented in Section 4.2, drilling muds and cuttings could be deposited at a uniform thickness of 1 cm (0.4 in) over an area of 0.4 km^2 (0.15 mi^2), an area equivalent to a 220 m (623 ft) diameter circle. This is considered negligible compared with the size of the ecosystem. Large motile epifaunal organisms (e.g., crabs, lobsters) should not be smothered because of their ability to avoid the discharge area.

Changes in Substrate Characteristics--

Benthic community structure and function are largely determined by the characteristics of the sedimentary habitat (see Gray 1974; Rhoads 1974). Therefore, changes in the characteristics of the sediments in the vicinity of the borehole may be expected to impact benthic communities. Such impacts will vary spatially and temporally as the drilling muds and cuttings are dispersed by currents and storm activity.

From studies at two sites on Georges Bank (see National Research Council 1983) and at 120-m (394-ft) depth off New Jersey (Menzie et al. 1980), it appears that alterations of sediment characteristics impact the benthos more subtly, but over larger areas, than does smothering. Menzie et al. (1980) observed significantly reduced (probability level not stated) abundances of polychaetes, molluscs, and crustaceans up to 370 m (1,214 ft) from the drill site. In all three cases, reduced abundances were significantly negatively correlated (probability level not stated) with the percent of drilling-derived clay in the sediments. Echinoderms (principally ophiuroids) were also reduced in abundance, but the reductions were not significantly negatively correlated (probability level not stated) with the drilling-derived clay content of the sediments. Shannon-Wiener diversity values (H') at the New Jersey site were somewhat reduced after drilling (ranging from 2.75-5.45, compared with predrilling values ranging from 4.34-5.29), with most low values observed in the immediate vicinity of the drill site. Menzie et al. (1980) attributed the lower diversity values to lower numbers of species. Species evenness (J) was relatively constant over the discharge area and increased somewhat after drilling (Menzie et al. 1980). Maurer et al. (1981) reported that neither species composition nor the predominant feeding types changed appreciably at the New Jersey site after the initiation of drilling.

Based on the studies on Georges Bank and off New Jersey, it appears that greatest impacts to benthic infauna communities due to sediment alteration occur in areas nearest the borehole. Reduced abundances of polychaetes, molluscs, and crustaceans are likely to occur, and Shannon-Wiener diversity values may be depressed. Major changes in species composition and feeding types were not observed in the vicinity of the New Jersey well site. Such changes near ODP drill sites cannot be eliminated as a possibility due to differences in the volumes of discharged materials, the physical characteristics of the receiving environment, and the affected benthic communities. Resident species at ODP drill sites that are intolerant of altered sediment characteristics may be replaced by species better adapted to the altered conditions.

Altered sediment composition may also compromise the abilities of infaunal or epifaunal invertebrates to recruit, grow, and propagate in the vicinity of the drill sites. Should altered sediment composition negatively impact the larvae, juveniles, or adults of commercially valuable benthic species, the amount of habitat available for those species would be reduced. Impacts on commercially valuable species of benthic invertebrates would be greatest in major fisheries areas such as Georges Bank.

It is difficult to determine the area over which subtle impacts to benthic infauna (e.g., changes in species composition and abundances, but not smothering) would occur in response to the deposition of drilling muds and cuttings, since no quantitative data on the relationship between depth of deposition and such changes are available. However, assume for the moment that changes in species composition and abundance will occur at deposition thicknesses of 1 mm (0.04 in) or greater. Based on results of the worst-case analysis presented above (Section 4.2), the maximum area over which muds and cuttings would be deposited at an even thickness of 1.0 mm (0.04 in) is 37 km^2 (14.3 mi^2), an area equivalent to a 6.9 km (4.3 mi) circle. As the concentrations of drilling muds and cuttings are reduced to undetectable levels through the actions of currents, tides, storms, and bioturbation, species composition and abundances are expected to return to predischarge conditions.

Large, motile epifaunal benthic species are not likely to be impacted directly by altered sediment characteristics, since they should be able to avoid areas of greatest deposition. They may be impacted indirectly if benthic infauna communities are greatly altered, since the abundances of prey organisms consumed by the epifaunal taxa may be reduced. Such reductions might occur if the epifaunal species were unable to utilize the "new" benthic prey organisms. However, impacts of altered sediment characteristics on large, motile epifaunal species are expected to be negligible because infaunal communities would be changed over only a minor portion of the total forage area available to an epifaunal predator.

To date, no studies have been conducted on the potential for pollutant impacts to the biota of hydrothermal vents. Hence, the sensitivities of those species to suspended and deposited solids are unknown. Vent species might exhibit high sensitivities to deposited solids, however, because they are dependent on sulfides and bacteria in the vent water, and on nutrients in the water column. Particulates suspended in the water column and on the bottom might interfere with the abilities of the biota to use these resources.

Acute and Chronic Toxicity--

Drilling muds and cuttings discharged on the seafloor may impact benthic organisms through the toxic actions of some of the drilling mud components. The toxic components of most concern are barium, chromium, cadmium, copper, iron, mercury, lead, and zinc (Neff 1981). Metal enrichment of the sediments in the vicinity of a drill site is typically very uneven, but usually decreases as one moves away from the drill site (Neff 1981). For surface-discharged muds and cuttings, major metal enrichments may occur within 100 m (328 ft) of the discharge point, and background concentrations may be reached within 1,000 m (3,281 ft) (Neff 1981). Bottom discharges from riserless drilling operations should exhibit higher metals concentrations near the borehole than do surface discharges from riser drilling operations. However, the gradient of metal concentrations should decrease more quickly with distance from the drill site.

Of the metals found in drilling muds, barium is usually the most highly concentrated in the sediments because it occurs at high concentrations in drilling muds, it is relatively insoluble, and it occurs in high-density forms (Neff 1981). However, as noted above (see section on Impacts of Nekton), the most toxic metal commonly found in water-based drilling muds is chromium, which may occur as chrome or ferrochrome lignosulfonate (National Research Council 1983). Chrome and ferrochrome lignosulfonates are generally "moderately toxic" to benthic invertebrates, with most 96-hour LC_{50} values ranging from 100 to 1,000 ppm. Tests have shown that pure barite is not a major toxicant to benthic organisms, except when present at very high concentrations for long periods of time (see Neff 1981). Such conditions might occur in the immediate vicinity of an ODP drill hole, but would eventually be eliminated as the mud and cuttings pile was dissipated by bottom currents and bioturbation. Moreover, most barite in drilling muds is tightly bound to the clay-lignosulfonate fraction and would be expected to behave differently (i.e., to be less toxic) than pure barite.

Overall, tests have shown that the suspended particulate phases of drilling muds to which benthic invertebrates would be exposed are only "slightly toxic" or "practically non-toxic" (Neff 1981; National Research Council 1983). Most short-term acute toxicity tests have LC_{50} values >10,000 ppm. Less than 2 percent of the suspended particulate phase tests were moderately toxic to the species tested (i.e., short-term LC_{50} values of 100-1,000 ppm). Invertebrate larvae tended to be more sensitive to the suspended particulate phases of drilling muds than were adult organisms. However, much of this increased sensitivity may have been due to the clogging of respiratory surfaces rather than to toxic effects of metals or other substances (Neff 1981). Organisms from one biogeographic region do not appear to be more sensitive to drilling muds than do organisms from any other biogeographic region (National Research Council 1983). Hence, results of tests on organisms from one region may be extrapolated to another region. No tests have been conducted on hydrothermal vent organisms, many of which are unique in the animal kingdom. Hence, their sensitivities to toxic substances in drilling muds are not known.

Chronic and sublethal effects of drilling mud components generally occur at concentrations one to two orders of magnitude less than those required to produce an acute toxic response (Neff 1981; National Research Council 1983). Chronic effects tend to occur at 10-1,000 ppm of the suspended particulate phase for most species tested. Chronic effects for sensitive species and sensitive (i.e., early) life stages generally occur at 10-100 ppm of the suspended particulate phase. Again, abrasion and clogging of respiratory surfaces, not toxicity, is often cited as the major cause of effects on sensitive species and early life stages. Results for chronic and sublethal toxicities are all based on tests for barite and various biocides; chrome lignosulfonate has not been tested for chronic effects (Neff 1981).

Because toxic components of drilling muds may be present in the vicinity of a borehole for months, or possibly years, chronic effects on benthic organisms may be important within that small area. Chronic and sublethal toxicity tests conducted to date have not attempted to realistically duplicate conditions that would be expected on the seafloor. Therefore the actual potential for chronic and sublethal toxic effects in the receiving environment is very difficult to assess.

In summary, toxicity tests have shown the components of drilling muds to be only "slightly toxic" to benthic organisms in most cases. This conclusion, coupled with the prediction that drilling muds and cuttings will cause major changes in the benthic environment over a very limited area [i.e., within 1,000 m (3,281 ft) of the drill site], suggests that the impacts of toxic substances on benthic organisms (with the possible exception of hydrothermal vent species) will be minor and will occur over very small areas of the seafloor.

Bioaccumulation--

Benthic organisms bioaccumulate metals found in drilling muds (see Neff 1981; National Research Council 1983). (Note, however, that no studies have been conducted which document the abilities of hydrothermal vent species to bioaccumulate metals.) Although chromium appears to be the metal most easily bioaccumulated, it is bound to clay particles and to high molecular weight lignosulfonate fractions of the drilling mud. Hence, it has a low bioavailability (Neff 1981). (Chromium and other metals are more readily bioavailable as ions in solution.) Lead, zinc, and possibly cadmium are also tightly bound to particulate fractions, and have a low bioavailability (Neff 1981). There is no evidence that metals found in drilling muds biomagnify to higher trophic levels (National Research Council 1983).

Although tests have documented the bioaccumulation of metals from drilling muds in benthic organisms, they have not determined whether these toxic substances are present at intracellular sites of toxic action. Nor have the tests documented whether the organisms are sequestering or detoxifying the bioaccumulated substances (National Research Council 1983). For these reasons, it is difficult to evaluate fully the impact of the bioaccumulation of metals from drilling muds on benthic organisms. However, Neff (1981) concluded that at the concentrations of drilling muds in the sediments to which benthic organisms will be exposed in the field, metals are unlikely to be bioaccumulated to levels that would pose a toxic hazard to the benthic organisms themselves or to predators, including humans.

The potential for bioaccumulation by benthic organisms will exist at an ODP drill site only as long as the metals content of the sediments is above background levels. Because drilling muds and cuttings are expected to be dispersed relatively quickly by storm activity and currents, because the area affected by drilling muds and cuttings is expected to be very small relative to the size of the ecosystem, and because initial concentrations of metals in the sediments are expected to be low, the impact of metals bioaccumulation on benthic organisms and their predators is expected to be negligible.

Riser Drilling Operations

As discussed above for riserless drilling operations, impacts on benthic communities are expected to be negligible and will only occur when drilling muds and cuttings do not disperse enough to prevent smothering. Compared with riserless drilling operations, muds and cuttings should be dispersed over a much greater area initially and are not expected to be deposited at thicknesses that would cause changes in benthic species composition or abundance.

IMPACT ON MARINE MAMMALS AND BIRDS

Marine Mammals

The ODP could potentially affect marine mammals in the following ways:

- The drillship, either in transit or on station, could interfere with marine mammal movements.

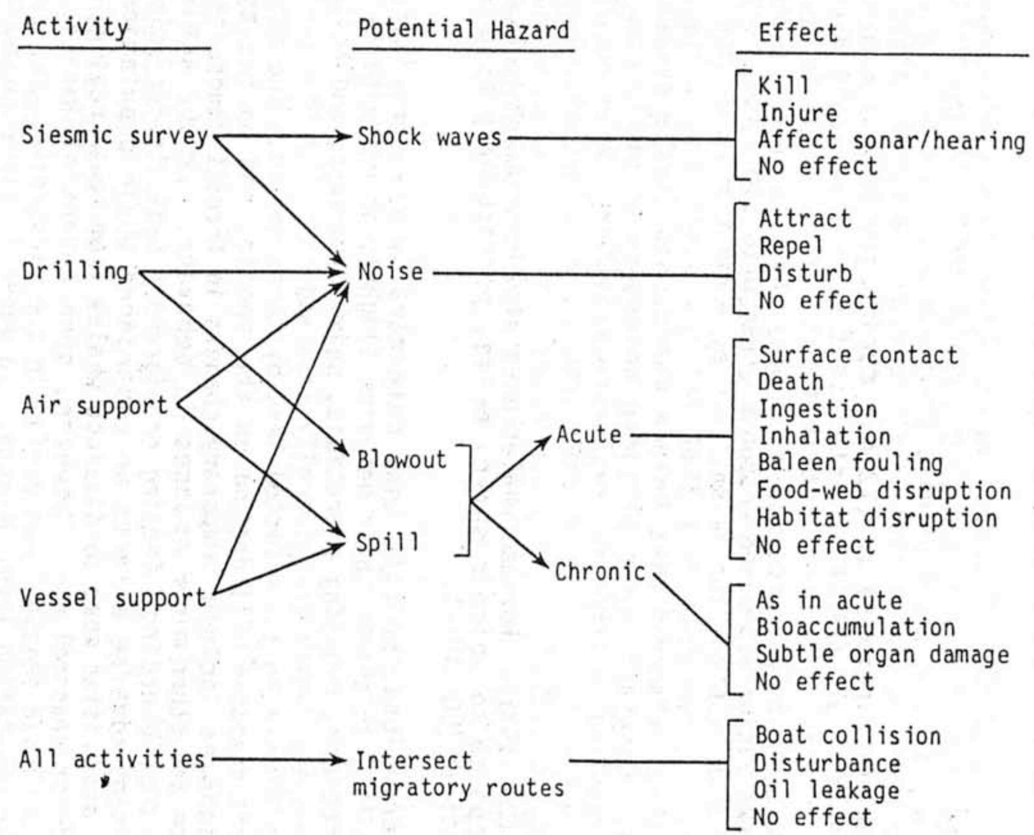
- Noise produced by ODP activities could disturb marine mammals or interfere with their vocalization.

- Discharges from the drillship could disturb marine mammals or affect their food sources.

The various components of ODP operations and the range of potential impacts resulting from those operations are summarized in Figure 49.

Presence of Drillship--

The physical presence of the drillship, whether in transit or on station, is unlikely to interfere significantly with marine mammal movement. Close approaches of the ship to marine mammals (or vice versa) are expected to be rare, considering that only one ship is involved and that the average



REFERENCE: ADAPTED FROM GERACI AND ST. AUBIN 1980

Figure 49. Factors associated with scientific drilling effects on marine mammals.

density of marine mammals in the open ocean is very low. When close approaches occur, the mobility of marine mammals and their ability to detect the ship would permit them to easily avoid contact, especially since the top speed of the ship is only 14 kn. Therefore, collisions between the drilling ship and marine mammals are not expected to occur. Detours made by marine mammals to avoid the ship will be a strictly temporary situation and will not represent a significant effect on the individuals involved.

ODP activities producing noises which could disturb marine mammals are seismic surveys, general ship noises (e.g., noise from drilling operations, engine operation, dynamic positioning), and helicopter operation. Seismic profiling, which produces the highest elevations over ambient conditions, will only be run for up to 19 km (12 mi) during the initial approach to the station. Malme et al. (1984) reported that gray whales avoid noises from all three of these sources, but that the strongest response was to seismic survey noise. The distances at which gray whales showed a 50 percent probability of exhibiting avoidance response (change in direction, reduction of speed) were 2.5 km (1.6 mi) for seismic survey activities, 1.1 km (0.7 mi) for drilling ships, and only 80 m (262 ft) for helicopter overflight. Stewart et al. (1983) observed that beluga whales had little response to drilling noise. Constant noise elicited no response, while changes in tone and level resulted in temporary avoidance behavior. When approached by boat or aircraft, bowhead whales have been observed to change behavior, including changing breathing rates, surfacing intervals, and time spent on the surface (LGL 1983). Bowhead whales have also been observed to change behavior in response to seismic survey noise, particularly at start-up of survey operations (LGL 1982).

These observations indicate that cetaceans in the vicinity of the drillship are likely to change their behavior slightly in response to noises from ship operations, drilling operations, seismic surveys, and helicopter operation. Pinnipeds, which are generally less acoustically oriented than cetaceans, are likely to be affected less by these noises. The magnitude of the behavioral response will depend on the species and on the type of activity. Responses include temporary changes in transit course to avoid the noise source and other minor changes in behavior. If ODP activities occur in important breeding, feeding or migratory habitats for endangered whales, significant adverse effects on endangered whale populations may occur if such activities were to displace whales from these regions during critical periods of seasonal use. However, such potential impacts would be limited to a single seasonal use period in the worst-case, thus reducing the potential for population level impacts. In general, since marine mammals will be close to the noise-generating ODP activities only a fraction of the operating time, and since relatively few individual mammals will be affected by these noises, the overall effect on any species' population is expected to be negligible.

Helicopter overflights will be infrequent and will affect a given location on the surface only temporarily. Disturbances to individual marine mammals at sea are expected only rarely, and, when they occur, in a temporary and insignificant manner. The greatest potential affect from helicopters is disturbance of pinnipeds breeding rookeries. Several pinniped species have been observed to temporarily vacate rookery areas for the water in response to aircraft overflights. Most individuals return to the shore within a few minutes of the end of the disturbance (Bowles and Stewart 1980). However, rookery abandonment can occur after repeated disturbance. ODP helicopter flights fly the same course twice. Due to movements of the ship and the infrequent nature of ODP helicopter use, the chance that a pinniped rookery will be abandoned due to helicopter overflight is negligible. Even one-time transitory disturbance of rookery areas is unlikely, due to the infrequency of flights and the small likelihood of flights passing over rookeries. Drilling and seismic survey operations will be too far offshore to affect rookeries or other nearshore areas used by pinnipeds.

The highest noise levels produced by ODP activities will be in the 100-200 Hz range, which coincides with the range of most cetacean call vocalizations. This raises the potential that ODP-generated noise will interfere with cetacean vocalization, communication, and possibly echo-location. According to Cummings et al. (1981), drilling and seismic operations are likely to interfere with vocalization of nearby cetaceans, but the degree and significance of this effect is not known. It would probably be minor since most animals would avoid these noise sources and since those that did not would be affected only until they moved out of the noise range. Effects would be insignificant for a given cetacean population. Echo sounding frequencies used for dynamic positioning may interfere with vocalization and echo location of toothed whales, although only in the immediate vicinity of the ship while on-station. Since pinnipeds rely less on acoustic cues for communication, navigation, and feeding, ODP-generated noise is less likely to interfere with vocalization and communication.

Drilling Operations--

Effects on water quality from drillship discharges are expected to be minor and localized near the ship (see Section 4.4). Disturbance effects are likely to keep mammals outside the small area where any harmful chemical effects might occur. Direct physical or toxicological effects of these discharges on marine mammals are therefore unlikely and few animals would be affected. However, some ingestion of toxic drilling mud constituents is possible by planktonic filter feeders and benthic detritivores. Indirect effects on marine mammals, such as effects on food organisms, are unlikely, because effects on plankton and fish are expected to be small (discussed earlier in this section). Resulting effects on marine mammal predators are expected to be negligible.

Marine Birds

The ODP could affect marine birds only through: 1) disturbance of bird colonies by helicopter overflights; 2) direct effects of various discharges on birds on or in the water; or 3) indirect effects of discharges on birds through effects on fish or plankton on which birds feed.

Presence of Drillship--

Low altitude helicopter flights over marine bird rookeries or resting areas on land or water are likely to startle birds causing some or all to take flight temporarily. Since disturbances are expected to be only occasional and transitory, conditions and bird behavior would quickly return to normal. Such disturbance of birds that are resting or congregating (but not nesting) should be insignificant. Nesting marine birds have been observed to be less easily startled than non-nesting birds. Nesting birds startled from the nest do not generally damage eggs or chicks, nor leave the nest long enough for predation on eggs or chicks to occur (Schreiber and Schreiber 1980). Therefore, single helicopter flights over rookeries should not result in significant mortality of eggs or chicks, or have adverse effects on marine bird populations. Repeated flights over rookeries, which would pose a greater potential for affecting nesting birds, are unlikely due to the infrequency of these flights and the drillship's frequent moves. Birds in flight (e.g., in transit, foraging) should be able to avoid the helicopter, and any resulting disturbances will be temporary and insignificant. Based on all the above considerations, ODP helicopter overflights are expected to (occasionally if at all) have minor adverse effects on marine birds.

Drilling Operations--

Surface discharges form the drillship (e.g., muds and cuttings, sanitary/domestic waste) are expected to have only minor affects on water quality in a very localized area near the drillship (Section 4.4). Therefore, significant direct physical or toxicological effects of ODP discharges on marine birds are not expected. The effects of ODP discharges on fish and zooplankton are expected to be minor and very localized (discussed earlier in this section), resulting in negligible indirect effects on marine birds.

IMPACT ON ENDANGERED SPECIES

Endangered and threatened species occurring in the four representative drilling locations are pinnipeds (Weddell Sea and eastern Tropical Pacific), cetaceans (all four locations), sea turtles (eastern tropical Pacific and Georges Bank), and four species of petrels (two species each in the eastern tropical Pacific and Georges Bank). It was concluded earlier in this section that the ODP would not have significant impacts on marine mammals and birds, and this would apply to endangered and threatened species with the exception of potential impacts resulting from avoidance of critical breeding, feeding, or migratory habitat by endangered whales due to ODP activities. Impacts to endangered whales because of avoidance of areas would be limited to less than one season, and should therefore have negligible effects on any whale population.

Sea turtles occur in both coastal and open ocean waters. However, three endangered species, the hawksbill (Eretmochelys imbricata), the Atlantic Ridley (Ledpidochelys kempii), and the Pacific Ridley (Lepidochelys olivacea) sea turtles are primarily coastal and vulnerable only in coastal drilling sites, such as the Middle America Trench (Pacific Ridley). Other sea turtles species could occur in most tropical, subtropical, or temperate drilling locations, whether nearshore or offshore.

The ODP could affect sea turtles through effects of ODP-generated discharges and through collisions between sea turtles and the drillship. Unlike marine mammals, sea turtles are not known to be acoustically sensitive or to depend heavily on acoustic cues for communication, navigation, or feeding. For this reason, they will not be potentially affected by ODP-generated noise. Because ODP surface discharges (e.g., drilling muds and cuttings, sanitary and domestic wastes) are expected to affect water quality in a minor and localized manner, relatively few sea turtles will be affected over the course of the program. Drill sites are far enough offshore that ODP-generated discharges should have a negligible effect on hatchling sea turtles.

Although sea turtles are generally not mobile enough to avoid the moving drillship in case of an imminent collision, such situations are expected to be very rare, because only one ship is involved and the density of turtles in the open ocean is very low. Therefore, very few, if any, sea turtles are likely to be involved in collisions with the drillship, and the resulting effects on turtle populations will be negligible.

IMPACT ON BIOLOGICALLY SENSITIVE AREAS

Areas considered biologically sensitive in the Weddell Sea are the terrestrial environment, ice-edge communities, and rookeries of marine mammals and birds. Surface discharges from ODP activities will not persist long enough to be transported to terrestrial or ice-edge habitats. Earlier in this section it was concluded that, while marine mammal and bird rookeries may infrequently be disturbed by ODP helicopter overflights, only temporary, negligible impacts on mammal or bird populations are expected.

Other biologically sensitive features are the productive fish populations and commercial fisheries. These are not expected to be significantly impacted by the ODP, as discussed earlier in this section and in Section 4.6.

ODP activities and related discharges will be located far enough offshore from biologically sensitive islands, such as the the Galapagos Islands, to not significantly impact biological resources at these locations. Likewise, ODP activities and discharges will be located too far offshore to affect sea turtle breeding areas on coastal beaches or other sensitive estuarine or marshland habitats.

The coincidence of ODP activities with periods of seasonal use of breeding, feeding, or migratory habitats by endangered whales may have impacts on whale populations that rely on these biologically sensitive areas. Impacts incurred in these areas could include disruption of whale food supplies or avoidance by the whales during the period of ODP activity. Either case results in limiting the quality and/or area of the habitat needed by these depressed populations. Impacts will be limited by the fact that only the one ship will occupy a site for less than three months, thereby reducing the potential of affecting the population level of any whale species. Seismic activities can be scheduled around these high-use periods.

Hydrothermal vent communities, due to their limited range, large variety of endemic species, and scientific value, should also be considered biologically sensitive areas. The probability of impacting a vent community by drilling at a vent site (causing smothering) or near one (diverting hdrothermal circulation) appears to be negligible. The bottom contour detail needed to accurately locate an on-ridge site would indicate the presence of vents. Any vents sites would not be drilled and the station would be relocated.

Section 4.6
IMPACT OF THE ODP ON THE SOCIAL, ECONOMIC, AND LEGAL ENVIRONMENT

IMPACT ON THE ECONOMY

The ODP is a long-term program of fundamental research on the earth's crust beneath the oceans. The scope is global, extending eventually into every ocean. The ODP components include planning, management, design, fabrication and construction, testing, field operations, sample handling, and data handling. The principal locations on land at which these activities take place are Washington, DC; College Station, Texas; Pascagoula, Mississippi; Palisades, New York, and a number of ports of call in the U.S. and other countries. All of these places will benefit economically by the local project-related expenditures and by the direct and indirect jobs thereby created.

The present ODP funding estimate for a 5-year program starting in 1984 is $192 million, of which $141 million will be contributed by the U.S. and $51 million by foreign participants. In 1984, about $22 million were budgeted to organize activities at Texas A & M University in College Station, Lamont-Doherty Geological Observatory in Palisades, New York, and in retrofitting the drillship JOIDES RESOLUTION at Pascagoula, Mississippi. Direct expenditures on payroll, goods, and materials have thus brought economic benefits to these communities. By creating other jobs, fusion of that money into the local economies has had a multiplier effect in the regional economics of Texas, Mississippi, and other areas where project-related expenditures have been made. Further expenditures in the future will similarly generate new employment and economic growth in areas where worker payrolls will be spent and project related equipment and supplies will be bought.

IMPACTS ON OTHER USES OF THE ENVIRONMENT

Since the ODP will involve only one ship and since drilling will not be conducted for more than 3 months in any given area, it seems unlikely that the program would have significant adverse effects on such activities as commercial fisheries, military operations, transportation, resource development, and other scientific research. The probability of adverse impacts is further reduced since state-of-the-art technology and procedures will be used to minimize the possibility of blowouts and the introduction of oil or other contaminants into the marine environment.

The potential for impacts on individual resources is further explored below. Both adverse and beneficial impacts are identified.

Commercial Fisheries

ODP activities will have a negligible impact on commercial fisheries (see Section 4.5). However, impacts could occur primarily from spatial exclusion of fishing by the drillship for the period of its operation in the area and from oil spills. Impacts to fisheries in the Georges Bank region were investigated by the Minerals Management Service-funded study

"Assessing the Impacts of Oil Spills on a Commercial Fishery" (University of Rhode Island and Applied Science Associates, Inc. 1982). Potential impacts from 15 hydrocarbon exploration wells and 78 delineation and production wells concentrated in one area were considered to be moderate. In the analysis, portions of regional populations changed in number and/or distribution for at least one year class (generation), but the regional population, as a whole, was unlikely to be adversely affected. Depending on the species and subsequent environmental conditions, this could have long-ranging impacts on a population.

ODP activity is not planned in geologic formations suitable for oil and gas accumulation. If drilling in such locations takes place, then it will be done with a riser and blowout prevention system. Therefore, the probability of an accidental oil spill is considered to be minimal. Compared to full-fledged oil and gas activities, ODP activity at sites with a productive fishery will be few and short-term. This reduces the risk of accidental oil spill still further. Mitigating measures employed by the ODP are discussed in detail in Section 4.8.

Military Uses

It is anticipated that ODP sites will avoid all areas of designated military activities. If scientific objectives of the program require investigation in areas where conflicts with military activities may occur, the U.S. Department of Defense, or similar agencies of the countries in whose jurisdiction the ODP activity may take place, will be consulted prior to selection of sites. During operations, the ODP notifies the Defense Mapping Hydrography/Topography Center of changes in location and activities that will occur at each site.

Transportation

Existence of one ship, JOIDES RESOLUTION, for a brief period in any given location (mostly in international waters) will not impact general transportation at sea. To the extent possible, sites will be chosen to avoid heavily traveled traffic lanes on the open seas. Within coastal waters, drilling will be avoided in designated traffic lanes and precautionary areas. If scientific objectives require drilling in areas where conflict may arise, prior consultation with U.S. Coast Guard or similar agencies in other countries will be carried out to minimize impacts.

Resource Development

ODP-related drilling activity could temporarily interfere with activities related to the development of other resources (e.g., oil, gas, and other minerals). Due to the very short duration of ODP activity in any given location, such interference, if any, would be minimal and insignificant. On the other hand, development of other resources may be made possible by the knowledge gained from ODP activity.

Other Scientific Research

The presence of JOIDES RESOLUTION could temporarily interfere with other scientific research occuring at the same time. The probability of such interference is small since all sites to be drilled are selected at least 1 year in advance. This information will be passed on to the countries in whose jurisdiction drilling may occur. These countries are also invited to send two of their scientists on that leg, offering a unique opportunity for scientific research that would have otherwise not been possible. In addition, beneficial effects of the knowledge gained during the ODP on other scientific research are likely.

IMPACT ON LEGAL AND REGULATORY ISSUES

Under international law, as reflected in the 1982 Convention on Law of the Sea, drilling within the Exclusive Economic Zone or on the continental shelf of another coastal nation, requires that country's prior consent. The Office of Marine Science and Technology Affairs in the U.S. Department of State, as the liaison between the NSF science operator and the country, formally requests permission to conduct research drilling in the country's territorial waters.

Several program components greatly enhance the gaining of permission from other coastal nations. A rigorous system of pre-drilling safety reviews minimizes the risk of encountering high pressure zones or hydrocarbon accumulations. Indemnification against accidental spillages or other problems that could arise out of the drilling operation has been provided for by Congress. Participation of the country's geologists and oceanographers is invited and expected to be accepted because of the inherent scientific interest. Geologic data collected including geophysical records, core descriptions and other pertinent results are made available to the country as soon as possible, and copies of resulting publications are supplied as they are printed.

All activities in the Antarctic are governed by the Antarctic Treaty of 1959, recommendations adopted under the Treaty, and the Antarctic Conservation Act of 1978. The ODP's proposed scientific drilling with free availability of the data retrieved differentiates it from resource prospecting which is voluntarily restrained under a 1977 Treaty agreement on mineral-resource exploration and exploitation (Treaty Recommendation IX-1). NSF's Division of Polar Programs, by annual transmittal of planned activities through diplomatic channels, will provide advance notice of Antarctic drilling operations to the governments of all other Antarctic Treaty Parties and to the Scientific Committee on Antarctic Research (SCAR is the primary scientific advisory body to the treaty nations). This EIS and information on planned research synopsis, ship's tracks, and participating scientists will be compiled and made available in the furtherance of the principles contained in Treaty Articles III(1) and VII(5). Thus, proposed ODP activities are consistent with the Antarctic Treaty and with the policy of voluntary restraint from mineral exploration and exploitation in Antarctica.

Article II of the Convention on Conservation of Antarctic Marine Living Resources (CCAMLR) establishes a "conservation standard" to protect Antarctic marine living resources. The CCAMLR and a U.S. law and implementing regulations have been in force since 1982; ODP operations in the Antartic will be guided by these regulations (see Applicable Laws and Regulations, Section 2.2).

IMPACT ON TECHNOLOGY DEVELOPMENT AND TRANSFER

Technology plays a major role in the ocean drilling program. ODP's predecessor, the Deep Sea Drilling Project (1968-1983), pioneered many of the technologies in common use in offshore industry today. These include

- Dynamic positioning of the drillship
- Roller core coring bit
- Re-entry of formerly drilled holes
- Recovery of undisturbed sediment cores; hydropiston coring, extended core barrels, and other coring equipment.

The ODP will again use a number of new tools, equipment and techniques in order to provide the maximum scientific returns. Among the technical advances of the Ocean Drilling Program are:

- A modern state-of-the-art drillship, JOIDES RESOLUTION, capable of drilling to 9,000 m (29,520 feet) in all of the world's ocean with well-equipped, spacious laboratories, and berthing for 50 scientists and technicians. The ship is ice-strengthened and is capable of high-latitude operations previously not feasible.

- A complete program of scientific logging including a suite of the most advanced logging tools available or developed particularly for ODP. Specially developed tools include:

  - Downhole wireline packer
  - Analog borehole televiewer
  - Twelve-channel sonic logging tool
  - Digital borehole televiewer
  - Logging tool heave compensation system.

- An enhanced program of support for downhole experiments such as:

  - Downhole seismology
  - Hydrogeology - downhole fluid flow and velocity
  - Resistivity, temperature, and heat flow
  - Downhole water chemistry
  - Stress and rate of strain in crustal boreholes.

- Development of advanced tools and techniques for drilling in previously inaccessible areas and for improving drilling and coring technology. These include:

  - A bare rock drilling system which will enable the drill to "spud in" in areas where little or no sediment cover exists
  - An improved drill-in-casing system; improved bit life and penetration rates in hard rocks
  - The use of mud motors to improve coring rates and recovery
  - Design of a 9,000-m (29,520-foot) drill string and drill string quality control and analysis programs
  - A drilling system that can be used in geothermally active regions where temperatures as high as 300° C may be encountered.

In addition to these tasks, ODP engineers will continue work on improving and developing scientific coring systems such as the hydraulic piston corer, the extended core barrel, and the pressure core barrel.

Any technological advances achieved by the ODP will be openly available to the countries participating in support of the program. Engineering plans and specifications for tools developed for the program will also be available to the members. The resulting development of equipment and technology will aid the petroleum industry and the people of all nations.

Section 4.7
MISHAPS AND ACCIDENTS

Mishaps and accidents occasionally occur in drilling operations, and the potential exists for these situations to arise during the course of the ODP. Impacts discussed earlier in the chapter are those resulting from normal ODP operations. Potential mishaps, accidents, and impacts that could result from encountering unexpected conditions are discussed in this section. Mishaps could result from storms, unexpected geologic anomalies, or blowouts. Most resulting impacts would be caused by material fluxes into the environment. In compliance with Council of Environmental Quality (CEQ) regulations, the range of potential impacts up to a hypothetical worst-case analysis is addressed. The probability of occurrence of any mishap during the ODP is low (as exemplified by the excellent safety record of the DSDP). The worst-case mishap is highly improbable. Contingency plans exist and shipboard personnel are properly trained to respond to emergency situations safely and effectively. Measures built into the ODP for preventing and mitigating impacts are discussed in Section 4.8.

OCCUPATIONAL HAZARDS

The occupational hazards expected for the ODP should not differ significantly from normal occupational hazards associated with the operations on an ocean-going vessel, a drill rig, or laboratory. Crew members are trained in safety measures, and specific procedures for normal operations and emergency situations are outlined in the SEDCO Safety Policy Manual (SEDCO 1982). In addition, the ODP provides the Shipboard Scientific Handbook (ODP 1985), which details operating procedures, safety measures, and emergency operations, to all cruise participants. The exceptional safety record compiled during the DSDP is expected to continue through the ODP.

LOSS OF RISER AND DRILL STRING

If a sudden, severe storm or squall should blow the ship off the drill site during drilling, loss of the drill string (riserless drilling) or riser and drill string (riser drilling), and all downhole or subsea equipment in use at the time, are possible. Geologic conditions, such as those identified in Section 4.3, could result in these same losses. The immediate and inevitable result would be the deposition of the equipment on the seafloor, with recovery probably being impractical.

Depending on downhole conditions at the time of the accident, it may be necessary to locate and re-enter the hole (if possible). A backup drill string and the technology to find and plug the hole do exist. Failure to plug the hole (if conditions monitored during the earlier drilling suggested it was necessary) may result in chronic exchange of formation fluids and seawater. Depending on the direction of flow and composition of formation fluid, impacts could range between none and a persistent exchange of local bottom water with formation fluids that are toxic to the local benthic community. In many situations, geothermal heating of the formation fluids could result in the release of a buoyant plume from the borehole. The plume, entraining ambient water as it rises, would eventually spread laterally at some level of neutral buoyancy in the water column. Resulting impacts to water column organisms would be localized and negligible. However, high dissolved solids concentrations and cooling before reaching the seafloor could result in a negatively buoyant plume that would spread down current from the borehole along the ocean bottom. These fluids could persist in the low-energy abyssal environment resulting in prolonged exposure to the local benthic community. Dissipation is largely by diffusion in these areas of minimal vertical mixing.

AQUEOUS SOLUTIONS

The probability of releasing substantial volumes of subsurface aqueous solutions is small. Evidence of excess fluid pressures in formations in the geological provinces planned for drilling was found in the Galapagos Spreading Center off the East Pacific Rise. Pressurized fluids could flow into the hole and out into the ocean environment until pressure equalization is achieved. However, intercommunication of fluids between formations is unlikely, limiting the total volume that could be released. As a preventive measure, every hole over 200 m (565 ft) deep will be logged, yielding information on formation properties that can indicate potential for fluid exchange. Abandonment procedures call for sealing off of the interval in question with either heavy mud or cement as conditions require.

When drilling into oceanic crustal rocks, temperatures as high as 260° C have been recorded. Fluids in the hole would be mainly seawater. After abandonment, thermal convection may develop in the holes, with the warmed fluid convecting out by mixing between convective cells that could develop from the thermal gradient in the rock. Dissolved gases and some solids would be present. No measurable environmental impacts would result and these holes will not have to be filled.

Evidence exists for hydrothermal circulation of fluids in oceanic crust for some distance out from spreading centers where heat flow is high. These migrations probably occur through fissures and voids. It is doubtful that a drilled hole would contribute significantly to this natural process. Holes can be filled with weighted mud and/or cemented to inhibit hydrothermal circulation through the hole.

MAGMAS

Magma chambers can exist as little as 1-3 km (0.6-1.9 mi) beneath active spreading centers, well within obtainable depths with ODP drilling. However, drilling cannot physically proceed to the point of encountering magma at depth, since metal failure of the bit would occur first. No evidence has been assembled to suggest that such activities might possibly produce a volcano that would not occur naturally, or accelerate such an occurrence.

BLOWOUT OF GAS OR BRINE

Geopressurized gas or formation fluids may be encountered whenever drilling into and through sedimentary sequences. The presence of shallow gas deposits and clathrate (gas hydrates) zones is of primary concern. Fortunately, both are usually detectable with the modern geophysical techniques used by the ODP during site selection surveys, greatly reducing the probability of encounter and the potential of a blowout.

Shallow gas deposits can occur in any water depth when pressurized gas has migrated up faults, unconsolidated shales or cherts, or fossiliferous zones, into unconsolidated sediments near the surface. In addition, decomposed clathrates can produce shallow gas accumulations with abnormally high pressure (Taylor et al. 1979). Potential conduits are usually detectable as shallow faulting or Landward Dipping Reflectors (LDRs) in the seismic record (Moore et al. 1982). The deposits themselves usually show up as "bright spots" in the seismic record, and their small dimensions can be easily avoided in selecting a drill site, reducing chances of a blowout to near zero (Matthews 1974).

In deeper waters, where most ODP activities occur, high pressures or large volumes of gas are unlikely. Therefore, explosive blowout causing damage to downhole equipment is also unlikely (Tucker et al. 1984). In shallower water on continental shelves, where gas deposits are more common, a riser, blowout preventer, and standard control procedures for shallow, high formation pressures will be employed (see Tucker et al. 1984).

A blowout could result in the loss of downhole equipment and a continuing release of gas (including H_2S) or formation fluids into the water column. Gas would bubble upwards diffusing into the water column. Concentrations of H_2S or hydrocarbons in the water column would be low because of short residence times of the bubbles in relation to the diffusion of gas from the bubbles into the water column. At a pH of 8, 85 to 90 percent of the H_2S released in the water column would be present in the ionized form HS^- (Rao and Hepler 1977) reducing toxicity to organisms. Reduction of oxygen concentrations as the H_2S and hydrocarbons in solution oxidize should not be significant because of the low concentrations expected. The portion reaching the surface (which could include C_1-C_4 hydrocarbon, H_2S, and other gases) would be released into the atmosphere, impacting air quality. The depth of drill sites makes it highly improbable that aeration of the water from released gas would cause loss of ship buoyancy. Impacts resulting from release of formation fluids from the hole are discussed earlier in this section.

Gas hydrates (clathrate) are solid, ice-like structures, formed of gas molecules within a lattice of water molecules under specific combinations of high pressure and temperature. The stability zone of gas hydrates in marine sediments is generally found in water depths as shallow as 500 m (1,640 ft) when bottom temperatures are 0° C. Stability zones are deeper in warmer waters. Pressurized gas and fluid may accumulate underneath this layer of gas hydrate in regions where no structural traps exist. However, the bottom of the hydrate zones are usually detectable as Bottom Simulating Reflectors (BSRs) on the seismic record (Tucholke et al. 1977; White 1978; Shipley et al. 1979; Dillon et al. 1980). In addition, pressure barrel cores will be taken to verify or deny the presence of gas hydrates in areas where they may exist. To reduce the risk of a blowout, drilling during the ODP is not allowed to penetrate through a gas hydrate layer or to proceed deeper when gas hydrates are encountered where the bottom boundary (BSR) is not detected.

Releases from a penetrated hydrate layer will be minor. Decomposition of hydrates from the hole into the marine environment is temporary and will seal itself. In the unlikely event that the bottom of the hydrate layer is penetrated and free gas or formation fluids are released, impacts will be similar to those discussed above. Mitigating measures outlining ODP protocol on hydrates encounter are discussed in Section 4.8.

BLOWOUT OF PETROLEUM

Petroleum accumulations may be encountered whenever drilling into and through sedimentary sequences. However, this is the least likely mishap in scientific drilling, since extensive measures are used to avoid potential petroleum accumulations during site selection and since drilling is stopped, the hole is plugged, and the site is abandoned when monitoring of cores indicates hydrocarbons. Details of the extensive safety reviews of each site location, methods for hydrocarbon monitoring, and protocol for abandonment are discussed later this section and in Section 4.8.

Fifteen years of drilling throughout the world's oceans have produced extensive information and experience on which to base the judgment that there is an extremely low probability of encountering reservoirs of oil or gas during riserless drilling. Much of the deeper drilling will be accomplished in areas that were already characterized during the DSDP as thin pelagic sediment cover. Other work will be done in areas that are very similar, from geophysical evidence. Sites are planned for those areas of the ocean least likely to contain reservoirs of hydrocarbons. In regions where hydrocarbons are more likely to be found, drilling will be postponed until later in the program when riser capability is available. This will permit well control procedures to contain the well until it can be plugged. The intention of assuring that sites are of extremely low probabilities of hydrocarbons encounter, and conservative monitoring of downhole conditions will remain the same for both riser and riserless operations.

During riserless drilling operations, the encounter and release of small amounts of hydrocarbons is possible. Certain procedures enable control of minor flows of formation fluids, including hydrocarbons, while operating without a riser. Weighted mud is held in readiness, pre-mixed, and prepared for pumping into the hole. Cement with calibrated setting time can be mixed and pumped to seal the hole. Even if all control attempts fail, volume of released petroleum is expected to be minor. The fate and effect of spilled oil in the marine environment are discussed in detail later in this chapter.

Worst-Case Analysis

Release of a substantial volume of hydrocarbons can occur only during riser drilling in thick sedimentary sequences (where potential for generation of large amounts exists). Although highly improbable because of intensive pre-drilling site safety reviews, the worst-case scenario entails a blowout of oil or gas and loss of the ship in a remote, environmentally-sensitive area. Hydrocarbons would continue to be released into the environment until another drillship with the depth capabilities of JOIDES RESOLUTION arrives and drills a relief well. This scenario results in large-scale impacts to the environment and loss of human life that would be unacceptable to the ODP. To reduce the probability of an oil spill and to guard against this worst-case scenario, strict precautions to ensure off-structure, minimal-risk drilling are implemented. A discussion of the probability of a spill and the resulting fate and effects of oil in the marine environment are presented below.

Oil Spill Risk Analysis

The risk of future oil spills from scientific drilling in the ODP has been estimated using three basic assumptions:

- Realistic estimates of future oil spill and blowout frequencies can be calculated from past outer continental shelf (OCS) drilling experience.
- Oil spill and blowout rates are dependent on the number of wells drilled (the exposure variable)
- Estimates of risk are conservatively high because of the "off-structure" drilling policy and site review of the ODP.

Many factors influence estimated oil spill and blowout rates, including the historical database, the exposure variable selected, and the drilling area used in the analysis. The historical database used herein covers exploratory and development drilling on the federal outer continental shelf from 1971 to 1982. Since production wells are drilled into known structures containing reservoirs that have previously been drilled, those statistics are not appropriate for use in an estimation of risk for ODP activities. Some data are available for drilling activities as early as 1950, but complete statistics separating exploratory and production drilling activities are not available for the years before 1971 (Minerals Management Service 1983b).

The exposure variable selected for this analysis was the number of wells drilled per unit time. Other exposure variables used in OCS lease sale areas (e.g., volume of flowthrough) were not appropriate for assessing the risks of scientific drilling activity.

Drilling sites chosen for the ODP will be carefully selected to minimize the chances of encountering hydrocarbon reservoirs. During the DSDP's 15 years of riserless drilling, 1,102 separate wells were drilled without a drilling-related mishap, blowout, or pollution incident (Pommerville 1984). In the ODP, the best available geological and geophysical data will be used to survey all prospective sites, and an intensive safety review will eliminate all sites with apparent risk. This safety review, discussed in detail later in this chapter, will be performed by two separate panels of geological, geophysical, and drilling industry experts. Each panel will have the authority to recommend removal of a particular site due to the potential of encountering overpressure zones or hydrocarbon accumulations, or to the lack of sufficient information to determine such potential. Because selected ODP drilling areas of unlikely to overlie hydrocarbon reservoirs, the use (in this analysis) of historical spill statistics generated by oil-related drilling should yield conservatively high projected oil spill and blowout rates for ODP activities.

From 1971 to 1982, approximately 11,564 exploratory or development wells were drilled on the U.S. outer continental shelf. During this time, 47 drilling-associated blowouts were reported (Minerals Management Service 1983b). Using these data, the historical blowout rate for OCS activity is calculated to be 4.1 blowouts/1,000 wells drilled. Oil spills 1 barrel (bbl) or greater did not occur at any of these 47 blowouts (Minerals Management Service 1983b). Therefore, the historical oil spill rate for spills greater than 1 bbl (based on exploration drilling activity from 1971 through 1982) is calculated to approach zero. All OCS oil spills have been related to production activities.

Both the blowout rate and the spill rate should represent conservatively high estimates for the ODP because the historical drilling activity used to calculate these rates was geared towards finding oil. Even industrial exploratory drilling in regions likely to contain oil will encounter any accumulations less than 10 percent of the time. The majority of the ODP program will employ riserless drilling, as did the DSDP. Riser drilling in thicker sediments (as is typical of OCS activities), may occur only during the latter stages of the ODP. Riser drilling sites will undergo a site safety review process at least as rigorous as that for the riserless drill sites.

Based on the foregoing considerations, it is reasonable to assume that the risk of a blowout during the ODP will be substantially less than the rate encountered during OCS drilling activities (4.1 blowouts/1,000 wells). At projected ODP drilling rates, this approaches a probability of 0.1 blow-outs/year. The oil spill occurrence rate for spills greater than 1 bbl should be near zero. In summary, because of the ODP site selection process and "off-structure" drilling policy, it is highly unlikely that oil will be encountered. If encountered, it is highly unlikely that oil will be spilled in substantial volumes.

Fate of Crude Oil in the Marine Environment

The fate of spilled oil in the marine environment can be affected by many physical, chemical, and biological processes. Short-term alteration, or weathering, begins as soon as oil enters the environment and generally lasts 1-2 days. Hydrocarbon fractions with boiling points above 250-300^{0} C are lost during this time (Council on Enviromental Quality 1974). Weathering is dominated by physical and chemical processes (e.g., spreading, evaporation, dissolution, emulsification, dispersion, sedimentation, and auto-oxidation), whereas long-term breakdown is largely accomplished by microorganisms. These processes are described in detail in Appendix B.

The movement of spilled oil is influenced by the complex interaction of wind-wave induced currents, tidal currents, and residual currents. A schematic example of the transport, dispersion, and weathering of a hypothetical oil spill was prepared by Mackay and Leironen (1977). The model simulates oil slick evaporation, dissolution, spreading, horizontal diffusion in the water column, vertical diffusion in the water column, and natural and chemically induced dispersion. Model users may vary oil composition, sea state, wind speed, temperature, and time of chemically induced dispersion. The oil used in their simulation represented a "typical" natural crude oil (Mackay and Leironen 1977). Additional assumptions were: volume of spill equals 900 bbl (120 tons); oil density equals 0.8575 g/cm^3 (API gravity 33.5); water temperature equals 15^o C; wind speed equals 18 kn; sea state is medium (4); and the initial spill radius is approximately 50 m (164 ft). Results of the model calculations are given in Figure 50 for slick radius vs. time and in Figure 51 for oil volume reduction vs. time. Calculations ended after 100 h, or about 4 days.

According to this model run, the slick reached a radius of approximately 1,000 m (3,281 ft) and only 15 percent of the original spilled volume remained in the slick after 100 h or 4 days. These results suggest that evaporation and dispersion substantially reduce oil volumes within a very short time period. Since most ODP drilling locations will be at least 322-644 km (200-400 mi) from shore, these natural processes will operate over large distances and will greatly reduce the potential for impacts to shorelines or impacts to resources (Pommerville 1984). Assuming a spill occurs 322 km (200 mi) offshore and travels directly to shore at a speed of 10 cm/sec (4 in/sec), the spill (if still intact) would contact land in approximately 37 days. After this length of time, significant reduction of volume and weathering of the spilled oil should have taken place as described above.

Special Consideration: Sea Ice--

Oil/ice interactions are complex and incompletely understood. The fate of oil in high latitudes depends as much on location of the spill as it does on time of year. Oil slicks encountering open pack ice accumulates in ice leads, where movement between the floes forces the oil onto the edges and surfaces of the ice. If oil is present during the open water season and persists during ice formation, the heat flux from the oil plume will maintain a hole in the ice throughout the winter (Wadhaus 1981).

Oil in pack ice is readily absorbed by both grease ice between floes and coarse upper ice or snow layers on the floes themselves. Once on the surface of the ice, the oil may increase the rate of ice melting through absorbtion of solar radiation. Albedo effects from oil on the ice surface should be confined to a small percent of the total ice coverage and not have significant effects on the heat balance (Ayers and Jahns 1974). Depending upon the season, the ice may either continue to melt (carrying the oil as it moves) or refreeze and immobilize the oil. In either case, oil in pack ice may be transported great distances before being released into the water.

Depending on bottom and mid-water currents, oil released from a blowout occurring on the ocean floor could be transported underneath shelf ice

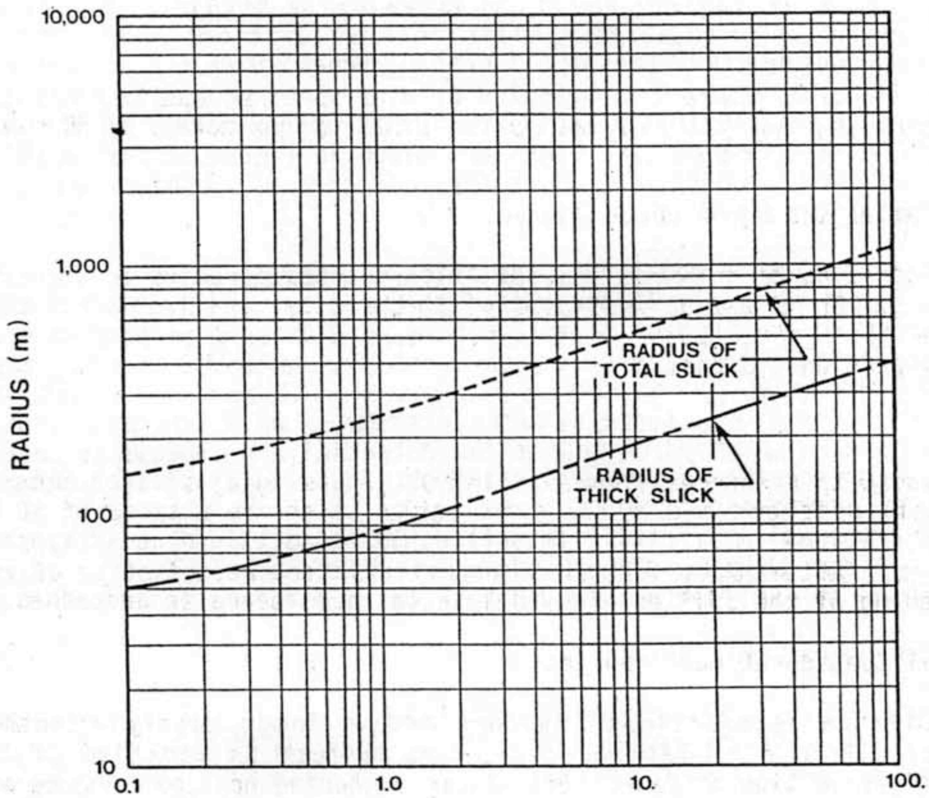
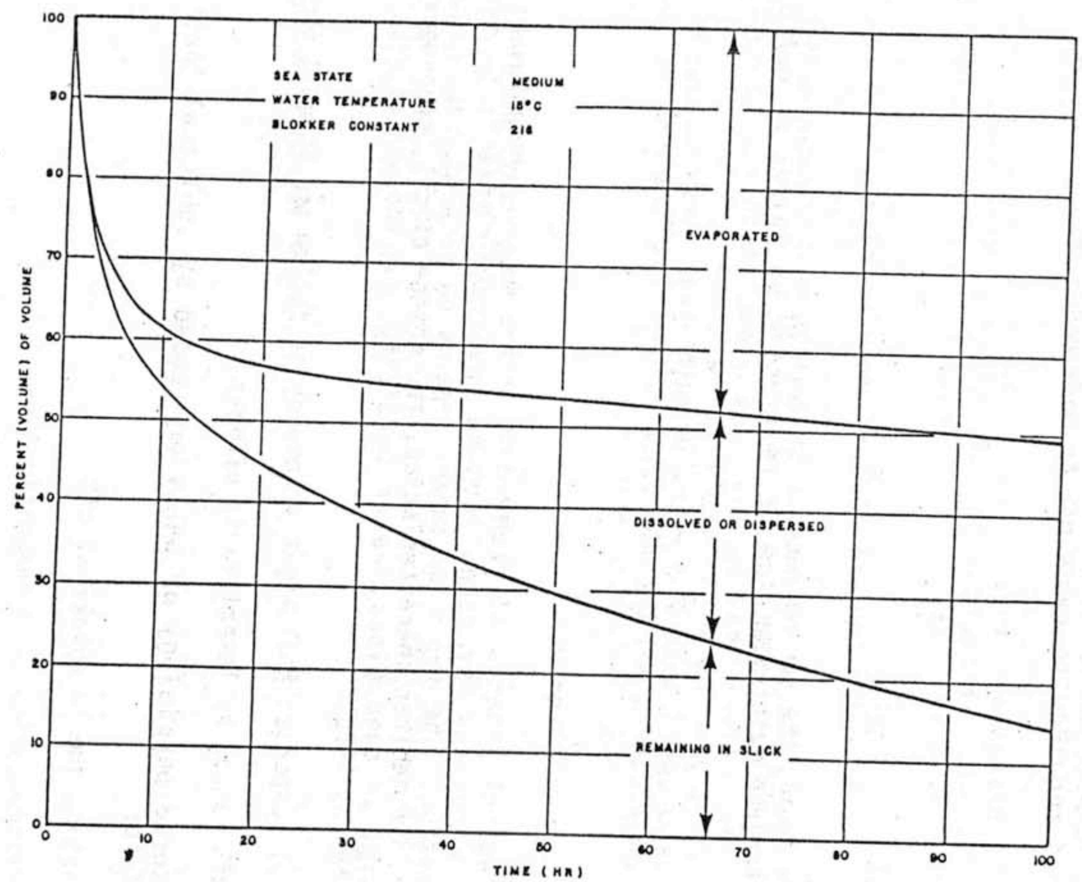


Figure 50. Slick radius versus time.



REFERENCE: MACKAY AND LEIRONEN 1977

Figure 51. Fate of oil on water.

or flows. When oil surfaces under fast ice, it becomes trapped in the upper-most irregular pockets at the sea/ice interface (Clark and MacLeod 1977). Oil trapped under ice will equilibrate at a minimum average thickness of about 10 mm. Thus, even a spill of 200,000 bbl under smooth ice would spread over an area of only about 6 km^2 (2.3 mi^2) (Office of Marine Pollution Assessment 1982). Because sub-ice currents of greater than 0.2 m/sec (0.66 ft/sec or the speed required to cause oil to move under ice) are quite rare, the oil tends to remain stationary relative to the ice cover (Office of Marine Pollution Assessment 1982). During the winter season, freezing may encapsulate the oil. Encapsulation effectively traps the oil until the spring thaw, at which time it is released in a virtually unweathered state.

Oil under ice migrates upward at a rate proportional to the number of cracks, "wormholes," and brine channels. Oil under first-year ice migrates upward rapidly during the spring because of melting brine channels, whereas oil migration through multi-year ice is restricted by layers of refrozen melt water at the surface, and by yearly ice accretion at the bottom. Oil trapped in first-year ice will likely be released by spring warming. This same process could take 2-3 years in multi-year ice. Because of the extremely low temperatures and the migration of high-latitude ice, entrapped oil tends to be released slowly over vast areas.

Biological Effects of Crude Oil

The biological impacts of crude oil in the marine environment may be chronic or acute, and may range from no observable effects to severe habitat destruction. The degree of impact depends on many factors, including the type of oil, the habitat characteristics, the dosage of oil, oceanographic and meteorological conditions, water turbidity, and the season (National Academy of Sciences 1975).

Biological responses that might accompany or follow an oil spill include:

- Death caused by lethal toxic effects
- Altered physiology or behavior caused by sublethal toxic effects
- Tainting due to uptake of oil
- Bioaccumulation or biomagnification
- Smothering and suffocation
- Habitat damage (Joint Group of Experts on the Scientific Aspects of Marine Pollution 1977).

The most toxic fractions of crude oil are the low molecular weight hydrocarbons, such as benzene and naphthalenes. These volatile fractions are also the most soluble. They may readily dissolve in the water column, but also tend to evaporate quickly, thereby limiting the amount of time they are in contact with biota. Non-volatile components of crude oils cause biological damage predominantly by coating and smothering organisms.

The following discussion is focused on the effects of crude oil on the major groups of marine organisms and major habitat types. Marine mammals are also discussed in detail in Appendix A.

Organism Impacts--

Phytoplankton--Due to drastic fluctuations in species dominance in planktonic communities, it is very difficult to determine the effects of oil on species composition and abundance. Impacts may vary greatly, depending on the extent and duration of the spill and on the state of phytoplankton growth at the time of contact with the oil. Experiments on the toxic responses of phytoplankton to oil and oil fractions have yielded results ranging from lethal toxicity to growth stimulation. In general, toxic effects can be seen at concentrations (of soluble aromatics) of 10-100 ppm (Council on Environmental Quality 1974). Although oil may be toxic to individual phytoplankters, they are so prolific that the effects of spills would likely last only as long as oil fractions are present at toxic concentrations (Joint Group of Experts on the Scientific Aspects of Marine Pollution 1977).

Zooplankton--Zooplankton includes holoplankton (i.e., permanent zooplankton), and meroplankton (i.e., eggs and larval stages of nektonic and benthic creatures). Although copepods are the most studied holoplankters, information about the effects of oil on these organisms is inconclusive. Copepods are known to ingest oil droplets (the size of their natural food), which pass through their gut virtually unmodified (Teal and Howarth 1984). In one nearshore spill of heavy refined oil, zooplankton densities near the spill site were depressed during the first 5 days of the spill. However, it is not known whether this was due to mortality or their avoidance of the area (Teal and Howarth 1984).

In general, larvae are 10-100 times more susceptible to soluble aromatics than are the adult stages of the same organisms. Because soluble aromatics do not persist in the water column, adverse impacts on larval and adult forms are likely to be short-term and localized.

Fishes and Fisheries--In most cases, adult fish will only encounter lethal concentrations of oil or dissolved aromatics in the immediate vicinity of a spill. Where large fish mortalities have been observed near crude oil spills, the deaths seem to have been caused by dispersants rather than by the oil itself.

The toxicity of crude oil to eggs, larvae, and juveniles probably poses a greater threat to fishes and fisheries than does the toxicity of crude oil to adult fishes. Typical lethal toxicities of soluble aromatics to eggs, larvae, and juveniles are in the range of 0.1-1.0 ppm, with larvae tending to be more sensitive than eggs (Massachusetts Institute of Technology 1973). Mortality usually occurs as a result of abnormal development that renders the organism more vulnerable to predation or less successful at competition.

Benthic and Intertidal Organisms--Organisms inhabiting benthic or intertidal areas are usually highly impacted by nearshore spills. Oil washed ashore may coat intertidal habitats, while oil that is in suspension or that settles out of the water may become readily incorporated into bottom sediments. Because intertidal organisms are important components of marine ecosystems and often have economic value, impacts to intertidal areas have far-reaching consequences. Members of the benthos and intertidal communities include algae, molluscs, crustaceans, echinoderms, polychaetes, coelenterates, and hydroids. Intertidal organisms that live on hard substrate (mussels, oysters, barnacles, macroalgae) are vulnerable to the effects of oil coating. The filter feeders are vulnerable to oil suspensions and dissolved hydrocarbons. Intertidal and sub-tidal organisms that live on or in soft substrates are vulnerable to oil coating, sediment incorporation, and dissolved hydrocarbons. Because oil can become closely associated with sediment, animals that are merely attached to the substrate tend to be less affected than those that live in the sediments or feed on them.

Microbes--Bacteria, yeasts, and molds transform liquid, gaseous, and solid hydrocarbons into more soluble and usually more reactive compounds. These compounds are in turn acted upon by other microorganisms, although no one species can utilize all the components of petroleum. Microbial populations respond to oil in two ways: naturally occuring bacterial populations are inhibited and petroleum-degrading bacterial populations are enhanced. An oil spill will induce a succession of dominant species as the oil is degraded. However, the mechanisms for this are not well known (Karrick 1977). Microbial populations in the sediment and in the water column in areas of chronic oil pollution often contain large numbers of oil-degrading bacteria.

Macroscopic Algae--Macroscopic algae are susceptible to coating by oil and to the toxicities of dissolved petroleum fractions. Sensitivities vary considerably among species. Spilled crude at Santa Barbara, California, caused little or no damage to three species of green algae, one species of brown algae, and kelp, but killed red algae. Some algae (such as kelp) secrete mucus, which provides protection against coating by oil (Council on Environmental Quality 1974). Estimated lethal toxicity ranges for algae are 0.1-1.0 ppm of dissolved aromatics (Massachusetts Institute of Technology 1973).

Marine Grasses--Damage to marine grasses is usually caused by coating. However, weathered crudes are generally less toxic to marine grasses than are fresh crudes. The severity of effects from a spill is highly dependent on time of year, environmental conditions, type and condition of oil, and duration of exposure. Observed effects of oil spills range from little or no damage to nearly complete mortality. Following the AMOCO CADIZ spill, eelgrass suffered little or no adverse impacts (den Hartog and Jacobs 1980; Jacobs 1980). In contrast, surf grasses and salt marsh grasses suffered heavy losses (75-100 percent) in the Santa Barbara and Milford Haven incidents (Council on Environmental Quality 1974).

Special Consideration: Marine Mammals and Birds--As individuals, all marine mammals are vulnerable in various degrees to impacts resulting from an oil spill. However, the potential impact to a marine mammal population is dramatically increased when the population is confined to a specific area (e.g., breeding grounds, localized ranges, relying on leads in ice). In addition, the population size is also a major factor affecting vulnerability of marine mammals to oil spills. Consequently, remnant and site-tenacious populations are more vulnerable to perturbations than are other more numerous or dispersed species.

Oil effects vary among species. Ecological characteristics that are most vulnerable to impacts include means of thermal regulation, site tenacity or timing of migration, preferred habitat, breeding system, foraging technique, and population size. Detailed evaluation on these impacts is presented in Appendix A. Species considered the most susceptible to population-level impacts include otters, fur seals, sereniads, monk seals, sea lions, and migratory baleen whales. Ecological effects are longer lasting for marine mammals than for other marine organisms due to relatively low mammalian reproductive rates. The most effective way to prevent adverse impacts is to avoid drilling in areas of special biological importance and/or during periods of maximum vulnerability (e.g., molting, breeding, pupping, migration).

The likelihood that an individual bird will suffer impacts of oiling depends on a number of behavioral factors (e.g., whether a bird spends all its time in the water, how it forages, and how it reacts to disturbance). The liklihood that a species will suffer impacts depends on factors like size and concentration of its world population, reproductive capability, and how gregarious it is (see Manuwal et al. 1979). Lower bird densities found in the tropics (Ainley unpublished manuscript) reduce vulnerability of a population, while greater densities and areas of concentration (e.g., nesting colonies, rich foraging areas) increase vulnerability significantly. Most bird concentrations (and increased periods of vulnerability) are related to seasonal breeding or foraging locations, although certain areas (e.g., Galapagos Islands) have several endemic and small populations year-round. The duration of an oil spill perturbation would also affect the extent of impacts on bird populations. Species of concern include those listed in the Red Data Book (King 1981) as Endangered, Threatened, or Rare species for reasons of limited population size or range.

Penguin species are the most vulnerable to oiling, since they rely on their feathers for insulation and inhabit ice pack regions which concentrates oil between floes. The alcids (e.g., mures, puffins), which spend almost all their time on the water, are also highly vulnerable. Diving birds (e.g., petrels, shearwaters, cormorants, boobies) also become oiled easily. Birds that forage along oceanic fronts (e.g., phalaropes) or exclusively in the ice pack (e.g., emperor and adelie penguins, antarctic and snow petrels), where oil may be concentrated, are subject to food web disruption and oiling. Many nearshore wintering species may be impacted if oil reaches shore.

Effects of oil on marine birds include mortality or disablement from fouling of their plumage, toxic effects, habitat loss, and food losses. Populations can take 50-100 years to recover from an oil spill (Wiens et al. 1978).

Impacts to Habitats--

Habitats are listed below in order of decreasing vulnerability to oil (ranking is based on relative impacts). Both physical environment and species vulnerability have been considered (Johnson and Pastorok 1982). Biological descriptions of each habitat are presented in Johnson and Pastorok

(1982). It should be noted that particular habitats within each category vary widely due to geographical, physical, and biological factors. Furthermore, the vulnerability of any given habitat might also vary seasonally.

Impacts of oil on organisms are often seen at the community level through several mechanisms:

- Selective elimination of species or functional groups that provide the resource base for higher trophic levels
- Disruption of detritus processing
- Selective elimination or depression of keystone predators or foundation species that control or dominate competitive interaction
- Sublethal impacts on physiology, growth, behavior, and reproduction of key species (Johnson and Pastorok 1982).

Salt Marshes--Salt marshes are perhaps the most oil-sensitive shoreline environments. Impacts occur mostly through direct contact of oil with surface-dwelling organisms, marsh plants, and substrate. The degree of oiling principally depends on the quantity of oil spilled and on the tidal level at the time of the spill. Because wave energy levels are low in marsh areas, spilled oil tends to disperse very slowly. Visual inspection of marshes 16 months after one spill revealed oil 5-10 mm (0.20-0.39 in) deep on the substrate, litter, and soil (Stebbins 1970).

Marsh vegetation provides structure and a detrital food base for the salt marsh community. Plant mortality, interference with detrital replenishment, or contamination of detrital reservoirs could have long-term effects on community structure and overall production. Oiled detritus can be particularly damaging to detritivores and filter feeders. The sensitivity of marsh plants to oil varies. Effects include a reduction in flowering, seed production, germination, photosynthesis, transpiration, growth, water uptake, and oxygen diffusion; and changes in respiration and translocation (Johnson and Pastorok 1982).

Most investigations of saltwater marsh recovery focus on vegetation. Recovery times depend on the type of oil, extent of the oil coverage, and the season. Baker (1971) found that recovery of marshes occurred within 1-2 years of oil spills in several locations, but that benthic populations required much longer periods. In lightly oiled areas of a spill at West Falmouth, Massachusetts, one species of crab showed considerable recovery after 4 years. In heavily oiled areas of the same spill, recovery of that crab did not begin for an additional 3 years (Krebbs and Burns 1977). The rate of recovery of benthic microfaunal populations in salt marshes is poorly known. These populations would be severely affected by patterns of vegetation regrowth.

Mangrove Forests--There are three sub-habitats in a mangrove community: supratidal canopy and trunk, intertidal prop roots, and subtidal substrate. The many components of each sub-habitat exhibit varying degrees of sensitivity to oil. Perhaps the most vulnerable are the epiphytes and those members of the food web that directly or indirectly depend on detritus as a food source. Grazers and filter feeders may also incur heavy mortalities from a spill.

The penetration of oil into a mangrove forest depends on tidal and wave influence, and on location and height of the shoreline berm. Factors strongly influencing the fate and effects of petroleum include tidal and land surface drainage patterns. Recovery of a mangrove forest from damage suffered through an oil spill depends primarily on the resident plant species. Fast-growing species may recolonize in as little as 8-10 years. Other species may take 80 years or more to fully recover (Johnson and Pastorok 1982). Little information is available about the recovery of the rest of the mangrove community.

Coral Reefs--Coral reefs are among the most biologically diverse and productive ecosystems of the world. The coral reef organisms provide a complex physical habitat for a large number of organisms. Coral reefs form an extremely coarse and porous micro- and macro-topography that can readily trap and hold oil. The calcium carbonate sediments, which are formed by erosion of reefs, can retain oil for decades (Johnson and Pastorok 1982). Coral reefs are highly sensitive to pollution stresses for three reasons: 1) reef organisms have narrow physiological tolerances, 2) key trophic interactions are easily disrupted, and 3) warmer temperatures enhance toxicity effects. Of the various reef zones, coral lagoons (within atolls) and intertidal reef flats are the most vulnerable to oil damage. Johannes et al. (1972) demonstrated that corals directly exposed to oil at low tide suffered complete tissue breakdown. Deeper reefs are considered less sensitive to oil damage, but may be adversely affected by sedimentation of fresh and weathered oil.

Recovery rates for impacted coral reefs depend on many physical, chemical, and biological factors. Generally, recovery is fastest on reef crests, reef flats, and the shallow fore reef, and slowest in lagoons and deep fore reef zones. After catastrophic destruction, reef recovery may take 30-40 years or more. Few studies have investigated the recovery of coral reefs after damage by oil spills. However, Loya and Rinkevich (1980) reported that a chronically oiled reef had not returned to its original structure after 10 years.

Gravel and Cobble Beaches--Characteristics of gravel and cobble beaches vary with degree of exposure and particle size. They may be classifed as exposed cobble beaches, exposed gravel beaches, sheltered cobble beaches, and sheltered gravel beaches. Oil may rapidly penetrate cobble beaches and persist for years. Thus, cobble beaches may be impacted longer (more than 3 years) from an oil spill than are gravel habitats (Nyblade 1972).

Compared with eight other temperate marine habitats (on a decreasing scale of vulnerability), boulder, cobble, and gravel habitats rank fifth for susceptibility to the physical impacts of oil, and first for susceptibility to toxicity impacts of oil (DOE 1975). Ecological succession is much more complex on cobble shores than it is on shores with gravel or mixed sediments. Therefore, biological recovery from an oil spill may be slower in the former area. There is little information on the recovery of gravel and cobble beaches after an oil spill. However, Straughan (1978) noted partial recovery of fauna 2.5 years after the METULA incident.

Sandy Beaches and Tidal Flats--The slope of the beach, average particle size, and wave energy are usually positively related, and determine, to a large degree, the impact of an oil spill. Mechanical breakdown and dispersal prevail in exposed environments. Thermal, biological, and chemical degradation dominate in sheltered habitats. In high wave-energy areas where sediment transport is rapid, oil may become buried in zones of accretion, where it can remain for a long period of time. However, in tidal flats where wave energy is low, beached oil tends to stay on the surface.

Because the biological communities of sheltered sandy and muddy beaches are detritus-based, they are very sensitive to the effects of oil contamination. Among the inhabitats of these areas, soft-bodied organisms are usually more susceptible than those with protective shells (Johnson and Pastorok 1982). Because microcrustaceans in sand/mud flat areas provide a stable food source for demersal fishes and shorebirds, these predators may also be impacted by oil contamination.

As a very general rule, the ranking of biological recovery rates (from fastest to slowest) for habitats in this category is: 1) exposed tidal flats; 2) sheltered sandy beaches; and 3) sheltered tidal flats. Actual recovery times largely depend on the persistence of the oil in the environment. Initial studies of artificially oiled beaches indicated potential recovery times of 31 months for protected sandy beaches and 46 months for tidal flats (Vanderhorst et al. 1980, 1981).

Rocky Intertidal--The severity of oil spill impacts in rocky intertidal areas generally increases as wave action decreases, because wave action speeds weathering. The most vulnerable areas are protected embayments, where oil may become stranded, and tide pools, which may act as natural "catch basins" for contaminated waters.

Echinoderms, detritivorous microcrustaceans, and sessile invertebrates are usually the most sensitive to oil contamination. Mass mortalities of the less sensitive grazers may cause blooms of green algae.

Natural recovery rates for rocky intertidal areas range from 2 months to more than 8 years. Recovery of macroflora and macrofauna after a severe spill probably takes 5-10 years (Johnson and Pastorok 1982).

Rocky Subtidal--With the possible exception of deep subtidal areas, oil will not tend to accumulate in rocky intertidal habitats because of strong flushing and intense wave action. However, oil may become entrapped in localized sediment pockets, where it can persist for several years before being completely broken down and released.

Kelp is less sensitive to contamination by oil than are many other inhabitants of the rocky subtidal habitat. For example, kelp grazers (e.g., sea urchins) and macroalgae other than kelp may be highly vulnerable to contamination by oil. Mass mortality of these grazers in an open bottom area may lead to extensive colonization by macroalgae.

Macroalgae and detritivores form the basis of rocky subtidal communities in the north temperate zone (Johnson and Pastorok 1982). Contamination of the detrital resource base, disruption of decomposition, or interference with detrital replenishment from macroalgae could lead to extensive long-term changes in food web structure or productivity. The recovery time for the rocky subtidal habitat after an oil spill depends on many factors, including: weather, type of oil, magnitude and duration of the spill, and species of macroalgae which are present (annual or perennial). For kelp beds, several stable intermediate stages may be reached during recovery. Complete recovery may take 50-100 years or more.

Seagrass Beds--Oil may reach seagrass beds in several ways: 1) sandy oil from beaches may wash back; 2) emulsified oil may impinge on the bottom; 3) oil may undergo sedimentation and sink to the bottom; and 4) oil released at the ocean floor may lead to direct contamination of sediments. Soft-bottom habitats are sensitive to oil contamination mainly because of their low flushing potential. Oil may be bound to sediment particles and buried in the sediment, where anaerobic conditions prevent rapid biodegradation.

Seagrasses are relatively insensitive to mild oil coating and to dissolved aromatics, but mass mortality of seagrasses may have serious ecosystem consequences. For example, eradication of seagrass in one area may cause the destabilization of sediments, resulting in severe disturbances to the benthic community. Within the sediments, oil would most severely impact microcrustaceans, polychaetes, molluscs, and other detritivores. Gastropods, bivalves and decapods may be less affected because of their heavy shells. Impacts to benthic organisms would, in turn, affect organisms at higher trophic levels (e.g., demersal fishes, shore-feeding birds, and mammals) that prey on benthic populations. Recovery from moderate disturbances to seagrass communities from oil may take several months to several years (Johnson and Pastorok 1982). Complete recovery of a seriously disrupted seagrass community may take a decade or more (Zieman 1975; Phillips 1978).

Pelagic Habitats--Rapid dispersion and weathering of oil in the open water environment make pelagic habitats vulnerable to oil on a short time scale. Open water food webs are based on phytoplankton which quickly recover reduced biomass and primary production rates. Sublethal impacts to zooplankton and pelagic fish could result from petroleum exposure and/or bioaccumulation. Recruitment of ecologically and commercially important species may also be affected, and could, depending on location, significantly impact an entire year class.

There is little information regarding the impacts of oil on ice algae communities. Mechanics of oil/ice interactions suggest that spilled oil contacting ice could cover both bottom and top surfaces of the ice. Ice algae would then be susceptible to both toxic effects of oil and shading (Percy and Wells 1984). However, other ice-associated water column phytoplankton populations will probably be no more affected by spilled oil than those in open waters (Percy and Wells 1984), reducing the impact on primary production.

Special Consideration: Antarctic Ice Edge Communities--Ice algae blooms supply the earliest available food each year. This early food source is important to krill (*Euphasia superba*), which is the food base for higher predators such as fish, squid, seals and six species of whales (NSF 1979; SCAR 1982).

Krill in the vicinity of an oil spill may be affected by a reduction of food supply, direct toxicity, or coating. While local populations would be affected, it is unlikely that even a very large oil spill (500,000 tons; over 3 million bbl, assuming a density of 0.9 g/cm^3) would have much affect on overall krill production (Holdgate and Tinker 1979).

Recovery times for ice edge communities are largely unknown. Because of the seasonal and transient nature of ice, oil would not persist in the same spot for long. However, if incorporated into permanent shelf ice, it could persist for years. Affects would be reduced because production in these areas is low. Impacts from a single event would probably be short-lived and localized, as pack ice breakup and melting would disperse the oil over great distances.

Spill Prevention and Cleanup Techniques

The principal pollution hazard from scientific drilling is the possible release of gas and oil to the ocean or atmosphere. During ODP operations, it is particularly important both for pollution and safety considerations to avoid all encounters with or release of hydrocarbons.

Spill Prevention--

Spill prevention measures outlined in the ODP include:

- Selection of "safe" drill sites (minimal risk of encountering hydrocarbon reservoirs)
- Proper planning of the drilling program at individual sites
- Early detection of hydrocarbons or high fluid pressures during drilling
- Procedures to cope with fluid flows encountered during drilling
- Procedures to abandon holes.

Preventive measures are outlined in detail in the Manual on Pollution Prevention and Safety (JOIDES Pollution Prevention and Safety Panel 1976).

Spill prevention is realistically accomplished by reduction of the probability of encountering hydrocarbon accumulations. Even exploratory drilling by industry only has a 10 percent probability of encountering hydrocarbons. Scientific drilling is characterized by the avoidance of any potential regions of hydrocarbon encounter. The careful selection of drill sites is the single most important factor in spill prevention. Drilling sites selected for the ODP are carefully chosen to minimize the chance of encountering hydrocarbon reservoirs. During DSDP, 1,105 boreholes were drilled under this site selection procedure with no encounter of reservoired oil or gas. Extensive geological and geophysical data are required to survey all prospective sites, and an intensive safety review eliminates all sites with any apparent risk or inadequate information to determine such risk. This safety review is discussed in detail in Section 4.8.

Proper drilling program planning at each drill site can reduce the spill potential. Individual drilling programs include provisions for maximum depth of penetration, a near-continuous coring program and a well-logging program [for all holes greater than 200 m (656 ft) deep]. In addition, during riser drilling, a mud logging program is designed for expected fracture gradients of each individual hole.

Monitoring of hydrocarbons during drilling aids in evaluating the spill potential prior to the encounter of substantial reservoirs. The primary procedure for early detection of hydrocarbons is the prompt analysis of all cores (riser and riserless drilling) and drilling fluid samples (riser drilling) for signs of oil or gas. Details of analyses, detection limits, and program protocol can be found in the Shipboard Organic Geochemistry Guide/Handbook (Simoneit 1981) and are discussed in Section 4.8. Examination of cores can also reveal the presence of certain rock formations that could indicate the presence of hydrocarbons. Cap rocks, undercompacted shales, clathrates, sulphur, evaporites, and other formations are warning signs of conditions favorable for hydrocarbon accumulations. In addition, the drilling rate will be monitored, and temperature and pressures at the bottom of the hole will be determined. Changes in drilling rate and bottom-hole pressures indicate changes in the formation. Measurement of bottom-hole temperatures will allow detection of temperature gradients that are associated with hydrocarbon accumulations.

Procedures for preventing or coping with fluid flows include the use of heavy muds or a barite plug; care in pulling out of a hole to avoid a swabbing effect; use of conventional blowout preventers for riser drilling; and early abandonment and plugging of holes when unfavorable conditions are encountered. Comprehensive well control policies are outlined in the SEDCO Safety Policy Manual (SEDCO 1982), which all crew are trained to follow.

Safety measures for hole abandonment and plugging include the following:

- All holes drilled in consolidated or semi-consolidated sediments should be plugged with cement (or barite) to the uppermost competent layer before abandonment.
- All holes drilled in unconsolidated sediments in which oil or gas are encountered should be filled with heavy mud before abandonment.
- Holes drilled beyond the continental margin in unconsolidated sediments in which no oil or gas are encountered, or holes in igneous rocks, may be abandoned without plugging.

Cleanup Options--

The various techniques available for containment, removal, or treatment of oil on the ocean surface include booms and skimmers, sorption, sinking, gelling and herding, chemical dispersal, burning, enhanced biodegradtion, and natural cleansing. Current technology for recovering spilled oil is severely limited above sea state 3, in winds above 40 kn, in rapidly moving ice-bearing waters, and at night. Standard cleanup procedures for small spills in harbors are in place and will be employed.

Offshore Spills--Cleanup guidelines set by the European Petroleum Organization for spills in the open ocean or rough seas [greater than 1 km (3.2 mi) from shore] are summarized in Table 25. For offshore oil spills, natural cleansing is the preferred cleanup option. Natural dispersion of oil in conjunction with mechanical recovery techniques are favored over other methods when potential for landfall or significant impact to resources is low.

Nearshore Spills--Cleanup guidelines set by the European Petroleum Organization for spills in nearshore waters [less than 1 km (3.2 mi) from shore] are summarized in Table 26. Booms and skimmers are generally more efficient in nearshore waters than in offshore areas and are the favored cleanup method for fresh oil spills. Sorption techniques can aid in mechanical recovery activities but may be impractical in rough seas. Use of chemical dispersants in shallow water is not generally recommended due to potential ecological hazards. Chemical dispersal may be favored in deep, nearshore waters where there is a high risk of oil stranding on the shoreline.

Contingency Planning--

The spill continency plan outlines procedures to follow in the event of a spill. Duties and areas of responsibility are explicitly assigned so that all persons know their jobs in an emergency. Procedures described in the contingency plan include:

- Discovery and notification of appropriate authorities
- Safety measures
- Containment and countermeasures
- Cleanup and disposal
- Restoration.

Planning and response will depend primarily on location of the drill site. In situations outside of a 200-mi EEZ, probability of landfall of a spill is negligible and contingency planning is distinctly different than for drill sites within a country's jurisdiction. In international waters, planning and response is strictly within the ODP. Contingency planning as required by a specific country is defined before drilling within an EEZ. If a spill moves from one jurisdiction to another, the authority to initiate pollution control measures shall shift as appropriate. If a spill affects waters controlled by two different nations, both contingency plans will be activated and pollution control measures will be fully coordinated.

Contingency planning for drill sites within U.S. jurisdiction is presented as an example. The National Contingency Plan (40 CFR Part 1510; revised

TABLE 25. CLEANUP GUIDELINES FOR OPEN OR ROUGH SEA (>1 km FROM SHORE) BY EUROPEAN PETROLEUM ORGANIZATION

Oil Type	Fresh Crude Spreading			Weathered Crude			Water-in-oil Emulsions			Bunker Oils Spreading			Distillate Oils			Non-Spreading Oils		
Spill Size	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg
Booms																		
(1) Anchored																		
(2) Towed																		
(3) Free-floating		1	1								1	1			1		1	1
(4) Bubble barriers																		
Pick-up																		
(1) Skimming															2			
(2) Absorbing															2			
(3) Pumping		2	2								2	2			2			
(4) Surface nets																1	2	2
Burning																		
(1) Without incendiary aids																		
(2) With incendiary aids																		
Sinking			3			2			2			3			3			
Absorbing																		
Dispersing	1	3	4	1	1	1	1	1	1	1	3	4	1	1	4			

Note: The numbers give the order of priority for action. Blank space indicates technique not recommended.

Reference: Beynon 1973, European Petroleum Organization 1974.

TABLE 26. CLEANUP GUIDELINES FOR NEARSHORE WATERS (< 1 km FROM SHORE) BY EUROPEAN PETROLEUM ORGANIZATION

Oil Type	Fresh Crude Spreading			Weathered Crude			Water-in-oil Emulsions			Bunker Oils Spreading			Distillate Oils			Non-Spreading Oils		
Spill Size	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg	Sm	Med	Lrg
Booms																		
(1) Anchored																		
(2) Towed																		
(3) Free-floating		1	1								1	1		1	1		1	1
(4) Bubble barriers																		
Pick-up																		
(1) Skimming																		
(2) Absorbing																		
(3) Pumping		2	2								2	2		2	2			
(4) Surface nets																1	2	2
Burning																		
(1) Without incendiary aids																		
(2) With incendiary aids																		
Sinking																		
Absorbing																		
Dispersing	1	3	3	1	1	1	1	1	1	1	3	3						

Note: The numbers give the order of priority for action. Blank space indicates technique not recommended.

Reference; Beynon 1973, European Petroleum Organization 1974.

FR 12 Feb 85) applies to the navigable waters of the U. S., the adjoining shorelines, and the water of the continental shelf. Responsibility of the various Federal agencies involved are delineated in the plan, providing a framework for a coordinated Federal response. The National Strike Force (formed around U.S. Coast Guard Strike Teams, one each on the east, west, and Gulf coasts, and the Environmental Response Team of U.S. EPA) is responsible for assisting in cleanup operations during offshore pollution emergencies. The ODP is responsible to notify the National Strike Force of the location and timing of drill sites and to coordinate response procedures and responsibilities before beginning operations.

SECTION 4.8
MITIGATING MEASURES INCLUDED IN ODP

Throughout ODP planning and implementation, the program participants will enact measures to prevent mishaps and accidents. Measures will also be investigated to mitigate the environmental impacts of accidents should they happen. This section describes program components that contribute to preventing accidents and mitigating adverse impacts.

LAWS AND REGULATIONS

A number of laws and regulations apply to the ODP, particularly to ship conversion and operation. Adherence to these statutes is a primary factor in preventing and mitigating situations with potential for causing significant adverse environmental impacts. A description of the laws and regulations that apply to the ODP have been previously addressed in Section 2.2, and are summarized in Table 27.

INSPECTION PROGRAMS

The ODP drillship is subject to inspection provisions of the International Maritime Organization (IMO) and MARPOL 73/78 as delineated in Navigation and Vessel Inspection Circular No. 8-83 (U.S. Coast Guard 1983). The U.S. Coast Guard has the responsibility to ensure that foreign ships entering U.S. navigable waters comply with the applicable provisions of MARPOL 73/78. The ship must have on board documentary evidence that it is designed and equipped to comply with all applicable requirements of MARPOL 73/78, including an International Oil Prevention Certificate. The ship is expected to maintain and must be able to produce an Oil Record Book and the recordings from a cargo and/or bilge monitor.

U.S. Coast Guard officials conducting ship inspections will use as guidance the "Procedures for the Control of Ships and Discharges" of MARPOL 73/78. If the Coast Guard determines that the condition of the ship or its equipment presents an unreasonable threat to the marine environment, the Coast Guard will ensure that immediate corrective actions are taken before the ship is allowed to put to sea.

OPERATIONAL PLANNING AND PROCEDURES

Procedures are included in the ODP planning process to prevent and mitigate environmental impacts, as summarized in this section.

Pre-Drilling Surveys

Detailed seismic profiling surveys are conducted before the commencement of drilling operations. These surveys are used to select drill sites away from locations with potential to contain hydrocarbon accumulations or areas

TABLE 27. APPLICABLE LAWS AND REGULATIONS

Responsible Agency/ Organization	Applicable Law/ Regulation	Program Component Involved
American Bureau of Shipping	Rules for Building and Classing of Offshore Mobile Drilling Units; Rules for Building and Classing Steel Vessels	Ship construction
International Maritime Organization	Requirements for the Control of Pollution from Drilling Vessels	Pollution control of oily discharges and release of undetected discharges from the ship
Minerals Management Service	Revised Outer Continental Shelf Orders Governing Oil and Gas Lease Operations	Drilling activity
U.S. Coast Guard	Regulation for Certification, Inspection, Safety, and Design of Equipment; Protocol of 1978 Relating to MARPOL 73/78; Act to Prevent Pollution from Ships	Ship safety, pollution abatement of ship-generated contaminants
	Safety of Life at Sea Rules	Ship construction
U.S. Department of Commerce	Endangered Species Act; Marine Mammal Protection Act	Compliance with protection of endangered species and marine mammals
U.S. Department of State	Customary International Law (as reflected in the 1982 Convention on Law of the Sea)	Drilling within Exclusive Economic Zone or on the continental shelf of a coastal nation
	Antarctic Treaty; Antarctic Conservation Act	Drilling activity notification
	Convention on Conservation of Antarctic Marine Living Resource	Compliance with conservation standards
U.S. Environmental Protection Agency	Federal Water Pollution Control Act; Marine Protection, Research, and Sanctuaries Act	Pollution control of sewage, solid wastes, oil, and drilling muds

of abnormal pressures and geologic hazards. The surveys also provide the data and information necessary to plan environmentally safe well programs.

Site Reviews

From the recommendations of the JOIDES Planning Committee, a number of drill sites are proposed on the basis of existing geological and geophysical data, and are supported by the dedicated site surveys mentioned above. These data are reviewed by the JOIDES Pollution Prevention and Safety Panel (PPSP) through a clearly defined procedure in the Manual on Pollution-Prevention and Safety (JOIDES Pollution Prevention and Safety Panel 1976). The panel is composed of petroleum geologists, geophysicists, and organic geochemists drawn from industry, government, and academia who are recognized authorities in the fields of marine research and offshore oil exploration. Several members of the DSDP PPSP are members of the new panel. To eliminate any conflict of interest, panel members are not active participants in the drilling program and have no personal interest in seeing any particular site drilled.

The panel reviews the geological and geophysical data assembled by the scientists who proposed the drilling sites. If sufficent, high quality data are not available to reliably evaluate site safety and the potential presence of hydrocarbons, the site is automatically disapproved. The panel also thoroughly evaluates each proposed leg by reviewing plans for each site, methods to anticipate hydrocarbons or high fluid pressures during drilling, measures to cope with flows of fluids anticipated during drilling, and measures to abandon holes. Important factors considered in the site selection process include:

- Thickness and character of underlying rock strata
- Structural attitude and probability of trap features
- Known oil and gas occurrences
- Abnormal pressures
- High geothermal gradient
- Water depth
- Significance of clathrates to safety of drill sites
- Weather.

On the basis of panel findings, proposed sites are rejected if deemed unsafe (anything greater than minimal risk). Alternatively, operating conditions are imposed to ensure reasonable pollution prevention and safety. An example of restrictions in operations at a specific drill site are the conditional limits on drilling when clathrates could be encountered. Because the calculated thickness of the clathrate zone may be in error on complex, compressive margins, drilling must be stopped when clathrates are recovered at a site where there is no Bottom Simulating Reflector (BSR) on the seismic record by which to determine the hydrate base. When a BSR indicates the depth of the base, coring with the Pressure Core Barrel and a strict hydrocarbon monitoring program are required. Drilling is required to stop immediately if: 1) cores obtained with the Pressure Core Barrel confirm the presence of methane hydrate, or contain measured volumes of gas greater than 80 times the volume of sediment; 2) the Pressure Core Barrel fails to function, but regular coring shows greater than normal amounts of hydrocarbons or indicates the presence of methane hydrate; or 3) coring yields evidence of hydrated gas, and bottom hole temperatures and pressures approach values at which gas hydrates change to free gas. This type of conditional drilling restrictions tailors the general safety policies of the ODP to the individual hole. Through this site-by-site review by the PPSP, the ODP reduces to minimal risk the potential of encountering conditions that may result in impacts to the environment.

As an added factor in the review system, the ODP science operator utilizes a separate group of safety advisors to evaluate those sites approved by the PPSP for each cruise leg (TAMU Safety Review Committee). Three exploration geologists with extensive knowledge of worldwide petroleum occurrences and years of experience serve on a voluntary basis. They review each proposed site and report their conclusion and advice separately to the ODP science operator. This advice is considered in the final decision of whether or not to drill the sites approved by the PPSP. This redundancy places the most conservative interpretation of degree of risk involved at any site drilled. After this safety review, a final cruise plan is assembled and distributed. It describes each site, defines its objectives, and outlines the drilling plan.

Well Planning

As described earlier in the EIS, well planning is the process whereby the procedures and programs to be used for each hole are determined. This activity will take place after sites have been chosen for their scientific merit and have been evaluated for pollution prevention and operational safety. During the process of planning each well, the ODP science operator specifies details in the various programs that together constitute the drilling operations at a site. This includes determining casing sizes to be used and the depths to which they shall extend (casing program), drill bit type and size (bit program), types and amounts of cements used to seat the casing (cementing program), mud weights and characteristics (mud program), and circulation velocities (hydraulics program). Initial plans are made before drilling begins. Refinement of the plans by the shipboard drilling operations manager occurs on site as additional data are received and evaluated.

On-Site Monitoring

Extensive data gathering occurs on board ship during drilling operations. Many of these are surface measurements to ensure that systems are operating as designed. Sensors provide data on the drill string, including the primary stresses that it is bearing, the running speeds, rate of penetration, and total depth drilled. Additional information is received on the drilling mud (riser drilling), including flow rate densities entering and exiting the hole, and volume. Information is also gathered on the formations to determine presence of gas or hydrocarbons and the nature of the formations.

Downhole logging tools provide additional data on conditions at the bit and in situ formation characteristics.

The monitoring of hydrocarbons in retrieved cores is one of the most important on-site mitigating procedures. Off-structure drilling effectively eliminates the potential of encountering substantial accumulations. However, small pockets of gas or areas of "dead oil" (where past migrations of oil through a formation have left the longer chain hydrocarbons) may not be detectable on the seismic record. Monitoring the rate of change of the methane/ethane ratio (gas accumulations) and C_5-C_{40} hydrocarbons (oil) can give early indications that the hole may be approaching an accumulation. The ODP enforces strict monitoring of rates of change and total concentrations for both parameters. If safe limits are exceeded, drilling terminates and the hole is plugged and abandoned. Slight changes in methods and equipment from those detailed in the Shipboard Organic Geochemistry Guide/Handbook (Simoneit 1981) allow lower detection limits and better precision, resulting in greater ability to detect hydrocarbon gradients that could indicate an accumulation.

Surface and downhole measurements during drilling operations provide valuable data to ensure against mishaps or accidents. If abnormalities are encountered during the course of drilling, corrective or mitigative procedures are employed to assure safety of the ship, the crew, and the environment.

CONTINGENCY PLANNING

The objective of contingency planning is to restore normal operations quickly and efficiently in the event of emergency. Personnel are trained to understand and implement proper procedures for handling the various emergencies that might occur during drilling operations. Primary consideration is given to personnel safety, minimizing environmental impacts, and to protection of equipment. Contingency planning has been done in several areas: ice encounter, well control, blowout without riser in place, blowout with riser in place, petroleum spill, and hydrogen sulfide presence. The following discussion addresses all of the above, except for petroleum spill contingency planning, which was previously discussed in Section 4.7.

Ice Encounter

SEDCO has established zones around the drillship, based on the degree of danger associated with icebergs, to eliminate ice encounter while drilling. All icebergs are charted by radar within 25 nmi of the ship. On the basis of time of projected encounter and distance from ship, successive zones are established that will allow sufficient time to safely suspend operations, to move off site, or to abandon the hole if necessary.

Well Control

SEDCO has comprehensive well control policies with which all personnel must comply. The SEDCO Safety Policy Manual (SEDCO 1982) consists of their own specifc policies and procedures, well as those of the International Association of Drilling Contractors Accident Prevention Manual, which is the standard for the drilling industry. Well control planning utilizes all available data to anticipate problems and to prepare a drilling prognosis. The prognosis reflects the best available methods to overcome or eliminate these problems safely and efficiently. The primary well control measure is careful use of drilling mud and mud circulation rate to control pressures exerted against formations and high formation fluid pressures. Secondary control is provided through the use of blowout preventers.

Blowout without Riser in Place

The primary means of controlling a well without a riser is to use weighted muds. Early warning of a kick provides the best means of successfully controlling this condition. Warning signs include evidence of hydrocarbons in cores, increased drilling rate, increased pump speed and decreased pump pressure, decrease in drill string weight, data from hole logging, televiewer, or other measurements while drilling. Upon detection, a kick can be controlled with heavy mud, barite pills, and cement. This usually signals the end of drilling at that particular site.

Blowout with Riser in Place

Indicators of a kick under riser conditions include those mentioned above for riserless conditions and the following: increase in mud flow returns; increase in mud volume; flow with pump off; gas, oil, or water cut mud; change in mud chlorides; change in shale density; temperature increase at flow line; change in cuttings; paleontology correlation; rotary torque increases; and loss of returns.

A blowout with the riser in place can be more dangerous to shipboard personnel than one without a riser because the discharge can occur at or very near the rig floor. The contingency plan contains procedures for reacting to a wide range of emergency conditions. Loss of control of the well under riser conditions could develop from any one of a number of conditions, including failure of the BOPs, failure in the choke and kill system, broaching of the seafloor outside the wellhead, collapse of the riser, loss of the wellhead, or loss of power and controls at a critical time. If a blowout occurred, control would be attempted through procedures outlined in the contingency plans specific to that condition.

Presence of Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a toxic gas that is often present in offshore formations. If any H_2S is encountered, considering the limited amount of possible safety areas for rig personnel, the hole will be abandoned for safety. Upon encountering H_2S, drilling or coring operations are to be suspended immediately and efforts taken to preserve the safety of the crew. Cement is to be pumped downhole to shut off the H_2S influx, and the well abandoned in an accepted industry manner as soon as possible.

SECTION 4.9
RELATIONSHIP BETWEEN SHORT-TERM USE AND MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The short-term use of the environment consists of scientific study in the following subject areas: tectonics of the ocean basins, the generation and destruction of ocean crust, paleoclimatology, paleonotology, and paleoceanography. In addition, scientific investigations of thick sedimentary sequences are focused on the history of the margins themselves; the erosion of the adjacent continents; and the deposition, thermal history, and chemistry of the sediments. These activities provide unique study opportunities for a variety of sciences.

The proposed action may result in short-term impacts to the physical environment involving marine water quality and acoustics. Drilling muds and cuttings would adversely affect local water quality. Drillship movement and drilling operations would increase local noise levels temporarily.

Short-term effects on marine biological communities could result from normal operations. Minor losses would occur in biological productivity and marine habitats. Endangered species and biologically-sensitive areas would not be seriously affected as a result of the proposed action.

Short-term effects on other uses of the environment could occur. Limited preclusion of commercial fisheries, military activities, and transportation would be associated with the proposed action.

If an oil spill occurs, longer-term impacts could occur involving reductions in biological productivity, changes in marine habitats, reductions in biological populations, and modifications of the food web. The marine environment is expected to return to pre-spill levels of productivity.

The goals of the ODP do not present a conflict between the short-term and long-term uses of the environment. In fact, the program's goal is to advance our understanding of the earth by adding to two aspects of long-term productivity: scientific information and data that may lead to future resource development. Understanding the nature and evolution of the earth's crust and its state of stress in various tectonic settings could contribute to better predictions of major natural geologic hazards (e.g., earthquakes, volcanic eruptions). Insight into the natural variability of long-term climatic changes and into the ocean's role in those changes may be gained by seafloor exploration. Improved knowledge of the ocean floors can provide a sound scientific basis for the evaluation of potential hydrocarbon and other mineral resources beyond the continental shelf.

Storage of the retrieved cores in a repository for future study reduces future effects on the marine environment, thus enhancing long-term productivity. As scientific discoveries lead to new questions in marine geology, further analyses of the stored samples obtained during the DSDP and the ODP can answer these questions and reduce the need to obtain new samples, thereby further reducing impact to the environment.

Section 4.10
IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

HUMAN RESOURCES

It is impossible to avoid all human casualties, but they will be minimized through safety precautions, on board training, and maintenance of excellent crew facilities. Fatalities and/or permanent impairment as a consequence of accidents and personnel error represent, of course, an irreversible and irretrievable commitment of human resources. Moreover, the efforts of the skilled personnel involved will redirect the knowledge and labor of the personnel from other related research activities.

ECONOMIC RESOURCES

The total monetary cost of the ODP is an irreversible and irretrievable commitment of economic resources. In addition, the drillship and supporting equipment involved in the ODP are suitable for offshore oil and gas drilling but will be unavailable for that purpose.

ENERGY AND MINERAL RESOURCES

Fabrication of required metal products represents an irretrievable commitment of resources. The ship's conversion provided scrap metal and utilized additional materials. However, this commitment can be retrieved in the future. Fuel expended to operate the ship represents an irretrievable commitment of resources. Loss of the drill string or riser, various downhole instruments, and wireline in the deep ocean would result in an irreversible, irretrievable, and possibly catastrophic event (in the event of the loss of the ship).

BIOLOGICAL RESOURCES

An irreversible or irretrievable commitment of biological resources could occur in the event of a blowout of gas or oil. However, it might be anticipated that once an area of the ocean recovered from a blowout, the natural flora and fauna would reoccupy a vacated habitat. In that respect, the effect may be reversible. If, on the other hand, the event occurred in an area occupied by a population of an endemic endangered species and caused severe losses, extinction of the species would have been accelerated. This would probably not be easily reversed.

CHAPTER 5

CONSULTATION AND COORDINATION WITH OTHERS

Section 5.1
PREPARATION OF THE ODP PROPOSAL

Since 1957, the NSF has supported scientific deep-sea drilling through several projects. Project Mohole and post-Mohole studies, in part, received scientific advisory planning and guidance from JOIDES, a consortium comprised of major U.S. oceanographic institutions. The Deep Sea Drilling Project, launched in 1968, continued to utilize the consortium for planning and guidance. The International Phase of Ocean Drilling involved the expansion of JOIDES to include oceanographic institutions from the Federal Republic of Germany, France, the United Kingdom, Japan, and the U.S.S.R. In 1980-1981, the Ocean Margin Drilling Program was sponsored jointly by the NSF and a consortium of 10 major U.S. oil companies; when the oil companies withdrew support, the program was terminated.

Scientific plans for the Advanced Ocean Drilling Program (AODP) were formulated at the Conference on Scientific Ocean Drilling in November, 1981. This program would have involved the extensive conversion and modification of the government owned ship, GLOMAR EXPLORER. However, when preliminary designs were completed in November, 1982, it became apparent that costs would exceed budgetary limits. Simultaneously, the charter rates for commercial drillships dropped dramatically and plans were formulated to charter a commercial vessel. The NSF moved ahead on the revised project, with the shortened name of Ocean Drilling Program, and with the same scientific objectives, management plans, and budget as the AODP.

The United States, United Kingdom, Federal Republic of Germany, France, Japan, Canada, and the European Science Foundation (composed of a consortium of Belgium, Denmark, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and Switzerland) are cooperating to organize and undertake the project. Scientific planning for the ODP is provided primarily by the JOIDES international scientific committee structure. Primary management responsibility for the ODP resides with JOI.

Section 5.2
PREPARATION OF THE EIS

In its initial stage, the ODP continues scientific drilling operations similar to those carried out in the International Phase of Ocean Drilling of the DSDP. For such operations, the EIS prepared in 1975 for the IPOD still applies. However, in view of the expanded activities under the ODP, the NSF decided to prepare this programmatic EIS. It addresses all possible types of drilling which could be undertaken over the expected life of the ODP.

PARTICIPANTS IN THE PRE-EIS SCOPING

A notice of intent was published in Federal Register 49(50):9512-9513, March 13, 1984. The NSF carried out a scoping process in accordance with NSF Regulations on Compliance with the National Environmental Policy Act. The NSF contacted Federal agencies with relevant environmental jurisdiction or expertise to request input in identifying the range of actions, alternatives, and impacts to be considered in the EIS, in determining the scope of issues to be addressed, and in identifying the significant issues related to the proposed action. The agencies contacted included:

- U.S. Department of Commerce
  - National Marine Fisheries Service
  - National Oceanic and Atmospheric Administration
- U.S. Department of Defense
  - Navy
- U.S. Department of Energy
- U.S. Department of the Interior
  - Bureau of Land Management
  - Fish and Wildlife Service
  - Geological Survey
  - Minerals Management Service
  - National Park Service
- U.S. Department of State
- U.S. Department of Transportation
  - Coast Guard
- U.S. Environmental Protection Agency
- Marine Mammals Commission

Information and comments received during the development of the proposal were used in preparation of the EIS.

PARTICIPANTS IN EIS PREPARATION AND REVIEW

Tetra Tech, Inc. was contracted by the Division of Ocean Sciences, NSF to prepare this EIS under the guidance and review of the Foundation in accordance with contract OCE-84-18886, awarded August 29, 1984, after evaluations of responses to RFP SP84-102 (issued March 15, 1984). Preparation and review of the EIS was coordinated by the NSF Project Officer for Environmental Impact Assessment, Mr. Thomas N. Cooley, utilizing key personnel involved in the Program from the NSF, JOI, and TAMU. Principle reviewers during the EIS preparation include:

National Science Foundation

Dr. Garrett W. Brass	Program Director, Ocean Drilling Program
Dr. Curtis A. Collins	Program Director, Physical Oceanography Program
Mr. Thomas N. Cooley	Project Officer for Environmental Impact Assessment, Ocean Drilling Program
Dr. M. Grant Gross	Division Director, Division of Ocean Sciences
Ms. Adair F. Montgomery	Staff Associate and Chairman, Committee on Environmental Matters
Mr. Charles E. Myers	Program Coordinator, Division of Polar Programs
Dr. Polly A. Penhale	Associate Program Director, Biological Oceanography Program
Mr. Alexander L. Sutherland, Jr.	Associate Program Director, Ocean Drilling Program
Mrs. Sandra D. Toye	Section Head, Oceanographic Centers and Facilities Section
Dr. Mary A. Tyler	Associate Program Director, Biological Oceanography Program

Joint Oceanographic Institutions, Inc.

Dr. D. James Baker	President, Joint Oceanographic Institutions

Texas A & M Research Foundation

Dr. Lou Garrison	Deputy Program Director, Ocean Drilling Program

Notice of availability of the DEIS was published in the Federal Register 50(123):26420, June 26, 1985. Close of the comment period was announced for September 27, 1985. Agencies, organizations, and individuals who requested or received the DEIS during the comment period are presented in Appendix C. Comments received on the DEIS are reproduced in Appendix D. In response to these comments, the National Science Foundation, in consultation with Tetra Tech, Inc., has prepared this Final Environmental Impact Statement (FEIS), which includes the Foundation's response to comments (Appendix E) and appropriate revisions to the text.

Section 5.3
CONSULTATION INITIATED BY THE ODP

Pursuant to Section 7 of the Endangered Species Act, formal consultation must take place with the U.S. Fish and Wildlife Service (FWS) and with the National Marine Fisheries Service (NMFS). The consultation process was initiated in May, 1985, prior to release of the DEIS. The FWS, in a telephone conversation to the ODP Project Officer, notified the NSF that formal consultation is not required on this project because the program's operations are outside FWS jurisdiction. The NMFS, in an opinion received in August, 1985 (Figure 52), indicated that the data contained in the Biological Opinions provided previously to the Minerals Management Service regarding potential effects of leasing and exploration activities in the North Atlantic OCS Region can be applied to potential ODP operations in Georges Bank (NMFS 1982, 1983). The NMFS concluded it may be possible to reach a "no effect" conclusion if high-use, preferred areas for right, humpback, and fin whales are avoided, and if seismic exploration is both limited to air gun use and seasonally restricted in those high-use areas.

Since there are no present plans to drill on Georges Bank, the NMFS recommended that the NSF suspend continuation of formal consultation until specific dill sites are chosen on Georges Bank. If and when drill sites are chosen on the OCS, the NSF will perform an Environmental Assessment (EA) to determine potential impacts. The NSF will reinitiate consultation with the NMFS if the EA identifies a potential for interactions with endangered or threatened species.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Washington, D.C. 20235

F/NER54:DB

AUG 29 198?

Dr. Thomas M. Cooley
Project Officer, Environmental
Impact Assessment, ODP
Division of Ocean Sciences
Oceanographic Centers and
Facilities Sections
National Science Foundation
Washington, D.C. 20550

Dear Dr. Cooley:

This is in response to your letter of May 6, 1985, initiating consultation with the National Marine Fisheries Service (NMFS) pursuant to Section 7 of the Endangered Species Act of 1973, as amended (ESA). Your request pertains specifically to the phase of the National Science Foundation's (NSF) 10-year Ocean Drilling Project (ODP) that is to be carried out near Georges Bank. We have reviewed the Draft Environmental Impact Statement for the Ocean Drilling Program (DEIS) and other information available to the NMFS that pertains to this project.

The ODP is a long-range, world-wide effort. The proposed drilling sites will only be specified 1 year in advance, and will be selected based on scientific merit and environmental and operational safety. Georges Bank is discussed in the DEIS only as one of four representative sites that encompass the scientific goals, geographic positions, and geological and ecological conditions of the ODP. The drilling schedule for the first 3 years, and the long-range plans through 1991, do not involve Georges Bank. The fact that specific areas of geological interest in the Georges Bank area are not identified in the DEIS makes an assessment of effects to endangered specius very difficult.

The actual drilling operations that may take place in the Georges Bank area under the ODP have been well defined and are well known. The plans call for the use of a dynamically positioned deep-sea drillship using a riser drilling technique. This drilling technique is familiar to us as it has been used several times in exploratory drilling operations for commercial oil and gas resources along the continental shelf edge. In fact, most of the ODP operations are virtually identical to the OCS oil and gas exploration activities that have been subjected to extensive environmental assessment in the past few years. Therefore, we believe that the data contained in Biological Opinions that NMFS has provided to the Minerals Management Service regarding the potential effects of leasing and exploration activities in the North Atlantic Region (enclosures) can be applied to the ODP-proposed use of Georges Bank.

Specifically, should NSF select a drilling site within the high-use, preferred areas noted for right, humpback, and fin whales in the Great South Channel and along the western edge of Georges Bank, then a full, formal consultation pursuant to Section 7 of the ESA would be necessary. Conversely, the fact that the ODP proposes to use only one dynamically positioned drillship at a time reduces the potential effects to the endangered species in areas outside the high-use or preferred areas identified above and in the enclosed opinions. Therefore, it may be possible to come to a "no effect" determination regarding the ODP on Georges Bank.

We suggest that NSF include more information in the FEIS regarding the use (frequency and seasonal timing) of seismic exploration in the Georges Bank. The potential for ODP site selection within the sensitive high-use areas for endangered whales should also be investigated and discussed in more detail in the FEIS. If this information shows that the high-use areas for whales are of low or no potential value for the ODP, and if seismic exploration can be limited to air gun use and seasonally restricted in certain endangered species high-use areas, then it is possible that a "no effect" conclusion could be stated in the FEIS.

We recommend that you work closely with our Northeast Regional Office regarding development of this aspect of the FEIS, and that you suspend continuation of a formal consultation pending the outcome of the further discussions mentioned above. Please keep Patricia Carter of the Office of Protected Species and Habitat Conservation (FTS 634-7471) and Douglas Beach of our Northeast Regional Office (FTS 837-9288) informed of your progress on the ODP and development of the FEIS.

Sincerely,

James E. Douglas, Jr.
for William G. Gordon
Assistant Administrator
for Fisheries

Enclosures

NOTE: Under the Paperwork Reproduction Act, these public documents (the enclosures, NMFS 1982; 1983) are included only by reference and are not included herein.

Figure 52. National Marine Fisheries Services formal consultation response pursuant to Section 7 of the Endangered Species Act.

CHAPTER 6

BIBLIOGRAPHY

Chapter 6
REFERENCES

Aaron et al. 1980. Environmental conditions relating to potential geologic hazards, U.S. Northeastern Atlantic Continental Margin. USGS Map MF-1193. (As cited in Minerals Management Service 1983c).

Ackley, S.F., K.R. Buck, and S. Taguchi. 1979. Standing crop of algae in the Weddell Sea region. Deep-Sea Res. 26A:269-281.

Ahlstrom, E.H. 1971. Kinds and abundance of fish larvae in the eastern tropical Pacific, based on collections made on EASTROPAC I. Fish. Bull. 69:3-77.

Ahlstrom, E.H. 1972. Kinds and abundance of fish larvae in the eastern tropical Pacific on the second multivessel EASTROPAC survey, and observations on the annual cycle of larval abundance. Fish. Bull. 70:1153-1241.

Ainley, D.G. Unpublished manuscript. The ecological structure of oceanic seabird communities of the South Pacific Ocean. Point Reyes Bird Observatory, CA.

Alexander, V., and H.J. Niebauer. 1981. Oceanography of the eastern Bering Sea ice-edge zone in spring. Limnol. Oceanogr. 26:1111-1125.

Amato, R.V., and J.W. Bebout (eds). 1980. Geological and operational summary, COST No. G-1 well, Georges Bank area, North Atlantic OCS. Open-File Report No. 80-268. U.S. Geological Survey, Washington, DC. 111 pp.

Amato, R.V., and E.K. Simonis (eds). 1980. Geological and operational summary, COST No. G-2 well, Georges Bank area, North Atlantic OCS. Open-File Report No. 80-269. U.S. Geological Survey, Washington, DC. 116 pp.

American Ornithological Union. 1983. Checklist of North American birds. (Sixth edition). Allen Press, Lawrence, KS. 876 pp.

Andriyashev, A.P. 1965. A general review of the Antarctic fish fauna. pp. 491-550. In: Biography and Ecology in Antarctica. P. van Oye and J. van Miegham (eds). W. Junk, The Hague, Netherlands. (Not seen; as cited in Everson 1981b).

Aravamudan, K., P. Raj, J. Ostlund, E. Newman, and W. Tucker. 1982. Break-up of oil on rough seas - simplified models and step-by-step calculations. USCG Report No. CG-D-28-82. USCG/DOT Office of Research and Development. Washington, DC.

Armstrong, L.R. 1965. Burrowing limitations in Pelecypoda. Veliger 7:195-200.

Arnaud, P.M. 1977. Adaptations within the Antarctic marine benthic ecosystem. pp. 135-157. In: Adaptations Within Antarctic Ecosystems - Proceedings of the Third SCAR Symposium on Antarctic Biology. G.A. Llano (ed). National Science Foundation, Washington, DC.

Association Europeenne Oceanique. 1980. Petroleum and the marine environment: PETROMAR 80. Billing and Sons, London. 788 pp.

Aubouin, J., R. von Huene, et al. 1982. Subduction without accretion: Middle America Trench of Guatemala. Nature 297:458-460.

Aubouin, J., J. Bourgois, and J. Azema. 1984. A new type of active margin: the convergent-extensional margin, as exemplified by the Middle America Trench off Guatemala. Earth Planet. Sci. Lett. 67:211-218.

Audunson, T., et al. 1980. SLIKFORCAST - A simulation program for oil spill emergency tracking and long term contingency planning. In: Petroleum in the Marine Environment, PETROMAR 80. Association Europeene Oceanique. Billing and Sons, London, UK. 788 pp.

Ayers, R.C., Jr., and H.O. Jahns. 1974. Oil spills in the Arctic Ocean: extent of spreading and possibility of large-scale thermal effects. Science 186:843-846.

Ayers, R.C., Jr., T.C. Sauer, Jr., D.O. Stuebner, and R.P. Meek. 1980. An environmental study to assess the effects of drilling fluids on water quality parameters during high rate, high volume discharges to the ocean. pp. 351-381. In: 1980 Symposium - Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, FL.

Baker, J.M. 1971. Oil and salt marsh soil. pp. 62-71. In: The Ecological Effects of Oil Pollution on Littoral Communities. E.B. Cowell (ed). Institute of Petroluem, London. (not seen).

Balech, E., and S.Z. El-Sayed. 1965. Microplankton of the Weddell Sea. pp. 107-124. In: Biology of the Antarctic Seas II. G.A. Llano (ed). Volume 5, Antarctic Research Series. American Geophysical Union, Washington, DC.

Balech, E., S.Z. El-Sayed, G. Hasle, M. Neushul, and J.S. Zaneveld. 1968. Primary productivity and benthic marine algae of the antarctic and subantarctic. Folio 10, Antarctic Map Folio Series. American Geographical Society, New York, NY.

Ballard, R.D., and J. Francheteau. 1982. The relationship between active sulfide deposition and the axial processes of the Mid-Ocean Ridge. Mar. Technol. Soc. J. 16:8-23.

Barker, P.F., and R.A. Jahn. 1980. A marine geophysical reconnaissance of the Weddell Sea. Geophys. J. Rastr. Soc. 63:271-283.

Beck, R.H. and P. Lehner. 1974. Oceans, new frontier in exploration. Am. Assoc. Pet. Geol. Bull. 58:376-395.

Beers, J.R., and G.L. Stewart. 1971. Microzooplankters in the plankton communities of the upper waters of the eastern tropical Pacific. Deep-Sea Res. 18:861-883.

Belyaev, G.M., and P.V. Uschakov. 1957. Certain regularities in the quantitative distribution of the benthic fauna in antarctic waters (in Russian). Dokl. Akad. Nauk SSSR 112:137-140. (not seen; as cited in Arnaud 1977).

Beynon, L.R., and E.B. Cowell (eds). 1974. Ecological aspects of toxicity testing of oils and dispersants. John Wiley and Sons, New York, NY. 149 pp.

Bigelow, H.B. 1926. Plankton of the offshore waters of the Gulf of Maine. Bull. U.S. Bur. Fish. 40:1-508.

Bigelow, H.B. 1927. Physical oceanography of the Gulf of Maine. Bull. U.S. Bur. Fish. 40:511-1027.

Bigelow, H.B., and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. Fishery Bulletin of the Fish and Wildlife Service, Vol. 53. Fishery Bulletin No. 74. U.S. Government Printing Office, Washington, DC. 577 pp.

Bigham, G., T. Ginn, A.M. Soldate, and L. McCrone. 1982. Evaluation of ocean disposal of manganese nodule processing waste and environmental considerations. Tetra Tech contract TC-3514. Prepared for NOAA, Office of Ocean Minerals and Energy, Washington, D.C. 423 pp.

Bigham, G., L. Hornsby, and G. Wiens. 1984. Technical support document for regulating dilution and deposition of drilling muds on the outer continental shelf. Prepared for U.S. EPA Region X by Tetra Tech, Inc., Bellevue, WA.

BIOMASS. 1977. Biological investigations of marine antarctic systems and stocks. Vol. 1: Research proposals. S.Z. El-Sayed (conveyor). Scientific Committee on Antarctic Research. SCOR Working Group 54.

Blackburn, M. 1966. Biological oceanography of the eastern tropical Pacific: summary of existing information. U.S. Fish and Wildlife Service Special Scientific Report, Fisheries No. 540. 18 pp.

Blackburn, M. 1968. Micronekton in the eastern tropical Pacific Ocean: family composition, distribution, abundance, and relations to tuna. Fish. Bull. 67:71-115.

Blackburn, M. 1973. Regressions between biological oceanographic measurements in the eastern tropical Pacific and their significance to ecological efficiency. Limnol. Oceanogr. 18:552-563.

Blackburn, M., R.M. Laurs, R.W. Owen, and B. Zeitschel. 1970. Seasonal and areal changes in standing stocks of phytoplankton, zooplankton, and micronekton in the eastern tropical Pacific. Mar. Biol. 7:14-31.

Bothner, M.H., E.C. Spiker, P.P. Johnson, R.R. Rendigs, and R.J. Aruscavage. 1981. Geochemical evidence for modern sediment accumulation on the continental shelf off southern New England. J. Sediment. Petrol. 51:281-292.

Bowles, A.E., and B.S. Stewart. 1980. Disturbances to pinnipeds and birds of San Miguel Island. In: Potential Effects of Space Shuttle Sonic Booms on the Biota and Geology of the California Channel Islands. J.R. Jehl and C.F. Cooper (eds). Research Reports. TR80-1. Center for Marine Studies, San Diego State University. Prepared in cooperation with Hubbs/Sea World Research Institute for U.S. Air Force, Headquarters Space Division, Los Angeles, CA.

Brandsma, M.G., T.C. Sauer, Jr., and R.C. Ayers, Jr. 1983. Mud discharge model, report and user's guide, model version 1.0. Exxon Production Research Company.

Bregman, M.L., and L.A. Frakes. 1970. Magnetic anomalies in the Weddell Sea and vicinity, Antarctica. Earth Planet. Sci. 9:322-326.

Brennecke, W. 1921. Die Ozeanographischen Arbeiten der deutschen antarktischen Expedition 1911-1912. Aud dem Archiv der Deutsch. Seewarte, 39, 1 Hamburg. 214 pp.

Brown, N.A. 1982. Prepared evidence on underwater noise. Canada National Energy Board Hearing into the Arctic Pilot Project, Phase II. Exhibit No. 670. Ottawa, Ontario, Canada. 23 pp.

Brown, R.G.B. 1978. Birds at sea: western Atlantic. Ibis 120:116-117.

Brown, R.G.B. 1980. Seabirds as marine animals. pp. 1-39. In: Behavior of Marine Animals. Volume 4. J. Burger et al. (eds). Plenum Press, New York, NY.

Brown, W.S. 1984. A comparison of Georges Bank, the Gulf of Maine, and New England Shelf tidal dynamics. J. Phys. Oceanogr. 14:145-167.

Buck, B.M., and D.A. Chalfant. 1972. Deep water narrowband radiated noise measurement of merchant ships. Delco Electronics Report TR72-28. Prepared for the Office of Naval Research, Washington, DC. 30 pp.

Buck, B.M., and C.R. Greene. 1979. Source level measurements of an arctic sea ice pressure ridge. J. Acoust. Soc. Am. 66 (Suppl. 1):S25-S26.

Buerkle, U. 1975. Sound generated by the oil/gas drilling rig in the Bay of Fundy. Int. Counc. Explor. Sea Tech. Rep. No. 563, C.M. 1975/B:10.

Bumpus, D.F. 1973. A description of the circulation on the continental shelf of the east coast of the United States. Prog. Oceanogr. 6:111-157.

Bumpus, D.F. 1976. Review of the physical oceanography of Georges Bank. Int. Comm. Northwest Atl. Fish. Res. Bull. 12:119-134.

Bumpus, D.F., and L.M. Lauzier. 1965. Surface circulation on the continental shelf of eastern North America between Newfoundland and Florida. Folio 7. Serial Atlas of the Marine Environment. American Geographical Society. 4 pl., 8 pp.

Butman, B. 1983. Georges Bank. In: Physical Oceanography of Continental Shelves. J.S. Allen et al. (eds). Rev. Geophys. Space Phys. 21:1167-1172.

Butman, B., R.C. Beardsley, B. Magnell, D. Frye, J.A. Vermersch, R.Schlitz, R. Limeburner, W.R. Wright, and M.A. Noble. 1982. Recent observations of the mean circulation on Georges Bank. J. Phys. Oceanogr. 12:569-591.

Carls, M.G., and S.D. Rice. 1984. Toxic contributions of specific drilling mud components to larval shrimp and crabs. Mar. Environ. Res. (in press).

Carmack, E.C., and T.D. Foster. 1975. On the flow of water out of the Weddell Sea. Deep-Sea Res. 22:711-724.

Cavanaugh, C.M., S.L. Gardiner, M.L. Jones, H.W. Jannasch, and J.B. Waterbury. 1981. Prokaryotic cells in the hydrothermal vent tube worm Riftia pachyptila Jones: possible chemoautotrophic symbionts. Science (Wash., DC) 213:340-342.

CETAP. 1982. A characterization of marine mammals and turtles in the mid- and North-Atlantic areas of the U.S. outer continental shelf. Final Report - 3 year summary. MMS Contract No. AA551-CT8-48. Washington, DC.

Clark, R.C., and W.D. MacLeod, Jr. 1977. Inputs, transport mechanisms, and observed concentrations of petroleum in the marine enviornment. pp. 91-224. In: Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Volume 1. Nature and Fate of Petroleum. D.C. Malins (ed). Academic Press, Inc. New York. 321 pp.

Clark, S.H., and B.E. Brown. 1977. Changes in biomass of finfishes and squids from the Gulf of Maine to Cape Hatteras, 1963-1974, as determined from research vessel survey data. Fish. Bull. 75:1-21.

Cline, D.R., D.B. Siniff, and A.W. Erickson. 1969. Summer birds of the pack ice in the Weddell Sea, Antarctica. Auk 86:701-716.

Coffey, D.J. 1977. Dolphins, whales, and porpoises: an encyclopedia of sea mammals. Macmillan Publishing Company, New York, NY. 223 pp.

Collins, B.P., and J.S. Watkins. 1985. Analysis of a gas hydrate of S.W. Mexico using siesmic processing techiques and DSDP Leg 66 results. Geophysics 50:16-24.

Colton, J.B., Jr., W.G. Smith, A.W. Kendall, Jr., P.L. Berrien, and M.P. Fahay. 1979. Principal spawning areas and times of marine fishes, Cape Sable to Cape Hatteras. Fish. Bull. 76:911-915.

Committee on Post-IPOD Science. 1979. The merits and potential of a proposed ocean drilling program for the 1980s. The report of the Committee on Post-IPOD Science. Submitted to the National Science Foundation. 50 pp.

Conroy, J.W.H. 1975. Recent increases in penguin populations in Antarctica and the subantarctic. pp. 321-336. In: The Biology of Penguins. B. Stonehouse (ed). University Park Press, Baltimore, MD.

Continental Shelf Associates, Inc. 1984. Assessment of the long-term fate and effective methods of mitigation of California OCS platform particulate discharges. Volume I: Technical report, Draft Final Report. Contract No. 14-12-0001-30056. Prepared for U.S. Department of Interior, Minerals Management Service, Pacific OCS Office, Los Angeles, CA.

Cooper, R.A., and J.R. Uzmann. 1971. Migrations and growth of deep-sea lobsters, Homarus americanus. Science (Wash., DC) 171:288-290.

Corliss, J.B., J. Dymond, L.I. Gordon, J.M. Edmond, R.P. von Herzen, R.D. Ballard, K. Green, D. Williams, A. Bainbridge, K. Crane, and T.H. van Andel. 1979. Submarine thermal springs on the Galapagos Rift. Science (Wash., DC) 203:1073-1083.

Coulbourn, W.T., and R. Moberly. 1977. Structural evidence for the evolution of fore-arc basins off South America. Can. J. Earth Sci. 14:102-116.

Council on Environmental Quality (CEQ). 1974. OCS oil and gas - an environmental assessment. Council on Environmental Quality. Washington, DC.

Crippen, R.W., S.L. Hood, and G. Greene. 1980. Metal levels in sediment and benthos resulting from a drilling fluid discharge into the Beaufort Sea. pp. 636-669. In: 1980 Symposium - Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, FL.

Cummings, W.C., D.V. Holliday, B.J. Graham, and W.T. Ellison. 1981. Underwater sound measurements from the Prudhoe region, Alaska, September-October 1980. Rep. No. T-81-SD-013-U, Tracor Appl. Sci., San Diego, for the Alaska Eskimo Whal. Comm. 104 pp.

Davis, T.H. 1978. Pelagic birding trips to Cox's Ledge from Montauk Point, Long Island. Kingbird: Summer 131-149.

Deacon, G.E.R. 1937. The hydrology of the Southern Ocean. Discovery Rep. 15: 1-124.

Deacon, G.E.R. 1979. The Weddell gyre. Deep-Sea Res. 26:981-995.

Dearborn, J.H. 1967. Food and reproduction of Glyptonotus antarcticus (Crustacea: Isopoda) at McMurdo Sound, Antarctica. Trans. Roy. Soc. N.Z. Zool. 8:163-168. (not seen; as cited in Arnaud 1977).

Deep Sea Drilling Project (DSDP). 1984. Operational technical achievements. Technical Note No. 6. Prepared for the National Science Foundation. 20 pp.

Dell, R.K. 1972. Antarctic benthos. Adv. Mar. Biol. 10:1-216.

Dengo, G. 1983. Tectonic igneous sequence in Costa Rica. pp. 133-161. In: Buddington Volume, Geol. Soc. Amer.

den Hartog, C., and R.P.W.M. Jacobs. 1980. Effects of the AMOCO CADIZ oil spill on an eelgrass community at Roscoff (France) with special reference to the mobile benthic fauna. Helgol. wiss. Meeresunters 33:182-191. (not seen; as cited in Johnson and Pastorok 1982).

Department of Ecology (DOE). 1975. Puget Sound baseline program: biological oil impact literature review: oil pollution and significant biological resources of Puget Sound. Vols. I and II. Washington State Department of Ecology, Olympia, WA.

de Schauensee, R.M. 1970. A guide to the birds of South America. Livingston Publishing Company, Wynnewood, PA. 470 pp.

DeWitt, H.H. 1971. Coastal and deep-water benthic fishes of the antarctic. Folio 15, Antarctic Map Folio Series. American Geographical Society, New York, NY.

Diachok, O. 1980. Arctic hydroacoustics. Cold Regions Sci. and Technol. 2: 185-201.

Dietz, R.S. 1961. Continent and ocean basin evolution by spreading of the sea floor. Nature 190:854-857.

Dillon, W.P., J.A. Grow, and C.K. Paul. 1980. Unconventional gas seals may trap gas off southeast U.S. Oil Gas J. Jan. 7.

Duke, T.W., and P.R. Parrish. 1984. Results of the drilling fluids research program sponsored by the Gulf Breeze Environmental Research Laboratory, 1976-1984, and their application to hazard assessment. EPA-600/4-84-055. U.S. EPA, Gulf Breeze, FL. 94 pp. plus appendices.

Ecomar. 1978. pp. 42. In: Fate and Biological Effects of Oil Well Drilling Fluids in the Marine Environment: A Literature Review. J.M. Neff (ed). Report No. 15077. U.S. EPA, Gulf Breeze, FL. (not seen; as cited by Petrazzuolo 1981).

Edmond, J.M., and K. Von Damm. 1983. Hot springs on the ocean floor. Sci. Am. 248:78-83.

Edwards, R.L. 1982. Harvesting and management. pp. 99-116. In: Georges Bank - Past, Present, and Future of a Marine Environment. G.C. McLeod and J.H. Prescott (eds). Westview Press, Boulder, CO.

EG&G. 1979. Appendix F of Tenth Quarterly Progress Report. Preliminary Progress Report, Contract AA551-CT8-46. Submitted to the U.S. Department of the Interior, Bureau of Land Management.

EG&G. 1980a. Brief summary of the New England Outer Continental Shelf Physical Oceanography Program. Prepared for the Shell Oil Company.

EG&G. 1980b. Monitoring program for Exxon's block 564 Jacksononville OCS area (Lease OCS-63705). Report prepared for Exxon Company, U.S.A., Houston, TX.

EG&G. 1982. Interpretation of the physical oceanography of Georges Bank. Final Report, Volume 1. Contract No. AA851-CT1-39. Prepared for U.S. Bureau of Land Management.

El-Sayed, S.Z. 1966. Prospects of primary productivity studies in antarctic waters. pp. 227-239. In: Symposium on Antarctic Oceanography, Santiago, Chile, 13-16 September, 1966. W. Heffer and Sons, Cambridge, England.

El-Sayed, S.Z., and E.F. Mandelli. 1965. Primary production and standing crop of phytoplankton in the Weddell Sea and Drake Passage. pp. 87-106. In: Biology of the Antarctic Seas II. G.A. Llano (ed). Volume 5, Antarctic Research Series. American Geophysical Union, Washington, DC.

El-Sayed, S.Z., and S. Taguchi. 1981. Primary production and standing crop of phytoplankton along the ice edge in the Weddell Sea. Deep-Sea Res. 28A:1017-1032.

El-Sayed, S.Z., and J.T. Turner. 1977. pp. 463-503. In: Polar Oceans. M.J. Dunbar (ed). Arctic Institute of North America, Calgary, Alberta, Canada.

Emery, K.O., and E. Uchupi. 1972. Western North Atlantic Ocean: topography, rocks, structure, water, life, and sediments. Amer. Assoc. Petrol. Geol. Memoir 17. 532 pp.

Erickson, A.W., and R.J. Hofman. 1974. Antarctic seals. Antarctic Map Folio Series, Folio 18: 4-13. American Geographical Society, New York.

Erickson, A.W., D.B. Siniff, D.R. Cline, and R.J. Hofman. 1971. Distributional ecology of Antarctic seals. pp. 55-95. In: Symposium on Antarctic Ice and Water Masses, Tokyo, September 1970. G. Deacon, (ed). Scientific Committee on Antarctic Research, Cambridge, UK.

Erwin, R.M. 1979. Coastal waterbird colonies: Cape Elizabeth, Maine to Virginia. FWS/OBS-79/10. U.S. Fish and Wildlife Service, Newton Corner, MA. 212 pp.

Erwin, R.M., and C.E. Korschgen. 1979. Coastal waterbird colonies: Maine to Virginia, 1977. FWS/OBS-79-08. U.S. Fish and Wildlife Service, Newton Corner, MA. 647 pp.

European Petroleum Organizations. 1974. European model code of safe practice for dealing with oil spills at sea and on shore. Applied Science Publishers, Ltd. London, UK. 97 pp.

Evans, W.E. 1982. Distribution and differentiation of stocks of Delphinus delphis in the northeastern Pacific. pp. 45-65. In: Mammals in the Sea. Volume IV. FAO Fish. Ser. No. 5. Rome, Italy.

Everson, I. 1981a. Antarctic krill. pp. 31-45. In: Biological Investigations of Marine Antarctic Ecosystems and Stocks (Biomass), Vol. II. S.Z. El-Sayed (ed). SCAR and SCOR, Scott Polar Research Institute, Cambridge, England.

Everson, I. 1981b. Fish. pp. 79-97. Biological Investigations of Marine Antarctic Ecosystems and Stocks (Biomass), Vol. II. S.Z. El-Sayed (ed). SCAR and SCOR, Scott Polar Research Institute, Cambridge, England.

Felbeck, H. 1981. Chemoautotrophic potential of the hydrothermal vent tube worm Riftia pachyptila Jones (Vestimentifera). Science (Wash., DC) 213:336-338.

Forster, R.A. 1984. The autumn migration: northeastern maritime region. Amer. Birds 38:175.

Foster, T.D., and E.C. Carmack. 1976. Temperature and salinity structure in the Weddell Sea. J. Phys. Oceanogr. 6:36-44.

Foster, T.D., and J.H. Middleton. 1979. Variability in the bottom water of the Weddell Sea. Deep-Sea Res. 26:743-762.

Francheteau, J., and R.D. Ballard. 1983. The East Pacific Rise near 21° N, 13° N, and 20° S; inferences for along-strike variability of axial processes of the Mid-Ocean Ridge. Earth Planet. Sci. Let. 64:93-116.

Fryxell, G.A., S. Taguchi, and S.Z. El-Sayed. 1979. Vertical distribution of diverse phytoplankton communities in the central Pacific. pp. 203-229. In: Marine Geology and Oceanography of the Pacific Manganese Nodule Province. J.L. Bischoff and D.Z. Piper (eds). Plenum Press, New York, NY.

Fukuchi, M., and A. Tanimura. 1981. A preliminary note on the occurrence of copepods under sea ice near Syowa Station, Antarctica. Mem. Natl. Inst. Polar Res., Tokyo. Series E. 34:37-43.

Gales, R.S. 1982. Effects of noise of offshore oil and gas operations on marine mammals - an introductory assessment, Vol. I. Naval Ocean Systems Center Technical Report 844. Prepared for U.S. Bureau of Land Management, New York. 79 pp.

Gallardo, V.A., J.G. Castillo, M.A. Retamal, and A. Yañez. 1977. Quantitative studies on the soft-bottom macrobenthic animal communities of shallow antarctic bays. pp. 361-387. In: Adaptations Within Antarctic Ecosystems - Proceedings of the Third SCAR Symposium on Antarctic Biology. G.A. Llano (ed). National Science Foundation, Washington, DC.

Garrett, C., J.R. Keeley, and D.A. Greenberg. 1978. Tidal mining versus thermal stratification in the Bay of Fundy and Gulf of Maine. Atmos. Oc. 16:403-423.

Geraci, J.R., and D.J. St. Aubin. 1980. Offshore petroleum resource development and marine mammals: a review and research recommendations. Mar. Fish. Rev. Nov. 12 pp.

Godfrey, W.E. 1966. The birds of Canada. Nat. Mus. Canada Bull. 203. 428 pp.

Godshall, F.A., R.G. Williams, J.M. Bishop, F. Everdale, and S.W. Fehler. 1980. A climatological and oceanographic analysis of Georges Bank region of the outer continental shelf. Final Report. Interagency Agreement No. AA551-IA8-14. Prepared for U.S. Bureau of Land Management. 290 pp.

Golob, R.S., and D.W. McShea. 1981. Implications of the IXTOC I blowout and oil spill. pp. 743-759. In: Petroleum in the Marine Environment: PETROMAR 80. Association Europeenne Oceanique. Billing and Sons, London. 788 pp.

Gordon, A.L. 1971. Spreading of antarctic bottom waters, II. pp. 1-17. In: Studies in Physical Oceanography - A Tribute to Georg Wust on His 80th Birthday. A.L. Gordon (ed). Gordon and Breach.

Gordon, A.L., and R.D. Goldberg. 1970. Circumpolar characteristics of antarctic waters. Folio 13, Antarctic Map Folio Series V. Bushnell (ed). American Geographical Society, New York, NY.

Gordon, A.L., and E.J. Molinelli. 1982. Southern Ocean atlas: thermohaline and chemical distributions and the atlas data set. Columbia University Press, New York, NY.

Gordon, A.L., E. Molinelli, and T. Baker. 1978. Large scale relative dynamic topography of the Southern Ocean. J. Geophys. Res. 83:3023-3032.

Graves, R.S., F.A. Kaharoeddin, and C.L. Humphreys. 1982. Summary of sediment descriptions of the ARA ISLAS ORCADAS cruise 15 piston cores. Antarctic Journal 16:132-135.

Gray, J.S. 1974. Animal-sediment relationships. Oceanogr. Mar. Biol. Annu. Rev. 12:223-262.

Green, K.A. 1977. Role of krill in the antarctic marine ecosystem. Final Report to the U.S. Department of State, Division of Ocean Affairs. Appendix E. In: Final Environmental Impact Statement for a Possible Regime for Conservation of Antarctic Living Marine Resources. U.S. Department of State, June, 1978.

Greene, C.R. 1982. Characteristics of waterborne industrial noise. pp. 249-346. In: Behavior, Disturbance Responses, and Feeding of Bowhead Whales Balaena mysticetus in the Beaufort Sea, 1980-81. W.J. Richardson (ed). LGL Ecol. Res. Assoc. Inc. Prepared for U.S. Bureau of Land Management, Washington, DC. 465 pp.

Grossi, S.M., S.T. Kottmeier, and C.W. Sullivan. 1984. Sea ice microbial communities. III. Seasonal abundance of microalgae and associated bacteria. McMurdo Sound, Antarctica. Microb. Ecol. 10:231-242.

Grow, J.A., 1973. Implications of deep sea drilling. Sites 186 and 187 on island arc structure. pp. 799-803. In: Initial Reports DSDP 19. J.S. Creager, D.W. Scholl et al. (eds). U.S. Government Printing Office, Washington, DC.

Grow, J.A. (ed). 1981. Summary report of the sediments, structural framework, petroleum potential, and environmental conditions of the U.S. middle and northern continental margin in an area of proposed oil and gas lease sale No. 76. Open File Report No. 81. Geological Survey. 109 pp.

Gusey, W.F. 1977. Fish and wildlife resources of the Georges Bank region. Shell Oil Co., Houston, TX. 553 pp.

Hameedi, M.J. (ed). 1982. Proceedings of a synthesis meeting: the St. George Basin environment and possible consequences of planned offshore oil and gas development. April 28-30, 1981, Anchorage, AK. Outer Continental Shelf Environmental Assessment Program. Juneau, AK. 162 pp.

Hamilton, W. 1977. Subduction in the Indonesian region. pp. 15-31. In: Island Arcs, Deep Sea Trenches, and Back-Arc Basins. M. Talwani and W.C. Pitman, III (eds). Am. Geophys. Union, Maurice Ewing Ser. 1. Washington, DC.

Hammond, P.S., and J.C. Laake. 1983. Trends in abundance of dolphins in purse-seine fishery, eastern Pacific Ocean, 1977-1981. pp. 570-582. In: 32nd Report of the International Whaling Commission. Cambridge, England.

Harding, G.C., K.F. Drinkwater, and W.P. Vass. 1983. Factors influencing the size of American lobster (Homarus americanus) stocks along the Atlantic coasts of Nova Scotia, Gulf of St. Lawrence, and Gulf of Maine: a new synthesis. Can. J. Fish. Aquat. Sci. 40:168-184.

Harris, M. 1974. A field guide to the birds of Galapagos. Taplinger, New York, NY. 160 pp.

Harrison, P. 1983. Seabirds: an identification guide. Houghton-Mifflin Company, Boston, MA. 448 pp.

Harrison, W.E., and J.A. Curiale. 1981. Gas hydrate in sediments of holes 497 and 498A, DSDP Leg 67. In: Initial Report DSDP 67. U.S. Government Printing Office, Washington, DC.

Hayes, S.P., J.M. Toole, and L.J. Mangum. 1982. Water mass and transport variability at 110° W in the equatorial Pacific. J. Phys. Oceanogr. 13: 153-168.

Hayes, P.K., T.M. Whitaker, and G.E. Fogg. 1984. The distribution and nutrient status of phytoplankton in the Southern Ocean between 20° and 70° W. Polar Biol. 3:153-165.

Hecker, B., and A.Z. Paul. 1979. Abyssal community structure of benthic infauna of the eastern equatorial Pacific: DOMES sites A, B, and C. pp. 287-308. In: Marine Geology and Oceanography of the Pacific Manganese Nodule Province. J.L. Bischoff and D.Z. Piper (eds). Plenum Press, New York, NY.

Hess, H.H. 1962. History of ocean basins. pp. 599-620. In: Petrological Studies: A Volume in Honor of A.F. Buddington. A.E.J. Engel et al. (eds). Geology Society of America. Boulder, CO.

Holdgate, M.W., and J. Tinker. 1979. Oil and other minerals in the antarctic: The environmental implications of possible mineral exploration or exploitation in Antarctica. Report of a workshop sponsored by the Rockefeller Foundation, Bellagio, Italy, 5-8 March 1979. Scientific Committee on Antarctic Research, House of Print, London. 51 pp.

Holmes, R.W., M.B. Schaefer, and B.M. Shimada. 1957. Primary production, chlorophyll, and zooplankton volumes in the eastern tropical Pacific Ocean. Int. Am. Tropical Tuna Comm. Bull. 2:129-169.

Hopkins, T.L. 1971. Zooplankton standing crop in the Pacific sector of the antarctic. pp. 347-362. In: Biology of the Antarctic Seas IV. G.A. Llano and I.E. Wallen (eds). Volume 17, Antarctic Research Series. American Geophysical Union, Washington, DC.

Horner, R.A. 1976. Sea ice organisms. Oceanogr. Mar. Biol. Annu. Rev. 14:167-182.

Horner, R.A. 1977. History and recent advances in the study of ice biota. pp. 269-283. In: Polar Oceans. M.J. Dunbar (ed). Arctic Institute of North America, Calgary, Alberta, Canada.

Hussong, D.M., and S. Uyeda. 1981. Tectonic processes and the history of the Mariana Arc: a synthesis of the results of Deep Sea Drilling Project Leg 60. pp. 909-929. In: Initial Report. DSDP 60. U.S. Government Printing Office, Washington, D.C.

Hussong, D.M., and L.K. Wipperman. 1981. Vertical movement and tectonic erosion of the continental wall of the Peru-Chile Trench near 11° 30" S latitude. pp. 509-524. In: Nazca Plate: Crustal Plate Formation and Andean Convergence. L.D. Kulm, J. Dymond, J.E. Dach, D.M. Hussong, and R. Roderrick (eds). Geol. Soc. Amer. Mem. 154.

Hussong, D.M., P.B. Edwards, S.H. Johnson, J.F. Campbell, and G.H. Sutton. 1976. Crustal structure of the Peru-Chile Trench: 8-12° S latitude. pp. 71-86. In: The Geophysics of the Pacific Ocean Basin and its Margin: A Volume in Honor of George P. Wollard. G.H. Sutton, M.H. Manghnani, R. Moberly, and E.U. McAfee (eds). Am. Geophys. Union Geophysical Monograph 19.

Jacobs, R.P.W.M. 1980. Effects of the AMOCO CADIZ oil spill on the seagrass community at Roscoff with special reference to the benthic infauna. Mar. Ecol. Prog. Ser. 2:207-212. (not seen; as cited in Johnson and Pastorok 1982).

Jannasch, H.W. 1984. The nutritional basis for life at deep-sea vents. Oceanus 27:73-78.

Jehl, J.R., Jr. 1974. The near-shore avifauna of the middle American west coast. Auk 91:681-699.

Jennings, J.C., Jr., L.I. Gordon, and D.M. Nelson. 1984. Nutrient depletion indicates high primary productivity in the Weddell Sea. Nature (Lond.) 309:51-54.

Johannes, R.E., J. Maragos, and S.L. Coles. 1972. Oil damages corals exposed to air. Mar. Pollut. Bull. 3:29-30.

Johnson, H.P., J.L. Karsten, J.R. Delaney, E.E. Davis, R.G. Currie, and R.L. Chase. 1983. A detailed study of the Cobb Offset of the Juan de Fuca Ridge: evolution of a propagating rift. J. Geophys. Res. 88:2297-2315.

Johnson, T.L., and R.A. Pastorok. 1982. Oil spill cleanup: options for minimizing adverse ecological impacts. Draft Report prepared for the American Petroleum Institute, Washington, DC. Tetra Tech, Inc., Bellevue, WA. 591 pp.

Johnston, R.C., and B. Cain. 1981. Marine seismic energy sources: acoustic performance comparison. Unpublished diagrams. Presented at 1981 Annual Meeting Acous. Soc. Am. Miami, FL. 35 pp.

Joint Group of Experts on the Scientific Aspects of Marine Pollution. 1977. Reports and studies: impact of oil on the marine environment. Food and Agriculture Organization of the United Nations. Rome, Italy. 250 pp.

Joint Oceanographic Institutions (JOI). 1979. Geology, geophysics, and scientific ocean drilling - a plan. Washington, DC. 59 pp.

Joint Oceanographic Institutions (JOI). 1980. Ocean Margin Drilling Program: a program for scientific ocean drilling and research in the 1980s. Volume II. Scientific program. Prepared for the National Science Foundation. 100 pp.

Joint Oceanographic Institutions (JOI). 1982. The Ocean Crustal Dynamics Program plan for the 1980s. Washington, DC. 302 pp.

Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). 1977. The future of scientific ocean drilling. University of Washington, Seattle, WA. 92 pp.

Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). 1981. Report of the Conference on Scientific Ocean Drilling. Houston, TX. 110 pp.

Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES). 1982. A program for 8 years of scientific ocean drilling after 1983. JOIDES. 229 pp.

Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) Pollution Prevention and Safety Panel. 1976. Manual on pollution-prevention and safety in connection with the Deep Sea Drilling Project and the International Phase of Ocean Drilling. JOIDES Journal No. 4. 46 pp.

Jones, M.L. 1981a. Riftia pachyptila, new genus, new species, the vestimentiferan worm from the Galapagos Rift geothermal vents (Pogonophora). Proc. Biol. Soc. Wash. 93:1295-1313.

Jones, M.L. 1981b. Riftia pachyptila Jones: observations on the vestimentiferan worm from the Galapagos Rift. Science (Wash., DC). 213:333-336.

Jones, M.L. 1984. The giant tube worms. Oceanus 27:47-52.

Karig, D.E., and G.F. Sharman. 1975. Subduction and accretion in trenches. Geol. Soc. Amer. Bull. 86:377-389.

Karrick, N.L. 1977. Alterations in petroleum resulting from physico-chemical and microbiological factors. In: Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Vol. I: Nature and Fate of Petroleum. D.C. Malins (ed). Academic Press. Washington, DC.

King, W.B. (ed). 1974. Pelagic studies of seabrids in the central and eastern Pacific Ocean. Smithsonian Contr. Zool. No. 158. Washington, DC. 275 pp.

King, W.B. 1981. Endangered birds of the world: the ICBP red data book, Volume 2: Aves. Smithsonian Institution Press, Washington, DC.

Klitgord, K.D., and J.C. Behrendt. 1979. Basin structure of the U.S. Atlantic margin. pp. 85-112. In: Geological and Geophysical Investigations of Continental Margin. Amer. Assoc. Petrol. Geol. Memoir 29.

Knauss, J.A. 1963. The equatorial current system. In: The Sea. Interscience, New York, NY.

Knox, G.A. 1970. Antarctic marine ecosystems. pp. 69-96. In: Antarctic Ecology, Vol. 1. M.W. Holdgate (ed). Academic Press, New York, NY.

Knox, G.A., and J.K. Lowry. 1977. A comparison between the benthos of the Southern Ocean and the North Polar Ocean with special reference to Amphipoda and Polychaeta. pp. 423-462. In: Polar Oceans. M.J. Dunbar (ed). Arctic Institute of North America, Calgary, Alberta, Canada.

Koh, R.C.Y., and Y.C. Chang. 1973. Mathematical model for barged ocean disposal of wastes. EPA-660/2-73-029. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC. 178 pp.

Kramer, J.R., H.D. Grundy, and L.G. Hammer. 1980. Occurrence and solubility of trace metals in barite for ocean drilling operations. pp. 789-798. In: 1980 Symposium - Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, FL.

Krebbs, C., and K.A. Burns. 1977. Long term effects of an oil spill on populations of the salt marsh crab Uca pugnax. Science 197:484-487. (not seen, as cited in Johnson and Pastorok 1982).

LaBrecque, J.L., and P. Barker. 1981. The age of the Weddell Basin. Nature 290:489-492.

Ladd, J.W., and J.S. Watkins. 1979. Tectonic development of the trench arc complexes on the northern and southern margins of the Venezuela Basin. pp. 363-371. In: Geological and Geophysical Investigations of Continental Margins. J.S. Watkins, L. Montadert, and P.W. Dickerson (eds). Am. Assoc. Pet. Geol. Mem. 29.

Ladd, J.W., A.K.. Ibrahim, K.J. McMillen, G.V. Latham, R.E. von Huene, J.S. Watkins, J.C. Moore, and J.L. Worzel. 1978. Tectonics of the Middle America Trench. Int. Symp. Guatemalan Earthquake and Reconstruction Process, 4 February 1976, Vol. 1. Guatemala City.

Laws, R.M. 1977a. Seals and whales of the Southern Ocean. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 279:81-96.

Laws, R.M. 1977b. The significance of vertebrates in the antarctic marine ecosystem. pp. 411-438. Adaptations Within Antarctic Ecosystems. G.A. Llano (ed). Gulf Publishing Company. Houston, TX.

Laws, R.M. 1985. The ecology of the Southern Ocean. Am. Sci. 73:26-40.

Leetmaa, A. 1982. Observations of near-equatorial flows in the eastern Pacific. J. Mar. Res. 40, Suppl:357-370.

Lewis, R.S., R.E. Sylwester, J.M. Aaron, D.C. Twichel, and K.M. Scanlon. 1980. Shallow sedimentary framework and related potential geologic hazards of the Georges Bank area. pp. 5-25. In: Environmental Geological Studies in the Georges Bank Area. U.S. Northeast Atlantic OCS, 1975-1977. Open-File Report No. 80-240. U.S. Geological Survey.

Le Quellec, P., J. Mascle, H. Got, and J. Vittori. 1980. Seismic structure of southwestern Peloponnesus continental margin. Am. Assoc. Pet. Geol. Bull. 64:242-263.

LGL Ecological Research Associates. 1982. Behavior, disturbance responses, and feeding of bowhead whales Balaena mysticetus in the Beaufort Sea, 1980-81. Prepared for Bureau of Land Management, Washington, DC. 455 pp.

LGL Ecological Research Associates. 1983. Behavior, disturbance responses, and distribution of bowhead whales Balaena mysticetus in the eastern Beaufort Sea, 1982. Prepared for Minerals Management Service, Reston, VA. 357 pp.

Longsdale, P. 1976. Abyssal circulation of the southeastern Pacific and some geological implications. J. Geophys. Res. 81:1163-1176.

Longsdale, P. 1977a. Inflow of bottom water to the Panama Basin. Deep-Sea Res. 24:1065-1101.

Longsdale, P. 1977b. Structural geomorphology of a fast spreading rise crest: the East Pacific Rise near 3° 25' S. Mar. Geophys. Res. 3:251-293.

Longhurst, A.R. 1976. Interactions between zooplankton and phytoplankton profiles in the eastern tropical Pacific. Deep-Sea Res. 23:729-754.

Love, C.M. (ed). 1971. Eastropac atlas, Volume 2. NMFS Circular No. 330. U.S. Department of Commerce, Washington, DC. 90 pp.

Lowry, J.K. 1975. Soft bottom macrobenthic community of Arthur Harbor, Antarctica. pp. 1-19. In: Biology of the Antarctic Seas V. D.L. Pawson (ed). Volume 23, Antarctic Research Series. American Geophysical Union, Washington, DC.

Loya, Y., and B. Rinkevich. 1980. Effects of oil pollution on coral reef communities. Mar. Ecol. Prog. Ser. 3:167-180. (not seen).

Macdonald, K.C. 1982. Mid-ocean ridges: fine scale tectnic, volcanic and hydrothermal processes within the plate boundary zone. Ann. Rev. Earth Planet. Sci. 10:155-190.

Macdonald, K.C., and J.C. Sempere. 1984. East Pacific Rise from Siqueiros to Orozco fracture zones: along-strike continuity of axial neovolcanic zone and structure and evolution of overlapping spreading centers. J. Geophys. Res. 89:6049-6069.

Maciolek-Blake, N., J.F. Grassle, J.A. Blake, and J.M. Neff. 1984. Georges Bank benthic infauna monitoring program: final report for the second year of sampling. Battelle New England Marine Research Laboratory, Duxbury, MA, and Woods Hole Oceanographic Institution, Woods Hole, MA. 173 pp. plus appendices.

Mackay, D., S. Paterson, and K. Trudel. 1980. A mathematical model of oil spill behavior. Prepared by the Department of Chemical Engineering and Applied Chemistry, University of Toronto, for the Environmental Protection Service, Fisheries and Environment, Canada.

Mackintosh, N.A., and S.G. Brown. 1974. Whales and whaling. Antarctic Map Folio Series, Folio 18:2-4. American Geographical Society, New York, NY.

Mais, K.F., and T. Jow. 1960. Exploratory longline fishing for tunas in the eastern tropical Pacific, September, 1955 to March, 1956. Calif. Fish Game 45:117-150.

Malme, C.I., P.R. Miles, C.W. Clark, P. Tyack, and J.E. Bird. 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior, Phase II: January 1984 migration. Bolt, Beranek and Newman Inc. Report No. 5586. Prepared for Minerals Management Service, Anchorage, AK. 183 pp.

Manuwal, D.A., T.R. Wahl, and S.M. Speich. 1979. The seasonal distributions and abundance of marine bird populations in the Strait of Juan de Fuca and Northern Puget Sound in 1978. Technical Memorandum ERL MESA-44. National Oceanographic and Atmospheric Administration. Boulder, CO. 391 pp.

Marine Board, National Academy of Engineering (NAE), and National Academy of Sciences (NAS). 1978. Engineering for deep sea drilling for scientiic purposes: interim report. Prepared by the Committee on Engineering Considerations for Continuation of Deep Sea Drilling for Scientific Purposes. NAS, Washington, DC. 55 pp.

Marine Mammal Commission. 1984. Letter to Thomas N. Cooley dated July 3, 1984. Marine Mammal Commission, Washington, DC.

Massachusetts Institute of Technology. 1973. Georges Bank petroleum study. MIT Offshore Task Group. Report No. MIT SG73-5. Prepared for Sea Grant.

Massachusetts Institute of Technology. 1974. Potential biological effects of hypothetical oil discharges in the Atlantic coast and Gulf of Alaska. In: OCS Oil and Gas - An Environmental Assessment: A Report to the President by the Council on Environmental Quality. Volume 5. CEQ, Washington, DC.

Matthews, C.D. 1974. Oil Gas J. 72:65 (as cited in Minerals Management Service 1983c).

Maurer, D., W.A. Leathem, and C. Menzie. 1981. The impact of drilling fluid and well cuttings on polychaete feeding guilds from the U.S. northeastern continental shelf. Mar. Poll. Bull 12(10):342-347.

McCollock, C.D., J.M. Neff, and R.S. Carr. 1980. Bioavailability of heavy metals from used offshore drilling muds to the clam Rangia cuneata and the oyster Crassostrea gigas. pp. 964-983. In: 1980 Symposium - Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, FL.

Menzie, C.A., D. Maurer, and W.A. Leathem. 1980. An environmental monitoring study to assess the impact of drilling discharges in the mid-Atlantic IV: the effects of drilling discharges on the benthic community. pp. 499-540. In: 1980 Symposium - Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, FL.

Milliman, J.D., O.H.. Pilkey, and D.A. Ross. 1972. Sediments of the continental margin off eastern United States. Geol. Soc. America Bull. 83:1315-1334.

Milne, A.R., J.H. Ganton, and D.J. McMillin. 1967. Ambient noise under sea ice and further measurements of wind and temperature dependence. J. Acoust. Soc. Am. 41:525-528.

Minerals Management Service. 1983a. Draft environmental impact statement: proposed southern California lease offering. U.S. Department of Interior, Los Angeles, CA. 742 pp.

Minerals Management Service. 1983b. Federal offshore statistics. Leasing, exploration, production, revenue. U.S. Department of Interior. 103 pp.

Minerals Management Service. 1983c. Final environmental impact statement: proposed April 1984 North Atlantic outer continental shelf oil and gas lease offering. U.S. Department of the Interior, Atlantic OCS Region, Vienna, VA.

Montecchi, P.A. 1976. Some shallow tectonic consequences of subduction and their meanings to the hydrocarbon explorationist. pp. 189-202. In: Circum-Pacific Energy and Mineral Resources. M.T. Halbouty, J.C. Maher, and H.M. Lian (eds). Am. Assoc. Pet. Geol. Mem. 25.

Moody, J.A., and B. Butman. 1980. Moored current and bottom pressure observations of the semi-diurnal tide on Georges Bank and in the Mid-Atlantic Bight. Open-File Report No. 80. U.S. Geological Survey, Washington, DC.

Moore, J.C., J.S. Watkins, T.H. Shipley, K.J. McMillen, S.B. Bachman, and N. Lundberg. 1982. Geology and tecktonic evolution of a juvenile accretionary terrane along a truncated convergent margin: synthesis of results from Leg 66 of the DSDP, southern Mexico. Bull. Geol. Soc. Am. 93:847-861.

Morton, B.R., G.I. Taylor, and J.S. Turner. 1956. Turbulent gravitational convection from maintained and instantaneous sources. Proc. R. Soc. London, Ser. A 234:1-23.

Mosby, H. 1934. The waters of the Atlantic Antarctic Ocean. Scientific results of the Norwegian Antarctic expeditions 1927-1928, I.

Murphy, R.C. 1936. Oceanic birds of South America. MacMillan Company. New York, NY. 1245 pp.

Naito, Y., and T. Iwami. 1982. Fish fauna in the northeastern parts of Lutzow-Holm Bay with some notes on the stomach contents. pp. 64-72. In: Proceedings of the Fifth Symposium on Antarctic Biology. T. Hoshiai and Y. Naito (eds). Mem. Natl. Inst. Polar Res., Special Issue No. 23. Tokyo, Japan.

National Academy of Sciences (NAS). 1975. EFFECTS. pp. 73-103. In: Petroleum in the Marine Environment. Workshop on Inputs, Fates, and the Effects of Petroleum in the Marine Environment. May 21-25, 1975, Arlie, Virginia. National Research Council, NAS. Washington, DC.

National Geographic Society. 1983. Field guide to the birds of North America. National Geographic Society, Washington, DC. 464 pp.

National Marine Fisheries Service (NMFS). 1982. Biological opinion--Endangered Species Act Section 7 consultation. Prepared for the Proposed 1982 OCS Oil and Gas Lease Sale Offshore the North Atlantic States: OCS Sale No. 52. Bureau of Land Management, New York OCS Office, New York, NY.

National Marine Fisheries Service (NMFS). 1983. Biological opinion--Endangered Species Act Section 7 consultation. Appendix F. In: Final Environmental Impact Statement: Proposed April 1984 North Atlantic Outer Continental Shelf Oil and Gas Lease Offering. Minerals Management Service, Atlantic OCS Region, Vienna, VA.

National Research Council. 1983. Drilling fluids and cuttings in the marine environment. Marine Board, Panel on Fates and Effects of Drilling Fluids and Cuttings in the Marine Environment. National Academy Press, Washington, DC. 180 pp.

National Research Council. 1985. Oil in the sea: impacts, fates, and effects. Steering Committee for the Petroleum in the Marine Environment Update. National Academy Press, Washington, DC. 601 pp.

National Science Foundation (NSF). 1975. Final environmental impact statement, international phase of ocean drilling of the Deep Sea Drilling Project. Washington, DC. 111 pp.

National Science Foundation (NSF). 1979. U.S. Antarctic Program draft environmental impact statement. Division of Polar Programs, Washington, DC.

National Science Foundation (NSF). 1980. U.S. Antarctic Program final environmental impact statement. Division of Polar Programs. Washington, DC. 283 pp.

National Science Foundation (NSF). 1982. Antarctic Conservation Act of 1978. (Public Law 95-541). Washington, DC. 38 pp.

National Science Foundation (NSF). 1983. The Ad Hoc Advisory Group on Crustal Studies. Report to the National Science Foundation. NSF 33-39. 10 pp.

National Science Foundation (NSF). 1984. U.S. Antarctic Research Program: personnel manual. Washington, DC. 86 pp.

Neff, J.M. 1981. Fate and biological effects of oil well drilling fluids in the marine environment: a literature review. Report 15077. U.S. EPA, Gulf Breeze, FL. 151 pp.

Nemoto, T., T. Doi, and K. Nasu. 1981. Biological characteristics of krill caught in the Southern Ocean. pp. 47-63. In: Biological Investigations of Marine Antarctic Ecosystems and Stocks (Biomass), Vol. II. S.Z. El-Sayed (ed). SCAR and SCOR, Scott Polar Research Institute, Cambridge, England.

Nelson, D.M., and L.I. Gordon. 1982. Production and pelagic dissolution of biogenic silica in the Southern Ocean. Geochimica et Cosmochimica Acta 46:491-501.

Niebauer, H.J., V. Alexander, and R.T. Cooney. 1981. Primary production at the eastern Bering Sea ice edge: the physical and biological regimes. pp. 763-772. In: The Eastern Bering Sea Shelf: Oceanography and Resources. D.W. Hood and J.A. Calder (eds). University of Washington Press, Seattle, WA.

North, W.J. 1973. Position paper on effects of acute oil spills. pp. 745-765. In: Background Papers, Workshop on Inputs, Fates, and Effects of Petroleum in the Marine Environment, National Academy of Sciences, Washington, DC. (not seen).

Northern Technical Services. 1981. Beaufort Sea drilling effluent disposal study. Prepared for Reindeer Island Stratigraphic Test Well Participants under direction of SOHIO Alaska Petroleum Co., Anchorage, AK. 329 pp.

Northern Technical Services. 1982. Above-ice drilling effluent disposal tests - Sag Delta No. 7, Sag Delta No. 8, and Challenge Island No. 1 wells, Beaufort Sea, AK. Prepared for SOHIO Alaska Petroluem Co., Anchorage, AK. 185 pp.

Nyblade, C.F. 1972. The Strait of Juan de Fuca intertidal and subtidal benthos. Second Annual Report, Spring 1977 - Winter 1978. Rept. EPA-600/7-79-213. U.S. Environmental Protection Agency. DOC/EPA Interagency Energy/Environment Research and Development Program, Washington, DC 129 pp. (not seen).

Ocean Drilling Program (ODP). 1984. Ocean Drilling Program FY 84-85 program plan. Joint Oceanographic Institutes, Inc. Contract 64-84. College Station, TX. June. 84 pp.

Ocean Drilling Program (ODP). 1985. Shipboard scientific handbook. Texas A&M Research Foundation. College Station, TX. 131 pp.

Office of Ocean Minerals and Energy. 1981. Deep seabed mining. Final programmatic environmental impact statement (Vol. 1). U.S. Department of Commerce, Washington, DC.

Owen, R.W., and B. Zeitschel. 1970. Phytoplankton production: seasonal change in the oceanic eastern tropical Pacific. Mar. Biol. 7:32-36.

Palmer, R.S. (ed). 1962. Handbook of North American birds. Volume 1. Loons through flamingos. Yale University Press, New Haven, CT. 567 pp.

Petrazzuolo, G. 1981. Preliminary report: an environmental assessment of drilling fluids and cuttings released onto the outer continental shelf. Prepared by U.S. EPA, Office of Water and Waste Management, and the Office of Water Enforcement and Permits, Washington, DC. 104 pp.

Petrazzuolo, G. 1983. Draft final technical support document: drilling fluids and cuttings released onto the OCS. Submitted to U.S. EPA Office of Water Enforcement and Permits, Washington, DC. 184 pp.

Percy, J.A., and P.G. Wells. 1984. Effects of petroleum in polar marine environments. Mar. Tech. Soc. J. 18:51-61.

Phillips, R.C. 1978. Seagrasses and the coastal marine environment. Oceanus 21:30-40. (not seen).

Pommerville, Y. 1984. Proposal for indemnification. Submitted by Ocean Drilling Program, Texas A & M Research Foundation.

Powers, K.D., and J.M. Laughlin. 1980. Pelagic birds of Georges Bank and adjacent waters: a pilot study. Manomet Bird Observatory, MA. 176 pp.

Powers, K.D., G.P. Pittman, and S.S. Fitch. 1980. Distribution of marine birds in the mid- and north-Atlantic U.S. outer continental shelf. Tech. Prog. Rep. January, 1978-July, 1980. Manomet Bird Observatory, MA. 165 pp.

Price, J.H., and P. Redfearn. 1966. The marine ecology of Signy Island, South Orkney Islands. pp. 163-164. In: Symposium on Antarctic Oceanography, Santiago, Chile, 13-16 September 1966. W. Heffer and Sons, Cambridge, England.

Rakusa-Suszczewski, S. 1983. The relationship between the distribution of plankton biomass and plankton communities in the Drake Passage and the Bransfield Strait (Biomass-FIBEX February - March, 1981). Mem. Natl. Inst. Polar Res., Tokyo. Series E. Special Issue No. 27:77-83.

Rao, R.S., and L.G. Hepler. 1977. Equilibrium constants and thermodynamics of ionization of aqueous hydrogen sulfide. Hydro. Metalurgy 2:293-299.

Rau, G.H. 1981. Hydrothermal vent clam and tube worm $^{13}C/^{12}C$: further evidence of nonphotosynthetic food sources. Science (Wash., DC) 213:338-340.

Reid, J.L., and R.J. Lynn. 1971. Influence of Norwegian-Greenland and the Weddell Sea upon the bottom waters of the Indian and Pacific oceans. Deep-Sea Res. 18:1063-1088.

Rhoads, D.C. 1974. Organism-sediment relations on the muddy sea floor. Oceanogr. Mar. Biol. Annu. Rev. 12:262-300.

Riley, G.A. 1982. Biological processes on Georges Bank. pp 61-76. In: Georges Bank--Past, Present and Future of a Marine Environment. G.C. McLeod and J.H. Prescott (eds). Westview Press, Boulder, CO.

Roper, C.F.E. 1981. Cephalopods of the Southern Ocean region: potential resources and bibliography. pp. 99-105. In: Biological Investigations of Marine Antarctic Ecosystems and Stocks (Biomass), Vol. II. S.Z. El-Sayed (ed). SCAR and SCOR, Scott Polar Research Institute, Cambridge, England.

Ross, D. 1981. Mechanics of underwater noise generation by ships. pp. 98-114. In: The Question of Sound from Icebreaker Operations: Proceedings of a Workshop. N.M. Peterson (ed). Arctic Pilot Project, Petro-Canada, Calgary, Alberta. 350 pp.

Rowe, G.T. 1983. Biomass and production of the deep-sea macrobenthos. pp. 97-121. In: Deep-Sea Biology. The Sea Vol. 8. G.T. Rowe (ed). John Wiley and Sons, New York, NY.

Rowlett, R.A. 1980. Observations of marine birds and mammals in the northern Chesapeake Bight. FWS/OBS-80/04. U.S. Fish and Wildlife Service, Washington DC. 87 pp.

Russell, W., and D. Finch. Unpublished manuscript. Pelagic birds from M.V. Bluenose, Northwest Harbor, ME. 11 pp.

Schandelmeier, L., and V. Alexander. 1981. An analysis of the influence of ice on spring phytoplankton population structure in the southeast Bering Sea. Limnol. Oceanogr. 26:935-943.

Schlee, J.S. 1973. The Atlantic Continental Shelf and Slope of the United States--sediment texture of the northeastern part. U.S. Geol. Survey Prof. Paper 529-L. 64 pp.

Schlee, J.S. 1981. Summary report of the sediments, structural framework, petroleum potential, and environmental conditions of the United States middle and northern continental margin in area of proposed oil and gas lease sale No. 82. Open-file Report No. 81-1353. U.S. Geological Survey, Washington, DC. 121 pp.

Schlee, J.S., and K.D. Klitgord. 1981. Geological setting of the Georges Bank area. In: Geological Studies of the COST G-1 and G-2 Wells, United States North Atlantic Outer Continental Shelf Area. Scholle, P.A., (ed). U.S. Geol. Survey Circular in press.

Schlee, J.S. and R.M. Pratt. 1970. Atlantic Continental Shelf and Slope of the United States--gravels of the northern part. U.S. Geol. Survey Prof. Paper 529-H. 39 p.

Schlee, J., R.E. Mattick, D.J. Taylor, O.W. Grard, T. Grow, E.C. Rhodehamel, W.J. Perry, Jr., K.C. Bayer, M. Furbush, C.P. Clifford, and J.A. Lees. 1975. Sediments, structural framework, petroleum potential, environmental conditions, and operational considerations of the United States North Atlantic Outer Continental Shelf. Open File Report No. 75-353. U.S. Geological Survey, Washington, DC. 179 pp.

Schneppenheim, R., and C.M. MacDonald. 1984. Genetic variation and population structure of krill (Euphausia superba) in the Atlantic sector of antarctic waters and off the Antarctic Peninsula. Polar Biol. 3:19-28.

Scholl, D.W., and M.S. Marlow. 1974. Global tectonics and sediments of modern and ancient trenches: some different interpretations. pp. 255-272. In: Plate Tectonics Assessments and Reassessments. C.F. Kahle (ed). Am. Assoc. Pet. Geol. Mem. 23. Tulsa, OK.

Scholl, D.W., M.S. Marlow, and A.K. Cooper. 1977. Sediment subduction and offscraping of Pacific margins. pp. 199-210. In: Island-Arcs, Deep Sea Trenches, and Back-Arc Basins. M. Talwani and W.C. Pitman, III (eds). Am. Geophys. Union, Maurice Ewing Ser. 1.

Schreiber, E.A., and R.W. Schreiber. 1980. Effects of impulse noise on seabirds of the Channel Islands, California. In: Potential Effects of Space Shuttle Sonic Booms on the Biota and Geology of the California Channel Islands: Research Reports. TR80-1. J.R. Jehl, and C.F. Cooper (eds). Center for Marine Studies, San Diego State University. Prepared in cooperation with Hubbs/Sea World Research Institute for U.S. Air Force, Headquarters Space Division, Los Angeles, CA.

Scientific Committee on Antarctic Research (SCAR). 1977. Biological investigations of marine antarcric systems and stocks. Scientific Committee on Antarctic Research. Cambridge, England.

Scientific Committee on Antarctic Research (SCAR). 1981. Antarctic environmental implications of possible mineral exploration and exploitation (AEIMEE) Report No. 1. Lincoln, NE. 13 pp.

Scientific Committee on Atarctic Research (SCAR). 1982. Antarctic environmental implications of possible mineral exploration and exploitation (AEIMEE) Report No. 2. Richardson, TX. 34 pp.

SCOR Working Group 54. 1977. Fishes. pp. 31-36. In: Biological Investigations of Marine Antarctic Systems and stocks (Biomass), Vol. I. S.Z. El-Sayed (ed). SCAR and SCOR, Scott Polar Research Institute, Cambridge, England.

SEDCO 1982. SEDCO safety policy manual. Dallas, TX. 165 pp.

Seely, D.R., P.R. Vail, and G.G. Watson. 1974. Trench-slope model. pp. 249-260. In: The Geology of Continental Margins. C.A. Burk, and C.L. Drake, (eds). Springer-Verlag, New York, NY.

Sherman, K., L. Sullivan, and R. Byron. 1978. Pulses in abundance of zooplankton prey of fish on the continental shelf off New England. Int. Counc. Explor. Sea Comm. CM 1978/L:25. Biological Oceanography. 11 pp.

Shingu, C., P.K. Tomlinson, and C.L. Peterson. 1974. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1967-1970. Int.-Am. Tropical Tuna Comm. Bull. 16:67-230.

Shipley, T.H., and G.F. Moore. In press. Sediment accretion and subduction in the Middle America Trench, OJI International Seminar in the Formation of Ocean Margins.

Shipley, T.H., M.K. Houston, R.T. Buffer, F.J. Shaub, K.J. McMillen, J.W. Ladd, and J.L. Worzel. 1979. Seismic evidence for widespread possible gas hydrate horizons on continental slopes and rises. Am. Assoc. Petrol. Geol. Bull. 63:2204-2213.

Shipley, T.H., K.J. McMillen, J.S. Watkins, J.C. Moore, J.H. Sandoval-Ochoa, and J.L. Worzel. 1980. Continental margin and lower slope structures of the Middle America Trench near Acapulco (Mexico). Mar. Geol. 35:65-82.

Silver, E.A., 1971. Transitional tectonics and the late Cenozoic structure of the continental margin off northernmost California. Geol. Soc. Amer. Bull. 82:1-22.

Simoneit, B.R.T., (ed). 1981. Shipboard organic geochemistry guide handbook. JOIDES Advisory Panel on Organic Geochemistry. 91 pp.

Smith, W.O., and D.M. Nelson. 1985. Phytoplankton Bloom produced by a receding ice edge in the Ross Sea: spatial coherence with the density field. Science (N.Y.) 227:163-166.

Somero, G.N. 1984. Physiology and biochemistry of hydrothermal vent animals. Oceanus 27:67-72.

Spiess, F.N., K.C. MacDonald, T. Atwater, R. Ballard, A. Carranza, D. Cordoba, C. Cox, V.M. Diaz Garcia, J. Francheteau, J. Guerrero, J. Hawkins, R. Haymon, R. Hessler, T. Juteau, M. Kastner, R. Larson, B. Luydendyk, J.d. MacDougall, S. Miller, W. Normark, J. Orcutt, and C. Rangin. 1980. East Pacific Rise: hot srings and geophysical experiments. Science (Wash., DC.). 207:1421-1433.

Stanley, D.J., 1969. Atlantic Continental Shelf and Slope of the United States - color of marine sediments. U.S. Geol. Survey Prof. Paper 529-D. 15 pp.

Stebbins, R.E. 1970. Recovery of salt marsh in Brittany sixteen months after heavy pollution by oil. Environ. Pollut. 1:163-167. (not seen).

Stewart, B.S., F.T., Aubrey, and W.E. Evans. 1983. Beluga whale (Delphinapterus leucas) responses to industrial noise in Nushagak Bay, Alaska, 1983. Hubbs-Sea World Res. Inst. Tech. Rep. 83-161. Prepared for National Oceanic and Atmospheric Administration, Juneau, AK. 22 pp.

Stewart, H.B. and G.F. Jordan. 1964. Underwater sand ridges on Georges Shoal. pp. 102-114. In: Papers in Marine Geology, Shepard Commemorative Volume. R.L. Miller (ed). MacMillan Company, New York, NY.

Stommel, H. 1982. Is the South Pacific helium-3 plume dynamically active? Earth Planet Sci. Let. 61:63-67.

Straughan, D. 1978. Biological studies of the METULA oil spill. pp. 364-377. In: Conference on Assessment of Ecological Impacts of Oil Spills, June 14-17, 1978, Keystone, CO. American Institute of Biological Sciences, Washington DC. (not seen; as cited in Johnson and Pastorok 1982).

Sullivan, C.W., and A.C. Palmisano. 1984. Sea ice microbial communities: distribution, abundance, and diversity of ice bacteria in McMurdo Sound, Antarctica, in 1980. Appl. Environ. Microbiol. 47: 788-795.

Sutherland, A.L., and A.R. McLerran. 1984. Scientific drilling in the Ocean Drilling Program. pp. 785-790. In: Proceedings of the Oceans 84, MTS/IEEE Conference Record. 10-12 Sept. Washington, DC.

Takahashi, M. 1983. Trophic ecology of demersal fish community north of South Shetland Islands, with notes on the ecological role of krill. pp. 183-192. In: Proceedings of the Biomass Colloquium in 1982. T. Nemoto and T. Matsuda (eds). Mem. Nat. Inst. Polar Res. Special Issue No. 27. Tokyo, Japan.

Targett, T.E. 1981. Trophic ecology and structure of coastal antarctic fish communities. Mar. Ecol. Prog. Ser. 4:243-263.

Taylor, A.E., R.J. Wetmiller, and A.S. Judge. 1979. Two risks to drilling and production off the east coast of Canada - earthquakes and gas hydrates. pp. 91-105. In: Symposium on Research in the Labrador Coastal and Offshore Region. W. Denner (ed). Memorial University of Newfoundland.

Teal, J.M., and R.W. Howarth. 1984. Oil spill studies: A review of ecological effects. Envionmental Management 8:27-44.

Tingley, S. 1983. The nesting season: northeastern maritime region. Am. Birds. 37:967.

Trumbull, J.V.A., 1972. Atlantic Continental Shelf and Slope of the United States--sand-size fraction of bottom sediments, New Jersey to Nova Scotia. U.S. Geol. Survey Prof. Paper 529-K. 45 p.

Tsuchiya, M. 1974. Variation of the surface geostrophic flow in the eastern tropical Pacific Ocean. Fish. Bull. 72:1075-1086.

Tsuchiya, M. 1975. Subsurface countercurrents in the eastern equatorial Pacific Ocean. J. Mar. Res. 33, Suppl:145-175.

Tucholke, B.E., G.M. Bryan, and J.I. Ewing. 1977 Gas-hydrate horizons detected in seismic-profiler data from the western north atlantic. Am. Assoc. Petrol Geol. Bull. 61:698-704.

Tuck, G.S. 1975. Observations at sea of seabirds in the subantarctic and antarctic zones south of 50°S-late November, 1973 to late March, 1974. See Swallow 24:7-21.

Tuck, G.S. 1980. A guide to seabirds on the ocean routes. Collins, London. 14 pp.

Tucker, J., L. Nunenmacher, and W. Williamson. 1984. Shallow gas events. OCS Report MMS 84-0029, Minerals Management Service, Metaire, LA. 32 pp.

Turl, C.W. 1982. Possible effects of noise from offshore oil and gas drilling activities on marine mammals: a survey of the literature. Naval Ocean Systems Center Tech. Rep. No. 776. San Diego, CA. 24 pp.

Turner, R.D., and R.A. Lutz. 1984. Growth and distribution of molluscs at deep-sea vents and seeps. Oceanus 27:55-62.

Uchupi, E. 1968. The Atlantic Continental Shelf and Slope of the United States- physiography. U.S. Geol. Survey Prof. Paper 529-C. 30 pp.

U.N. Food and Agriculture Organization. 1978. Report of the FAO Advisory Committee on marine resources research, Working Group on Marine Mammals. In: Mammals in the Sea. Volume 1. FAO Fisheries Series No. 5. Rome, Italy.

U.N. Food and Agriculture Organization. 1983. Yearbook of fishery statistics, 1982. Rome, Italy.

University of Rhode Island and Applied Science Associates, Inc. 1982. Assessing the impact of oil spills on a commercial fishery. MMS Contract No. AA 851-CTO-75.

Urick, R.J. 1983. Principles of underwater sound. 3rd Edition, McGraw-Hill Book Co. 423 pp.

U.S. Bureau of Land Management. 1979. Final supplemental environmental statement. OCS Sale No. 42, Offshore of the North-Atlantic States. U.S. Department of the Interior, Washington, DC.

U.S. Coast Guard. 1983. Navigation and vessel inspection Circular No. 8-83. Washington, DC. 40 pp.

U.S. Department of State. 1978. Final environmental impact statement for a possible regime for conservation of antarctic living marine resources. Washington, DC.

U.S. Fish and Wildlife Service. 1982. Republication of lists of endangered and threatened species. U.S. FWS, Washington, DC.

Vanderhorst, J.R., J.W. Blaylock, P. Wilkinson, M. Wilkinson, and G. Fellingham. 1980. Recovery of Strait of Juan de Fuca intertidal habitat following experimental contamination with oil (Second annual report, fall 1979-winter 1980). EPA-600/7-80-140. U.S. EPA, DOC/EPA Interagency Energy/Environment R & D Program, Washington DC. 73 pp. (not seen; as cited in Johnson and Pastorok 1982).

Vanderhorst, J.R., J.W. Blaylock, P. Wilkinson, M. Wilkinson and G. Fellingham. 1981. Effects of experimental oiling and recovery of Strait of Juan de Fuca intertidal habitats. EPA-600/7-181-088. U.S. EPA, DOC/EPA Interagency Energy/Environment R & D Program, Washington DC. 129 pp. (not seen; as cited in Johnson and Pastorok 1982).

Verrall, R. 1981. Acoustic transmission losses and ambient noise in Parry Channel pp. 220-233. In: The Question of Sound from Icebreaker Operations: the Proceedings of a Workshop. N.M. Peterson (ed). Arctic pilot project Petro-Canada, Calgary, Alberta. 350 pp.

Vickery, P.D. 1981. The autumn migration: northeastern maritime region. Am. Birds 35:157.

Wadhaus, P. 1981. Oil and ice in the Beaufort Sea- the physical effects of a hypothetical blowout. pp. 299-318. In: Petroleum in the Marine Environment: Petromar 80. Association Europeene Oceanique. Billing and Sons, London, UK. 788 pp.

Washington Department of Ecology (WDOE). 1975. Puget Sound Baseline Program: biological oil impact literature review: oil pollution and significant biological resources of Puget Sound. Volumes I and II. Washington State Department of Ecology, Olympia, WA (not seen).

Watkins, J.S., J.C. Moore et al. 1981. Initial Report, DSDP 66. U.S. Government Printing Office, Washington DC.

Watson, G.E. 1975. Birds of the antarctic and subantarctic. American Geophysical Society, Washington, DC. 350 pp.

Wearn, R.B., and D.J. Baker. 1980. Bottom pressure measurements across the antarctic circumpolar current and their relation to the wind. Deep-Sea Res. 27:857-888.

Weiss, R.F., and J.L. Bullister. 1984. Chlorofluoromethane in the Southern Ocean: the ventilation of the Weddell gyre. ECS 65:915.

Weller, G. 1969. Ameridional surface wind speed profile in Mac Robertson Land, Antarctica. Pure Appl. Geophys. 77:193-200.

Wenz, G.M. 1962. Acoustic ambient noise in the ocean: spectra and sources. J. Acoust. Soc. Am. 34:1936-1956.

White, R.S. 1978. Gas hydrate layers trapping free gas in the Gulf of Oman. Earth Planet Sci. Let. 42:114-120.

White, W.B. 1971. The westward extension of the low-oxygen distribution in the Pacific Ocean. J. Geophys. Res. 77:5981-5986.

Wiens, J.A., G. Ford, D. Heinemann, and C. Fieber. 1978. Simulation modeling of marine bird population energites, food consumption, and sensitivity to perturbation. Annual Report RU 108. Oregon State University, Corvallis, OR. 136 pp.

Wigley, R.L. 1961. Bottom sediments of Georges Bank. J. Sediment Petrol. 31:165-188.

Wooster, W.S., and T. Cromwell. 1958. An oceanographic description of the eastern tropical Pacific. Bull. Scripps Inst. Oceanogr. (Univ. Calif.) 7:169-182.

Wust, G. 1936. Schictung und zirkulation des atlantischen ozeans. Das bodenwasser und stratosphare. Wiss. Ergebn. Dt. Atlant. Exped. Meteor. 6:1-288.

Wyrtki, K. 1962. The oxygen minima in relation to ocean circulation. Deep-Sea Res. 9:11-23.

Wyrtki, K. 1965. Surface currents of the eastern tropical Pacific Ocean. Int.-Am. Tropical Tuna Comm. Bull. 9:270-304.

Wyrtki, K. 1966. Oceanography of the eastern equatorial Pacific Ocean. Oceanogr. Mar. Biol. Annu. Rev. 4:33-68.

Wyrtki, K., and G. Meyers. 1976. The trade winds field over the Pacific Ocean. J. Appl. Meteorol. 15:698-704.

Zieman, J.C. 1975. Tropical seagrass ecosystems and pollution. pp. 63-74. In: Tropical Marine Pollution. E.J. Ferguson and R.E. Johannes (eds). Elsevier Scientific Publishing Company, Oxford, England. (not seen).

Zwally, J.H., J.C. Comiso, C.L. Parkinson, W.J. Campbell, F.D. Casey, and P. Gloersen. 1983. Antarctic sea ice, 1973-1976: satellite passive-microwave observations. NASA SP-459. U.S. Government Printing Office, Washington, DC.

CHAPTER 7

GLOSSARY

CHAPTER 7
GLOSSARY

Abyssal - Of or pertaining to the great depths of the ocean.

Accretion - The process in which material from the outer plate or trench is offscraped and added to the outer continental margin; large accumulations are termed accretionary prisms.

Active or Convergent Margins - Plate boundary between oceanic and continental crust where subduction or movement between plates occurs.

Albedo - The fraction of incident electromagnetic radiation reflected by a surface.

Alcids - Bird species that spend the majority of the time on the water surface; includes murres, puffins, etc.

Anthropogenic - Of human origin.

Anticline - An upfold or arch of stratified rock in which the beds or layers bend downward in opposite directions from the crest or axis of the fold.

Asthenosphere - The layer or shell of the earth below the lithosphere, in which magmas may be generated; equivalent to the upper mantle.

Authigenic - Formed by chemical processes after initial deposition.

Baleen Whale - Marine mammals of the suborder Mysticeti; whales that lack teeth and utilize baleen plates to filter seawater for feeding.

Bare Rock Spud-in - The process of starting a drillhole in the ocean on bare rock, without the usual sediment accumulation normally needed for bit stability.

Basalt - An extrusive igneous rock composed primarily of calcic plagioclase, pyroxene, with or without olivine. More generally, any fine-grained, dark colored igneous rock.

Basement Rock - Rock in the earth's crust beneath all sedimentary rocks.

Bed - A rock mass, usually of greater horizontal dimension than vertical or near vertical thickness, bounded (especially on its upper side) by material with different physical properties.

Bentonite - A clay formed from the decomposition of volcanic ash having a great ability to absorb or adsorb water.

Berm - The near horizontal portion of a beach formed by deposition of material by wave action; it marks the normal limits to high tide.

Biogenous - Formed by biological processes.

Biogeography - The biological study of the geographical distribution of plants and animals.

Biosphere - The totality of regions of the earth that support self-sustaining and self-regulating ecological systems.

Biostratigraphic - Pertaining to the correlation of the layering of sediments based on fossils.

Blowout - An uncontrolled flow of gas, oil or other fluids from a well to the atmosphere or ocean. A well blows out when formation pressure exceeds pressure applied to the well by the column of drilling fluid.

Blowout Preventer (BOP) - A stack or an assembly of heavy-duty valves attached to the top of the well casing to control pressure.

Borehole - A hole drilled in the earth's crust.

Bottom Simulating Reflector (BSR) - Seismic reflection at depth that follows the bottom topography on a seismic record.

Calcareous - Composed of or pertaining to calcium carbonate ($CaCO_3$).

Casing - Steel pipe used in oil wells to seal off fluids in the rocks from the bore hole and to prevent the walls of the hole from sloughing off or caving.

Cenozoic - The latest of the four eras into which geologic time, as recorded by stratified rocks at the earth's crust, is divided. It extends from the close of the Mesozoic era (63 million years ago) to the present.

Clathrate - Solid, ice-like structures formed of low molecular weight gas molecules within a lattice of other molecules (usually water).

Concentration (ice) - The ratio expressed in tenths or oktas, describing the mean areal density of ice in a given area.

Continental Drift - The theoretical slow shifting of continents due to weakness in the suboceanic crusts.

Continental Margin - A zone separating the emergent continents from the deep sea bottom and including the Continental Shelf and Continental Slope.

Continental Rise - Submarine surface beyond the base of the Continental Slope, occurring at depths from about 2,000 to 5,000 feet and leading down to abyssal plains.

Continental Shelf - A broad, gently sloping, shallow feature extending under the sea from the shore to the Continental Slope. It varies greatly in width around the continents.

Continental Slope - A relatively steep, narrow feature paralleling the Continental Shelf; the region where the deepest descent to the bottom of the ocean occurs.

Contingency Plan - A plan for possible offshore emergencies prepared and submitted by an oil or gas operator as part of the plan of development and production.

Convective Circulation - Circulation driven by temperature gradients.

Craton - A part of the earth's crust which has attained stability and which has been little deformed for a prolonged period.

Cretaceous - The third and most recent of the periods included in the Mesozoic era, from about 135 million to about 63 million years ago.

Deformation - A general term for the process of folding, faulting, shearing, compression, or extension of the rocks as a result of various earth forces.

Demersal - Living on or near the bottom of the sea.

Deposition - The laying down of any material; the settling of sediment from suspension in water, percipitation from solution, or accumulation of organic material; sedimentation.

Detrital - Sediments or particles of sediments derived from formerly existing rocks.

Diagenesis - As applied to sediments, this means all chemical, physical and biologic changes, modifications or transformations undergone by a sediment after its initial depositions (i.e., after it has reached its final resting place in the current cycle of erosion, transportation and deposition) and during and after its lithification, exclusive of surficial alteration (weathering) and metamorphism.

Diapir - A piercing fold; an anticlinal fold in which a mobile core, such as salt, has broken through the brittle overlying rocks.

Dike - A tabular body of igneous rock that cuts across the structure of adjacent rocks or cuts massive rocks.

Directional Drilling - A technique of drilling at an angle from the vertical by deflecting the drill bit.

Dome - A roughly symmetrical upfold in which the beds dip in all directions, more or less equally, from a point; any structural deformation characterized by a local uplift approximately circular in its outline; for example, the salt domes of Louisiana and Texas.

Drill Pipe - Heavy, thick-walled steel pipe used in rotary drilling to turn the drill bit and to provide a conduit for the drilling mud.

Drilling Mud - A special mixture of clay, water, and chemical additives pumped downhole through the drill pipe and drill bit. The mud cools the rapidly turning bit; lubricates the drill pipe as it turns in the well bore; carries rock cuttings to the surface; serves as a plaster to prevent the well or the borehole from crumbling or collapsing, and provides the weight or hydrostatic head to prevent extraneous fluid from entering a well bore and to control downhill pressures that may be encountered.

Dynamic Positioning System - A system that maintains a drillship on location by continuous activation and control of the normal propulsion systems and of specially located propulsion systems. The dynamic positioning system is normally used in waters too deep to use mooring lines and anchors economically.

Emulsification - The process of forming a suspension of one fluid (oil) in another (water).

Endemic - Native or confined to a certain region.

Environmental Assessment - A concise public document required by the National Environmental Policy Act of 1969 (NEPA). In the document a Federal Agency proposing an action provides evidence and analysis for determining whether it must prepare an environmental impact statement or whether it finds there is no significant impact (FONSI).

Eocene - An epoch of geologic time of the lower Tertiary period. Between the Paleocene and the Oligocene.

Epifauna - Animals which live at the water-substrate interface, either attached to the bottom or moving freely over it.

Evolution - A gradual process in which something changes into a significantly different, especially more complex or more sophisticated, form.

Extratropical - Origin outside of tropical lattidues.

Facies - A part differentiated from other parts in a rock by appearance; a rock distinguished from related or similar rocks.

Fault - A fracture in the earth's crust accompanied by a displacement of one side of the fracture with respect to the other.

Floating Ice - Any form of ice found floating in water. The principal kinds of floating ice are lake ice, river ice, sea ice, which forms by the freezing of water at the surface, and glacier ice (ice of land origin) formed on land or in an ice shelf. The concept includes ice that is stranded or grounded.

Floe - Any relatively flat piece of sea ice. Floes are subdivided according to horizontal extent as follows:

Giant	Over 10 km (5 1/2 mi) across
Vast	2-10 km (1 1/2 mi) across
Big	500-2,000 m across
Medium	100-500 m across
Small	20-100 m across
Ice Cake	Less than 20 m across.

Formation - The primary unit in lithostratigraphy, consisting of a succesion of strata useful for mapping or description.

Fracture Zone - On the deep sea floor, an elongate zone of irregular topography commonly separating regions of different depths.

Genesis - The formation of; origin.

Geochemical - Of or relating to the science dealing with the chemical composition of and the actual or possible chemical changes in the crust of the earth.

Geochemical Pathway - The route followed by a chemical species from its source to its ultimate resting place.

Geologic Hazard - A feature or condition that, if undetected, may seriously jeopardize offshore drilling and, once identified, may necessitate special engineering procedures or relocation of a well. Such hazards may include unstable bottom conditions or underwater canyons.

Geologic Trap - An arrangement of rock strata involving their structural relations or varied lithology and texture, that favors the accumulation of oil and gas.

Geophysical - Of or relating to physics of the earth, especially the measurement and interpretation of geophysical properties of the rocks in an area.

Geothermal - Pertaining to the internal heat of the earth.

Graben - An elongate, relatively depressed crustal unit bounded by faulting along the long axis; rift valley.

Grease Ice - The thin ice that initially forms between floes.

Habitat - The area or type of environment in which an organism or biological population normally lives in or occurs.

Hemipelagic Deposits - Deep-sea sediments containing a small amount of material eroded from the land surface as well as remains of pelagic organisms.

Holoplankton - An organism that is planktonic during its entire life cycle.

Hydrocarbon - Any of a large class of organic compounds containing primarily carbon and hydrogen, comprising paraffins, olefins, members of the acetylene series, alicyclic hydrocarbons, and aromatic hydrocarbons.

Hydrothermal Circulation - Convective circulation of water through oceanic crust near active spreading centers.

Ice Cover - The ratio of an area of ice of any concentration to the total area of sea surface within some large geographic locale; this locale may be global, hemispheric, or prescribed by a specific oceanographic entity such as Baffin Bay or the Weddell Sea.

Infauna - Animals who live buried in soft sediments.

Jurassic - The middle period (from about 205 million years ago to about 138 million years ago) of the three periods comprising the Mesozoic era.

Katabatic Wind - A local wind that moves downward (e.g., as a result of surface cooling during the night).

Land Uses - The function for which people employ an area of land.

Layer 1, 2, 3 - Geophysically determined layers of the earth's oceanic crust based on sonic velocity.

Lithosphere - The solid outer portion of the earth.

Magma - Molten rock material within the earth from which an igneous rock results by cooling and crystallization.

Magnetic Anomaly - Any departure from the normal magnetic field of the earth as a whole.

Mantle - The zone of the earth below the crust and above the core (to a depth of 3,480 km).

Marine Sanctuary - An area protected under the Marine Protection, Research, and Sanctuaries Act of 1972.

Meroplankton - An organism that is planktonic during part of its life cycle.

Mesozoic - One of the grand divisions or eras of geologic time, following the Paleozoic era and succeeded by the Cenozoic era. It extended from about 240 million years ago to about 63 million years ago. The Mesozoic era comprises the Triassic, Jurassic, and Cretaceous periods.

Metalliferous - Containing metal.

Metamorphism - Any alteration in composition, texture, or structure of rock masses, caused by great heat or pressure.

Migration - The movement of oil, gas, or water through porous and permeable rock.

Mohorovicic Discontinuity - Seismic discontinuity situated about 35 km below the continents and about 10 km below the oceans which separates the earth's crust from the mantle.

Neritic - Pertaining to the waters and deposits of a shoreline.

Neutral Buoyancy - Location in the water column where the density of an object or plume is the same as the water.

NPDES - National Pollutant Discharge Elimination System. Every industrial facility that discharges wastes into water must have an NPDES permit. The permits are issued either by the Environmental Protection Agency (EPA), or by States with EPA-approved programs for administering the system. An NPDES permit generally specifies discharge limitations for specific pollutants, establishes schedules for upgrading controls to meet such limits, and requires periodic reports on compliance.

Odontacete - Marine mammals of the suborder Odontaceti, toothed whales.

Oligocene - Geologic time period of the lower Tertiary period, after the Eocene and before the Miocene.

Ophiolite Complexes - A group of mafic and ultramafic igneous rocks, whose origin is associated with an early phase of the development of a geosyncline.

Orogeny - The process of mountain building, especially by folding and faulting of the earth's crust. Orogenic - adj.

Outer Continental Shelf (OCS) - All submerged lands that comprise the Continental Margin adjacent to the U.S. and seaward of state offshore lands. The OCS has been under federal jurisdiction and control since enactment of the Submerged Lands Act (43 USC 1301 and 1302).

Over Pressure Zone - Excessive fluid pressure in a formation greater than ambient conditions.

Pack Ice - Term used in a wide sense to include any area of sea ice, other than fast ice, no matter what form it takes or how it is disposed.

- Close - Pack ice in which the concentration is 7/10 to 8/10, composed of floes mostly in contact.
- Open - Pack ice in which the ice concentration is 4/10 to 6/10, with many leads and polynyas, and the floes are generally not in contact with one another.
- Very Open - Pack ice in which the concentration is 1/10 to 3/10 and water predominates over ice.
- Open Water - A large area of freely navigable water in which sea ice is present in concentrations of less than 1/10 (1/8). There may be ice of land origin present although the total concentration of all ice shall not exceed 1/10 (1/8).
- Ice Free - No ice present. If ice of any kind is present this term should not be used. cf. Open water.

Paleoceanography - The study of past oceans and its phenomena.

Paleoclimatology - The study of past climates throughout geologic time, and of the causes of their variatons.

Paleoenvironment - Ancient environments.

Paleontology - Study of fossils to determine life forms which existed in ancient geologic time.

Passive Margins - Boundary between oceanic and continental crust that is not in motion relative to one another.

Pelagic - Of, pertaining to, or living in open oceans rather than waters adjacent to land or inland waters.

Permeability - The ability to transmit fluids.

Perturbation - The state or condition of being agitated or disturbed; a disruption of the system.

Photic Zone - Surface waters in which sufficient light is present to support plant life.

Plate - One of the large, nearly rigid, but still mobile segments or thin blocks involved in plate tectonics, with a thickness (50-250 km) that includes both crust and some part of the upper mantle.

Plate Tectonics - Theory that earth's continents and oceans are a dozen or so "plates" of irregular shape and size which are constantly in motion and which ride on viscous material deep in the earth.

Pleistocene - An epoch of the Quarternary period - syn. Ice Age.

Porosity - The capability to contain fluids within void spaces; the percent of open space within a rock.

Province - An area through which geological history has been essentially the same or that is characterized by certain structural, petrographic, or physiographic features.

Remnant Magnetism - That magnetism remaining in a rock resulting from its history; in the case of igenous rocks, resulting from having cooled or recrystallized in a magentic field, i.e., the earth's.

Repository - A place where the cores are stored under conditions to preserve samples.

Ridge Crest - A ridge is a relatively narrow elevation which is prominent on account of the steep angle at which it rises. A ridge crest is the top edge of the ridge. Specifically used as the crest of a spreading submarine ridge.

Rifting - The process of faulting, subsidence, and volcanism that occurs at the loci of spreading centers.

Riser - A casing extending from a drilling platform through the water to the sea bed through which drilling is done. Also, a large pipe connecting the drilling vessel to the blowout preventer and the hole through which drilling muds can be circulated.

Sea-Floor Spreading - A hypothesis that the oceanic crust is increasing by convective upwelling of magma along the mid-oceanic ridges, and moving away of the new material.

Sea Ice - Any form of ice found at sea which has originated from the freezing of sea water.

Seamount - A submarine mountain rising more than 500 fathoms above the line of the ocean floor. Generally a volcanic cone.

Sediment - Material deposited by water, wind, or glaciers, or a mass of deposited material.

Seismic - Pertaining to, characteristic of, or produced by earthquakes or earth vibration; having to do with elastic waves in the earth.

Seismic Velocity - The rate of propagation of an elastic wave, usually measured in km/sec. The wave velocity depends upon the type of wave as well as the elastic properties and density of the earth material through which it travels.

Sill - A tabular body of igneous rock that parallels the structure of the adjoining rock.

Spud - To begin drilling a well.

Stratum (pl., Strata) - A tabular mass or thin sheet of sedimentary rock formed by natural causes and made up usually of a series of layers lying between beds of other kinds.

Structural Trap - A geologic feature that includes a reservoir, capable of holding oil or gas, that is formed from crustal movements in the earth that fold or fracture rock strata in such a manner that oil or gas accumulating in strata is sealed off and cannot escape. In some cases "structure" may be synonymus with structural trap.

Subduction - The condition of one crustal plate having been moved beneath another plate; referring to the lower of two such plates.

Subsidence - A local mass movement that involves the gradual downward settling or sinking of the earth's surface with little or no horizontal motion.

Swabbing Effect - To pull drill pipe too fast and induce negative pressure in the hole which could cause fluid to flow out of the formation.

Tectonic - Of or pertaining to the rock structure and external forms resulting from the deformation of the earth's crust.

Tidelands - The portion of the Continental Shelf between the shore and the boundaries claimed by the states.

Trap - A geologic feature that forms a reservoir enclosing and preventing escape of accumulated fluids, including water and hydrocarbons.

Triassic - The earliest (from about 240 million years ago to about 205 million years ago) of the three geologic periods that comprise the Mesozoic ear.

Tsunami - A great wave caused by submarine crustal displacement of landslides; associated with volcanic eruptions or major earthquakes. Also called a "seismic sea wave."

Turbidite - A sediment or rock deposited from a turbidity current.

Turbidity Current - A bottom-flowing current laden with suspended sediment, moving swiftly down a slope and spreading horizontally on the floor of the body of water.

Volcanism - The processes by which magma and its associated gases rise into the crust and are extruded onto the earth's surface and into the atmosphere.

CHAPTER 8

LIST OF PREPARERS

PRINCIPAL TETRA TECH PREPARERS

Mr. Robert C. Barrick, Chemical Oceanography
Mr. Gary N. Bigham, Project Management
Dr. Gordon R. Bilyard, Marine Ecology
Mr. Pieter Booth, Marine Policy
Dr. Dale E. Brandon, Marine Geology
Ms. Marcy Brooks-McAuliffe, Technical Writing
Dr. Thomas C. Ginn, Marine Biology
Ms. Lys L. Hornsby, Environmental Engineering
Dr. Raj B. Mathur, Socioeconomics
Mr. Jeffrey H. Stern, Oceanography/EIS Coordination
Dr. Ted R. Turk, Marine Ecology
Mr. Victor M. Yamada, Environmental Engineering

CONSULTANTS

Mr. Frederic L. Felleman, Marine Mammals
University of Washington Cooperative Fishery Research Unit
Dr. Paul Johnson, Marine Geology
University of Washington School of Oceanography
Dr. Erodogan Ozturgut, Physical Oceanography
Ozturgut Oceanographics
Mr. Terance R. Wahl, Marine Birds
Western Washington University Dept. of Biology

SUPPORTING TETRA TECH STAFF

Mr. A. Brian Carr, Graphics Illustrator
Ms. Betty Dowd, Graphics Illustrator
Mr. Brad Fogle, Graphics Illustrator
Ms. Lisa Fosse, Word Processing Operator
Ms. Barbara McShane, Secretary
Ms. Dana Schai, Word Processing Operator
Ms. Gail Singer, Word Processing Operator
Ms. Gestin Suttle, Word Processing Operator
Ms. Stephanie Turco, Production Assistant

APPENDICES

APPENDIX A

GLOBAL DISTRIBUTIONS OF MARINE MAMMALS AND THE POTENTIAL IMPACTS OF OFFSHORE SCIENTIFIC DRILLING AS IT RELATES TO LIFE HISTORY REQUIREMENTS

APPENDIX A

GLOBAL DISTRIBUTIONS OF MARINE MAMMALS AND THE POTENTIAL IMPACTS OF OFFSHORE SCIENTIFIC DRILLING AS IT RELATES TO LIFE HISTORY REQUIREMENTS

INTRODUCTION

Scientific drilling differs markedly from the petroleum industry drilling in that its primary aim is to gain information about the geologic record and is not directed towards potential oil resources. Consequently, there is much less likelihood of adverse impacts on marine mammals individually or on their population as a result of the greatly reduced potential of direct contact with oil. Ecological characteristics used to evaluate a species vulnerability to impacts include means of thermal regulation, site tenacity or timing of migration, preferred habitat, breeding system, foraging technique, and population size.

Some entire families are so reduced in numbers (e.g., Balaenidae and Monachinae) that they could be easily disturbed by human intervention and are protected by both the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. All marine mammals receive protection in United States waters, but critical habitat for those that are listed as endangered is also protected from destruction or modification. In all, there are 110 potentially vulnerable species considered that may be impacted by operations of the ODP, of which only 16 are vulnerable to population level impacts. To facilitate assessment of potential impacts, reviews of impacts associated with scientific drilling were used to categorize the major families of marine mammals based on their expected vulnerability to the impacts (see Table 1). Distribution maps of each species are organized taxonomically within the categories of vulnerability (see Figures 1 to 4d).

POTENTIAL IMPACTS

Potential impacts can be summarized under six categories: 1) acoustic, 2) noxious, 3) foraging, 4) respiratory, 5) reproductive, and 6) thermal. All marine mammals may be affected by the first five impacts to varying degrees. Thermal impacts, though crucial, will only be significant for those species relying on fur for thermal regulation (otters, fur seals, polar bears). In general, species that are site-tenacious or return to specific habitats suffer increased risk of repeated exposure. It is important to note that secondary impacts such as reproductive disorders may occur as a result of stresses induced by any of the impacts.

Noise associated with most phases of scientific drilling is generated by: seismic surveying, drilling, air support, and ship support. Acoustic impacts associated with shock waves generated during seismic surveys are a threat to all marine mammals within critical range of the blast. However, more recent applications of air guns reduces the possible severity of this impact. Most studies of hearing loss due to cochlear damage have utilized high frequency sounds (Raumprashad et al. 1973). However, drilling operations are more likely to generate low-frequency disturbances which may result in stress-related problems or avoidance. Stress-mediated reactions of birds and mammals to noise may reduce an organism's resistance to disease, increase its vulnerability to environmental disturbances, and create endocrine imbalances that affect reproduction (Fletcher 1971). Most marine mammals use sound as a form of communication or for navigation and locating prey (Norris 1969). Background noise may interfere with these basic processes, resulting in social disruption, decreased feeding efficiency, or disorientation due to echo confusion (Geraci and St. Aubin 1980).

Geraci and St. Aubin (1980) suggested that two types of noise may affect marine mammal behavior: impulse and chronic background noise. A sudden disturbance can cause pinnipeds to leave their rookeries (Salter 1979). Repeated disturbances can cause the abandonment of traditional breeding sites in favor of less suitable ones (Geraci and St. Aubin 1980). Cetaceans are also potentially affected adversely by increased boat traffic, which is thought to disturb migration routes (Nishiwaki and Sasao 1977) and breeding grounds (U.S. Department of Commerce 1983). The groups most likely to be affected by noise disturbances are those confined to critical habitats (e.g., Sirenia and Monachinae), haul-outs (e.g., Pinnipedia), or breeding grounds (e.g., E. robustus and M. novaeangliae). Displacement from critical habitats could cause dramatic alterations to their breeding success. Pinnipeds most vulnerable to noise disturbance may include perinatal females, nursing pups, molting animals, and those stressed by parasitism or disease (Geraci and Smith 1979). Cetaceans on their breeding grounds are also more vulnerable due to the stresses of lactation, which are often compounded by fasting. Displacement from their breeding or feeding grounds may also result in reduced reproductive fitness of the population.

Noxious effects of oil spills common to all marine mammals include irritation of the eyes and mucous membranes, as documented in experimentally oiled ringed seals (Phoca hispada) (Geraci and Smith 1979). Cetacean skin, though unlikely to accumulate oil, may be particularly sensitive to surface contact with oil due to the lack of a keratin layer in the epidermis (which is likened to the sensitivity of a mucous membrane) (Ling 1974). Walrus and sireniad skin, though poorly studied, is thought to be similar in sensitivity (King 1964). Cetaceans in estuarine systems may have exaggerated skin sensitivity to surface contact with oil due to the low salinity of the environment.

The dependence of pinnipeds and otters on specific substrates during pupping, molting, and breeding activities may force them into repeated exposure to shoreline accumulations of oil, thereby increasing their vulnerability to noxious effects (Davis and Anderson 1976). Smith and Geraci (1975) suggested that short-term inhalation of volatile hydrocarbons was not harmful to the respiratory tract of ringed seals experimentally immersed in oil-covered water for 24 hours. Prolonged inhalation is more likely to have greater consequences. Reactions to chronic exposure of petroleum vapors have been studied in rats and include central nervous system disturbance, bronchopneumonia, and death (Carpenter et al. 1978).

Marine mammals may ingest and accumulate oil from surface feeding (e.g., baleen whales), grooming (e.g., otters), or eating contaminated prey. Crude oil density and viscosity increase with weathering due to evaporation of the volatile portions. The more viscous forms could foul baleen plates, rendering them ineffective as filters. Raw crude oil or lighter oil fractions have less fouling potential, but are volatile and destructive to tissue. Such fractions could also interfere with the functioning of baleen plates (Geraci and St. Aubin 1980). Ingested oil is potentially lethal resulting from acute cytotoxic damage (Moore and Dwyer 1974). Ringed seals and harp seals (Phoca groenlandica) rapidly absorbed crude oil hydrocarbons into body tissues and fluids, but showed no immediate evidence of tissue damage (Englehart et al. 1977; Geraci and Smith 1976). Herbivorous Sirenia would probably suffer from ingestion of oil through effects on gut flora and secretory activity of the gastric glands, thereby interfering with digestion (Kenchington 1972).

Bioaccumulation of hydrocarbons through the food chain can be deleterious to all marine mammals. Benthic invertebrates accumulate aromatic hydrocarbons to varying degrees from seawater (Stegeman and Teal 1973) and from bottom sediments (Roesijadi et al. 1978). Generally, benthic and deposit feeders accumulate hydrocarbons to a greater extent than do suspension feeders (Geraci and St. Aubin 1980). The walrus (Odobenus spp.), bearded seal (Erignathus barbatus), gray whale (Eschrichtius robustus) and otters would have elevated exposure to these impacts because of their benthic food preferences. The killer whale (Orcinus orca) has been shown to accumulate high levels of toxic substances in blubber (Calambokidis et al. 1984). The problems of bioaccumulation are probably common to all higher level predators (e.g., polar bear, leopard seal). Hodgins et al. (1977) provided evidence for the carcinogenic properties of petroleum hydrocarbons on invertebrate and vertebrate species.

However, even if the marine mammal is not directly killed by the ingestion or inhalation of petroleum, or starved from reduced feeding efficiency, the possibly deleterious secondary impacts on future reproductive success due to stresses associated with these impacts are critical to the impacts on the population.

There is strong evidence that animals which rely on fur or hair for insulation will be severely affected by surface contact with oil. Based on experiments with various species of pinnipeds and otters (Kooyman et al. 1977), organisms with a large blubber layer appeared to be less affected by thermal stress resulting from surface contact with oil than those relying on fur or hair. Experimentally oiled sea otters (Enhydra lutris) spent 75 percent of their time trying to clean their pelage (Williams 1978). This diversion from their normal behavioral reportoire will undoubtedly stress their energetic requirements because of increased work to stay warm with fouled pelage and diversion from foraging, which would be the only way to satisfy increased metabolic needs. Solvent-emulsifiers used to clean the pelage may cause additional problems due to detrimental effects resulting from excessive handling (Davis and Anderson 1976) or degradation of natural oils on their fur (Williams 1978). Therefore, drilling operations should take particular caution in the vicinity of populations of species that rely on fur or hair for thermal insulation.

POPULATION IMPACTS

Four general categories of vulnerability have been formulated based primarily on means of thermal regulation and site tenacity (Table 1). However, the size of a population is a major factor affecting its overall vulnerability to disturbances associated with the ODP, since the affect of an individual on a population increases as population declines. Consequently, the remnant populations of the Balaenidae family are more vulnerable to perturbation than some of the species in the family Delphinidae, even though Balaenidae is listed in a lower ranking category (Tables 1 and 2).

The species listed within each category in Table 1 (unless otherwise noted) are particularly vulnerable to population-level disturbances because of their reduced numbers. However, even though most of the species listed in Table 1 are endangered, not all can be considered equally vulnerable. The potential of the proposed project to dramatically impact an entire population is heightened if the impact occurs to a threatened population that is confined to an area of concentration (e.g., breeding ground or localized distribution range). Therefore, the consequences of the impact will affect a major proportion of the population. Consequently, the species selected from the families in each category are to be considered the most vulnerable to population-level impacts and will be reviewed with some detail so that their critical natural history requirements can be considered.

The species listed in category 1 in Table 1 are potentially the most vulnerable. They all rely on fur or hair for thermal regulation, are found in aggregations (except polar bear), and are reduced in population size (Figure 1, Table 2). The marine otter (Lutra felina) is highly vulnerable in its remnant range. Little is known about its movements or reproduction. The sea otter (Enhydra lutra) appears to be increasing in number in Alaska, but the stability of its existence along the California coast is still in question. It bears young in late spring to early summer, and depends on kelp forests for its survival. As a benthic feeder, it is also subject to long-term problems associated with bioaccumulation. The polar bear (Ursus maritimus) is never found in dense aggregations, but its close association with ice flows, where accidentally spilled oil may accumulate, deserves some attention. In addition, as a higher order predator, its vulnerability to disorders associated with bioaccumulation is heightened. The three most vulnerable fur seals to population impacts are the Galapagos fur seal (Arctocephalus galapagoensis), which pups year round in the Galapagos Islands, the Juan Fernandez fur seal (A. philippi), which pups in December on the islands off the central coast of Chile, and the Guadalupe fur seal (A. townsendi), which begins to aggregate on Guadalupe Island in May (King 1983). The Northern fur seal (Calorhynus ursinus), though not endangered, deserves consideration because of its confined breeding sites and recent population declines.

The endangered or threatened species that rely on blubber for thermal regulation and are site-tenacious are listed in category 2 (Table 1). These include all the Sirenia, the monk seals (monachus spp.), the Australian sea lion (Neophoca cinera), Hooker's sea lion (Phocarctos hookeri), and cochito (Phocoena sinus), the most recently declared endangered species (U.S. Fish and Wildlife Service 1985) (Table 2). The Sirenia are vulnerable to population impacts because of their restricted habitat, reduced population

TABLE 1. CATEGORIES OF VULNERABILITY

1 Fur or Hair/Site Tenacious or Coastal	2 Blubber/Site Tenacious or Coastal	3 Blubber/Pelagic or Coastal Breeding	4 Blubber/Pelagic
Figure 1 Mustelidae (otters) - *Enhydra lutra* - *Lutra felina* Ursidae (polar bear) - *Ursus maritimus* Arctocephalinae (fur seals) - *A. townsendi* - *A. galapagoensis* - *A. philipii*	Figure 2a Dugongidae (dugong) - *Dugong dugong* Trichechidae (manatee) - *T. manatus* - *T. inunguis* - *T. senegalensis* Figure 2b Phocidae (true seals) - *Monochus monachus* - *M. tropicalis* - *M. schauinslandi* Figure 2c Odobenidae (walrus) Otarinae (sea lions) - *Neophoca cinerea* - *Phocarctos hookeri* Figure 2d Delphinidae (dolphins) - coastal only Phocoenidae (porpoises except *P. dalli*) - *Phocoena sinus* Monodontidae (Arctic)	Mysticeti (baleen whales) Figure 3 Balaenidae (right whales) - *B. glacialis* - *B. australis* - *B. mysticetus* Eschrichtidae (gray whale) - *E. robustus* Balaenopteridae (rorquals) - *M. novaeangliae* - *B. musculus* - *B. physalus* - *B. borealis*	Odontoceti (toothed whales) Figure 4a Physeteridae (sperm whales) - *P. macrocephalus* - *K. breviceps* - *K. simus* Ziphidae (beaked whales) Figure 4b Globicephalidae (pot head whales) Figure 4c Delphinidae (dolphins) spp. other than stenella or delphinus (not vulnerable) Globicephalidae (*G. griseus* only) Phocoenidae (porpoises, *P. dalli* only) Figure 4d Delphinidae (dolphins) - Stenella and Delphinus (not vulnerable)

Note: Only endangered or threatened species are listed that could be subject to population level impacts.

TABLE 2. POPULATION ESTIMATES OF MARINE MAMMAL SPECIES VULNERABLE TO POPULATION-LEVEL IMPACTS

Name	Estimated World Total[a]	Comparison of Population Data[b]	Population Distribution
Category 1			
Family: Mustelidae			
Sea otter *Enhydra lutra*	130,000[c]	Incomplete	Pacific - 100,000 Alaska; 1,500 North America
Marine otter *Lutra felina*	200/300[d]	Incomplete	Pacific - 200/300 South America
Family: Ursidae			
Polar bear *Ursus maritimus*	15,000/[e] 20,000	Incomplete	Circumpolar arctic - 15,000/20,000
Subfamily: Arctocephalinae			
Guadalupe fur seal *Arctocephalus townsendi*	1,000	Complete	Pacific - 1,000 Guadalupe Is.
Juan Fernandez fur seal *Arctocephalus philippii*	705/ 750	Complete	Pacific - 705/750 Islands off South America
Galapagos fur seal *Arctocephalus galapagoensis*	1,000/ 5,000	Incomplete	Pacific - 1,000/5,000 Galapagos Is.
Category 2			
Family: Phocidae			
Mediterranean monk seal *Monachus monachus*	500	Best	Mediterranean - 500 Aegean Sea
Caribbean monk seal *Monachus tropicalis*	extinct or near extinct	Best	Caribbean - [f]
Hawaiian monk seal *Monachus schauinslandi*	500/ 1,500	Complete	Pacific - 500/1,500 Hawaiian leyward Is.
Family: Dugongidae			
Dugong *Dugong dugong*	no data	Incomplete	Indian and Pacific - Asia[f]

TABLE 2. (Continued)

Family: Trichechidae			
Amazon manatee *Trichechus inunguis*	no data	Incomplete	Atlantic - South America[f]
African manatee *Trichechus senegalensis*	no data	Incomplete	Atlantic - Africa[f]
West Indian manatee *Trichechus manatus*	no data	Incomplete	Caribbean and Atlantic - North, Central, and South America[f]
Family: Phocoedae			
Cochito *Phocena sinus*	no data	Incomplete	Pacific - Gulf of California[f]
Subfamily: Otarinae			
Australian sea lion *Neophoca cinerea*	2,000/ 3,000	Complete	Pacific - 2,000/3,000 Australia
Hooker's (New Zealand) sea lion *Phocarctos hookeri*	6,000		Pacific - 6,000 New Zealand
Category 3			
Family: Eschrichtidae			
Gray whale *Eschrichtius robustus*	17,000	Best	Pacific - 17,000 Alaska and North America
Family: Balaenopteridae			
Sei whale *Balaenoptera borealis*	42,000	Incomplete	Worldwide - 30,000 Pacific; 10,000 southern ocean; 2,000 North Atlantic
Fin whale *Balaenoptera physalus*	117,600/ 120,300	Best	Worldwide - 17,000 North Pacific; 15,600/18,300 North Atlantic; 85,000 Southern Ocean
Blue whale *Balaenoptera musculus*	11,700	Complete	Worldwide - 1,600 North Pacific; 100 North Atlantic; 10,000 Southern Ocean
Humpback whale *Megaptera novaeangliae*	10,275	Incomplete	Worldwide - 1,000 North Pacific; 6,775 North Atlantic; 2,500 Southern Ocean
Family: Balaenidae			
Right whale *Balaena glacialis*	3,500/ 3,700	Best	High latitudes - 200 Bering; 300/500 North Atlantic; 3,000 Southern Ocean
Bowhead whale *Balaena mysticetus*	4,000	Complete	High latitudes - 3,871 Arctic and Bering Seas

TABLE 2. (Continued)

Category 4			
Family: Physeteridae			
Sperm whale Physeter catodon	904,000	Complete	Worldwide - 472,000 Pacific; 22,000 Atlantic; 410,000 Southern Ocean
Pygmy sperm whale Kogia breviceps	no data	Incomplete	Middle latitudes - [f]
Dwarf sperm whale Kogia simus	no data	Incomplete	Middle lattitudes - [f]

[a] Population data extracted from Marine Mammal Protection Act Annual Report (U.S. Department of Commerce 1984), except as noted.

[b] Best = The most comprehensive estimates throughout the range of the species.

Complete = Good population estimates throughout the range of the species.

Incomplete = Population estimates only in parts of the range of the species.

[c] Population data from Lentfer (1978).

[d] Population data from Brownell (1978).

[e] Population data from Kenyon (1978).

[f] Although a population occurs in this area, the numbers are either unknown or the data are not available.

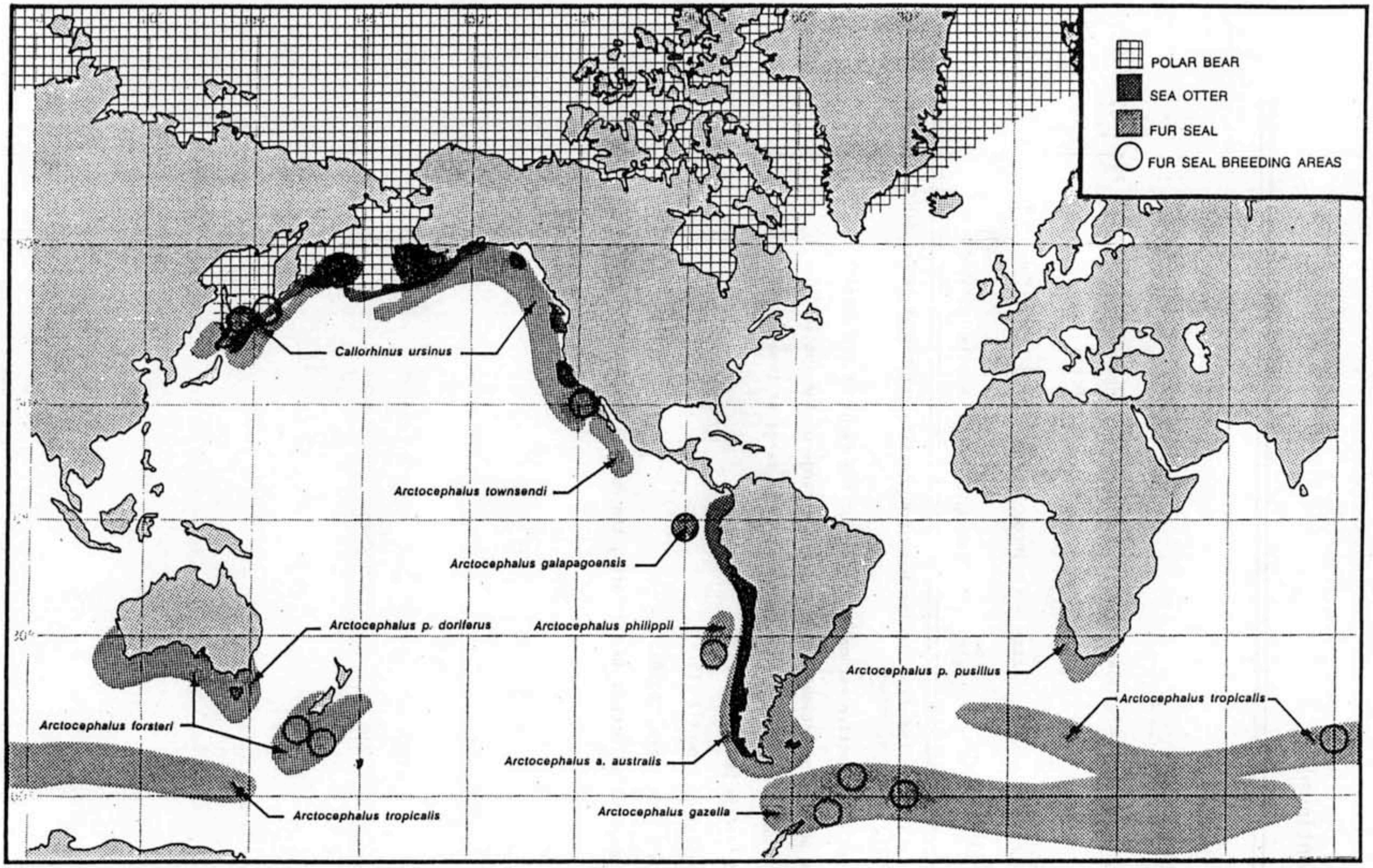


Figure 1. General distribution of marine mammals that rely on fur or hair for insulation and are site tenacious (Category 1).

size, acoustic sensitivity, and herbivorous diet which makes them more prone to noxious effects of ingested oil (Kenchington 1972). The Amazon manatee (Trichechus inunguis) is sparsely distributed over the Amazon basin (Figure 2a). Its limited contact with the coast makes it the least vulnerable of the Sirenia (Husar 1977). The African manatee (T. senegalensis) is distributed in rivers, estuaries, and coastal regions of West Africa from Senegal to Angola (Figure 2a). Its distribution is limited to waters of 18° C or higher and it apparently breeds year-round (Husar 1978b). The West Indian manatee (T. manatus) occurs throughout the year, but is confined to short estrus periods. They are susceptible to pneumonia and bronchial disorders, but in Florida heavy boat traffic is believed to be the major source of mortality. They seek refuges in the winter when water temperatures fall below 15° C (Husar 1978c). The dugong (Dugong dugong) is the only living species of the family Dugongidae. Its range includes the coastal waters within the tropical and subtropical latitudes of the Indian and Pacific oceans (Figure 2a). They are most abundant in Africa along Kenya and the Somali Republic, but the greatest concentrations appear in northern Austrailian waters. They are probably the most vulnerable of the Sireniads because they do not ascend up rivers, but prefer sheltered waters of 2-8 fathoms with a temperature range of 21°-38° C (Husar 1978a).

The monk seals are all extremely threatened due to their inability to coexist with human disturbances. The Mediterranean monk seal (Monachus monachus) is most common in the eastern Agean Sea, where pups are born between September and October (Figure 2b) (King 1983). The West Indian monk seal (M. tropicalis) is possibly extinct, therefore no particular areas of concentration can be cited (Figure 2b) (King 1983). The Hawaiian monk seal (M. schaunslandi) lives on the atolls of the leyward chain of the Hawaiian Islands (Figure 2b). They pup from March through May (King 1983). Their continued decline has led NMFS to redesignate most of their distribution as a critical habitat (U.S. Fish and Wildlife Service 1985).

Two southern hemisphere sea lions are vulnerable to population impacts. The Australian sea lion (Neophoca cinera) is nonmigratory, with a distribution restricted to southern Australia, and does not have a defined breeding season (Figure 2c) (King 1983). The New Zealand sea lion (Phocarctos hookeri) also has a very restricted distribution (Figure 2c). They congregate on Enderby and Dundas Island in January to breed (King 1983). Cochito, also known as the Gulf of California harbor porpoise (Phocoena sinus) is only found in the northern third of the Gulf of California (Figure 2d). It has been seriously depleted as a result of incidental takes in commercial gillnets. No confirmed sightings have been reported since 1980 (U.S. Fish and Wildlife Service 1985).

Ranking vulnerability by potential impacts to individuals determines the likelihood an organism is affected by an activity. However, the wide pelagic distributions of the marine mammals listed in categories 3 and 4 reduce the potential that a significant portion of a population will be impacted; in effect, lowering that ranking. The greatly reduced numbers of the baleen whales (Table 2) due to extensive whaling increases the potential that these species can be significantly impacted compared to other pelagically distributed species. The bowhead (Balaena mysticetus), right (Balaena glacialis; B. australis), humpback (Megaptera novaeangliae), and gray

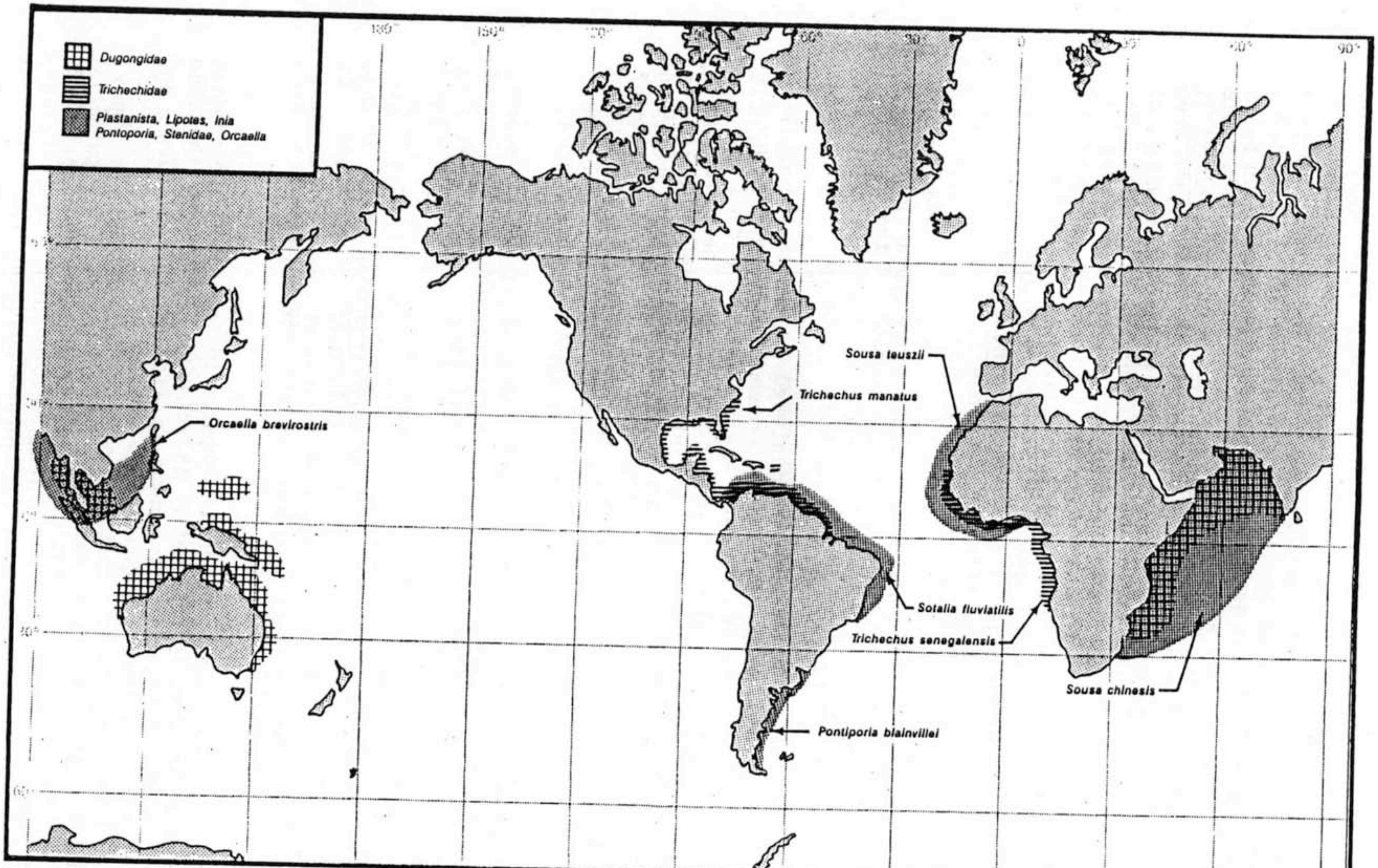


Figure 2a. General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).

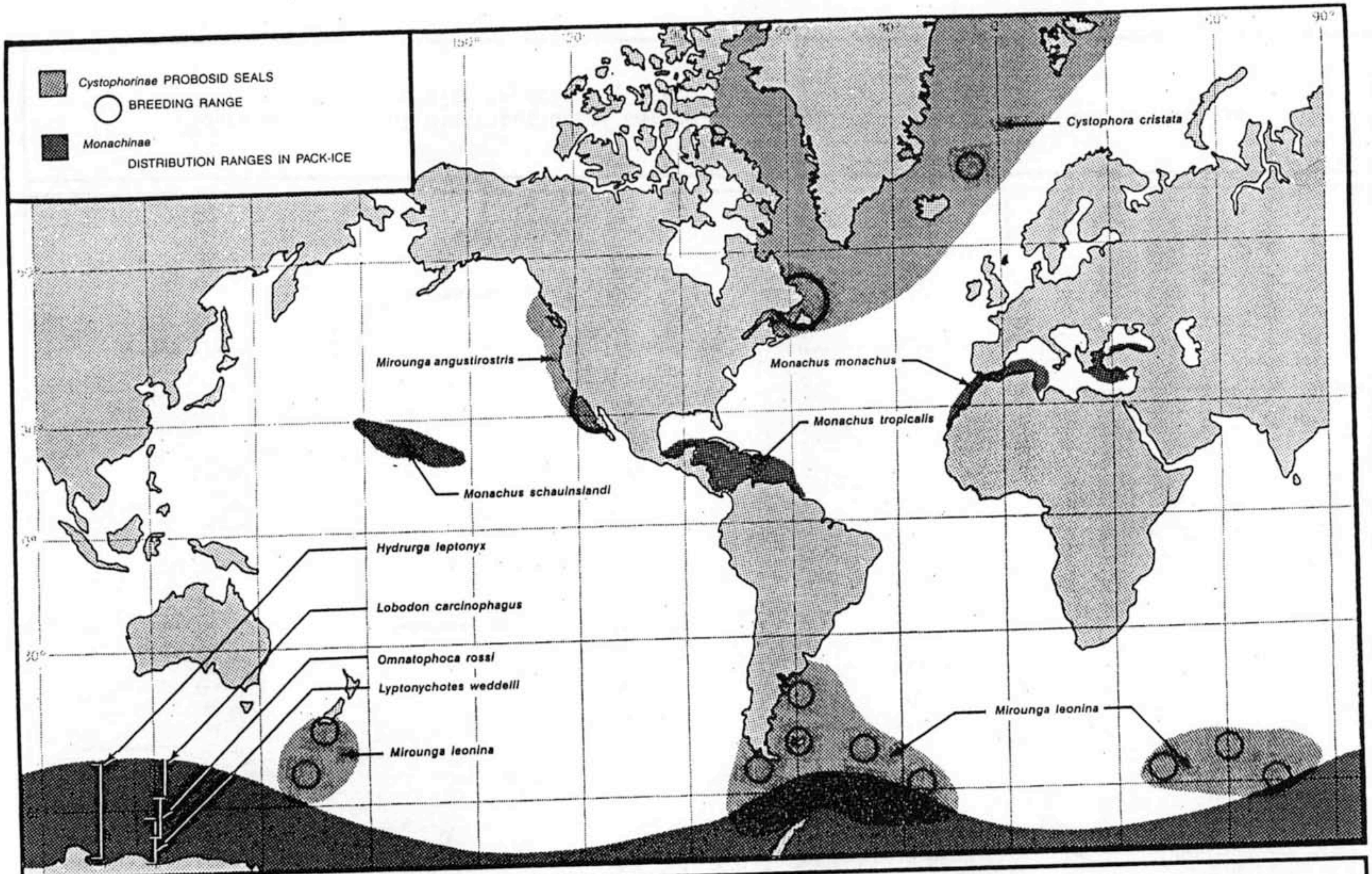


Figure 2b. General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).

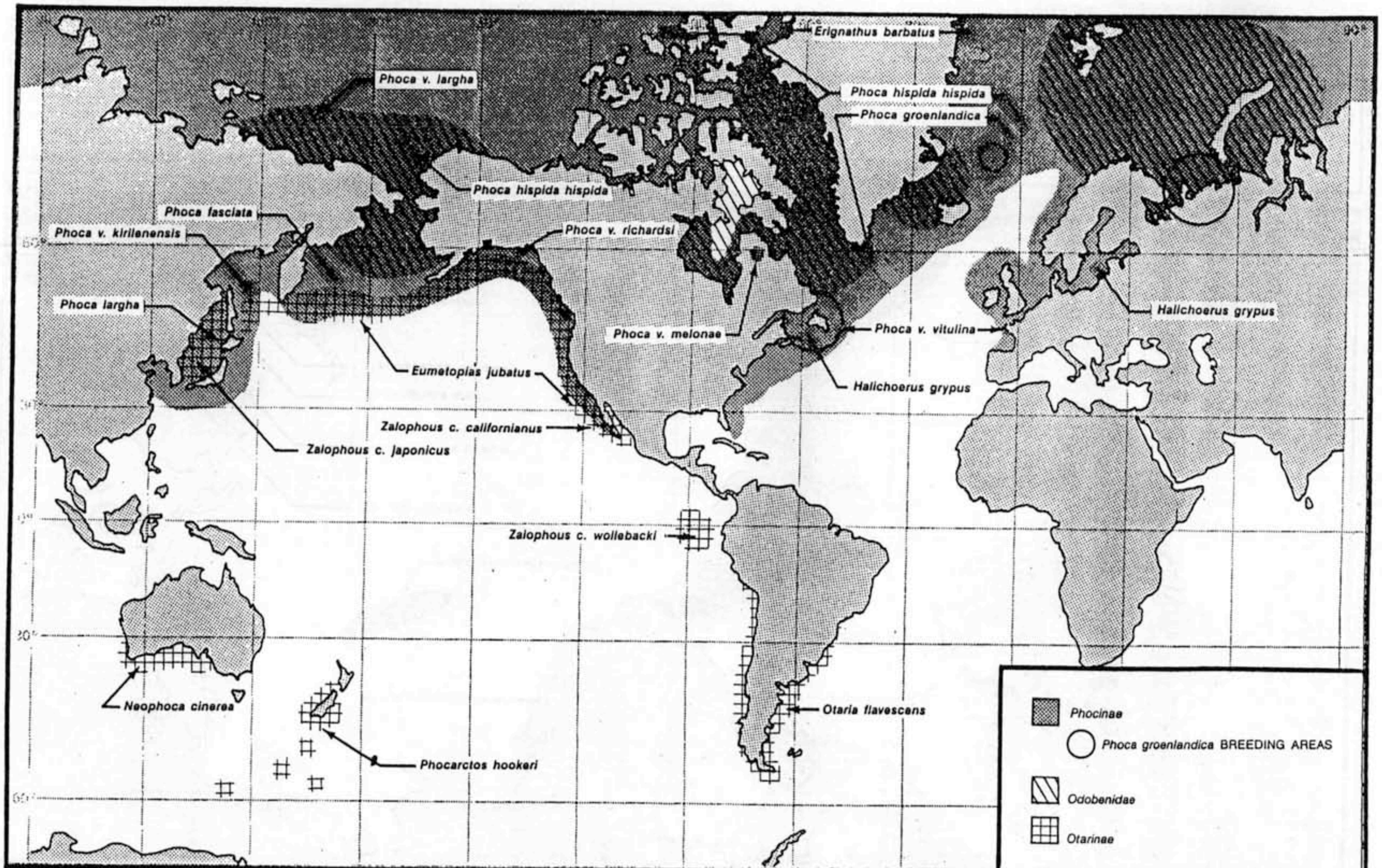


Figure 2c. General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).

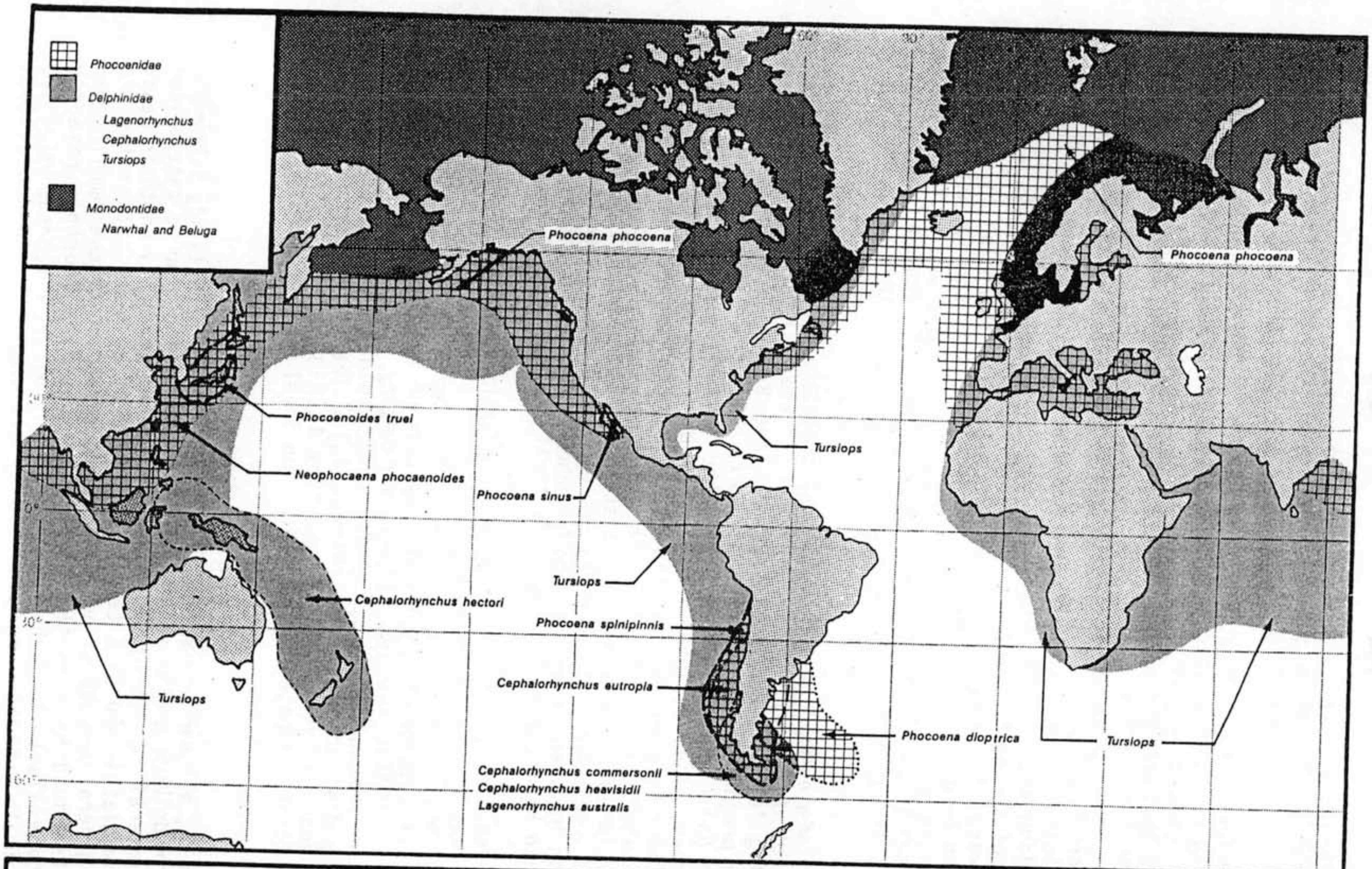


Figure 2d. General distribution of marine mammals that rely on blubber for insulation and are site tenacious (Category 2).

whale (Eschichtius robustus) populations have regular migratory movements that render them vulnerable to major impacts when they are aggregated in high concentrations on their breeding grounds or along migration corridors.

There are four remnant populations of bowhead whales (Balaena mysticetus) whose movements are somewhat confined by ice coverage (Figure 3). The most abundant population is in the Canadian Arctic and moves from Banks Island and the Beaufort Sea in the summer, to the Chukchi Sea through the straits to the Bering Sea in the winter. The second population is in the Sea of Okhotsk. The third population moves between Baffin Bay and Hudson Bay in eastern Canada, traveling into the Labrador Sea in winter. The smallest population occurs in the Greenland and Barents Seas, once their primary breeding grounds (Watson 1981). The right whale (B. glacialis; B. australis) of the northern and southern hemispheres, respectively, moves coastally towards the equator in the winter and to the poles in summer. B. glacialis can be observed in the Bay of Fundy from July through September. B. australis can be observed in Patagonia, Argentina from mid-July through November (Watson 1981). All the members of the family Balaenidae are potentially exposed to the impacts of baleen fouling due to their surface feeding techniques.

The gray whale (Eschrichtius robustus) travels approximately 13,000 mi between its breeding grounds and feeding areas (Figure 3). In late September, after spending four months in the Chukchi and Bering Seas they begin to go south with pregnant female leading the way. They travel along the west coast of the United States and arrive in the lagoons of the Baja peninsula in late December. They return north in February and are last seen from the Washington coast in May (Watson 1981). Very little is known about the remnant west Pacific population. The humpback whale (Megaptera novaeangliae) population is composed of discrete stocks which feed in polar regions of both hemispheres and return to the tropics in the winter (Figure 3). Humpbacks can be seen in Hawaii from December to April, in the West Indies from January to March, and off Bermuda in April and May (Watson 1981).

While also listed in category 3, the populations of blue (Balaenoptera musculus; B. brevicaudia), fin (B. physalus), and sei whales (B. borealis), though endangered, are too widely distributed to incur any potential population impacts from ODP activities (Figure 3). Species of the family Physeteridae are the only specific species listed in category 4 (Table 1). It is not likely that any geographically specific event could significantly affect this globally distributed group (Figure 4a). The wide distribution of the other pelagic toothed whale in category 4 (Figure 4b-4d) reduces to a negligible level the potential of population level impacts on these species.

SUMMARY

In summary, all marine mammals as individuals are potentially vulnerable to impacts from drilling and/or accidental oil spills. They can be categorized into four general levels of vulnerability based primarily on their means of thermal regulation and site tenacity (Table 1). These categories are necessarily general because of our limited understanding of the ramifications these impacts could have on the species in question. Further research is needed to evaluate the behavioral and physiological responses exhibited by marine mammals encountering potentially disruptive human activities.

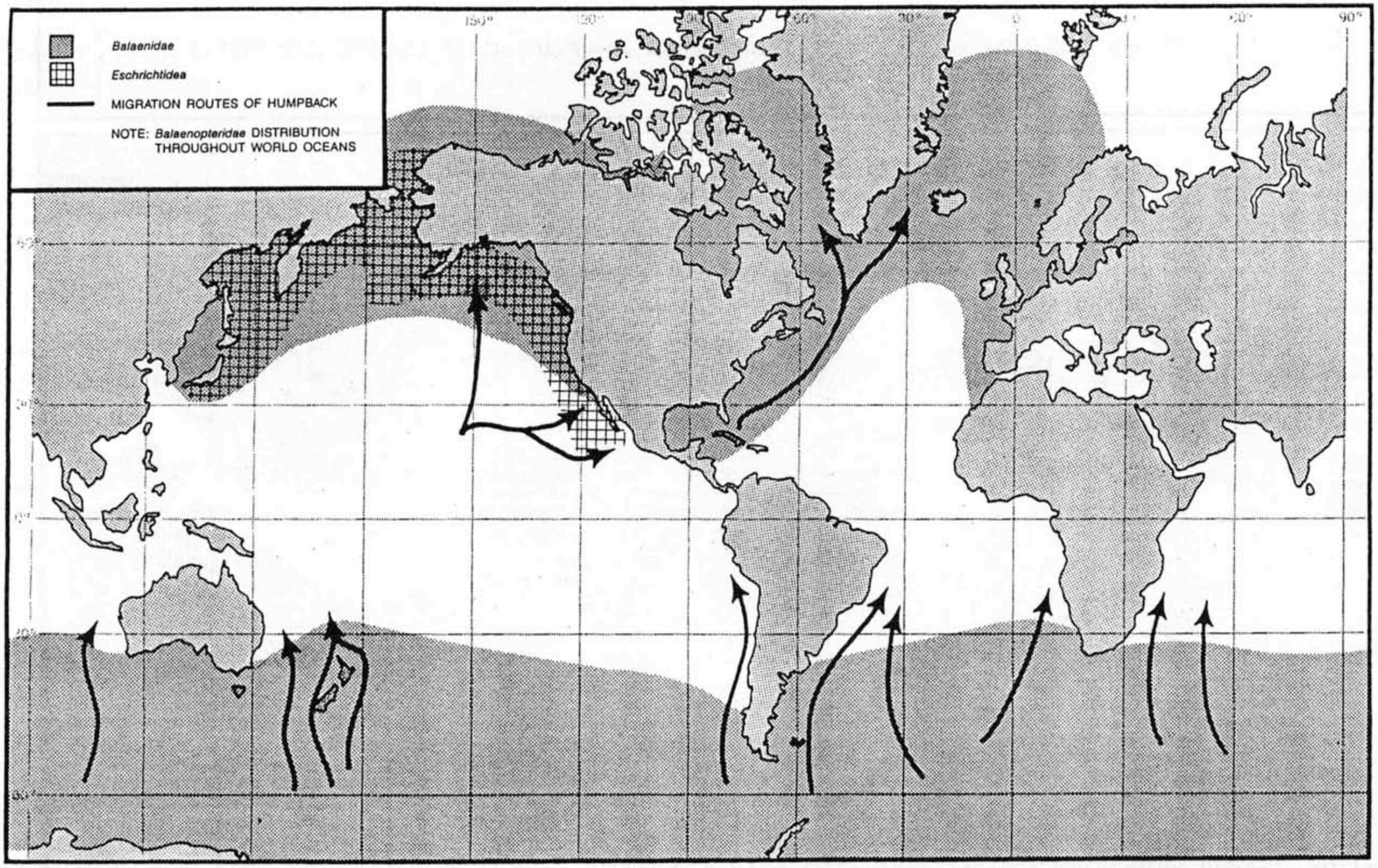


Figure 3. General distribution of the baleen whale (Category 3).

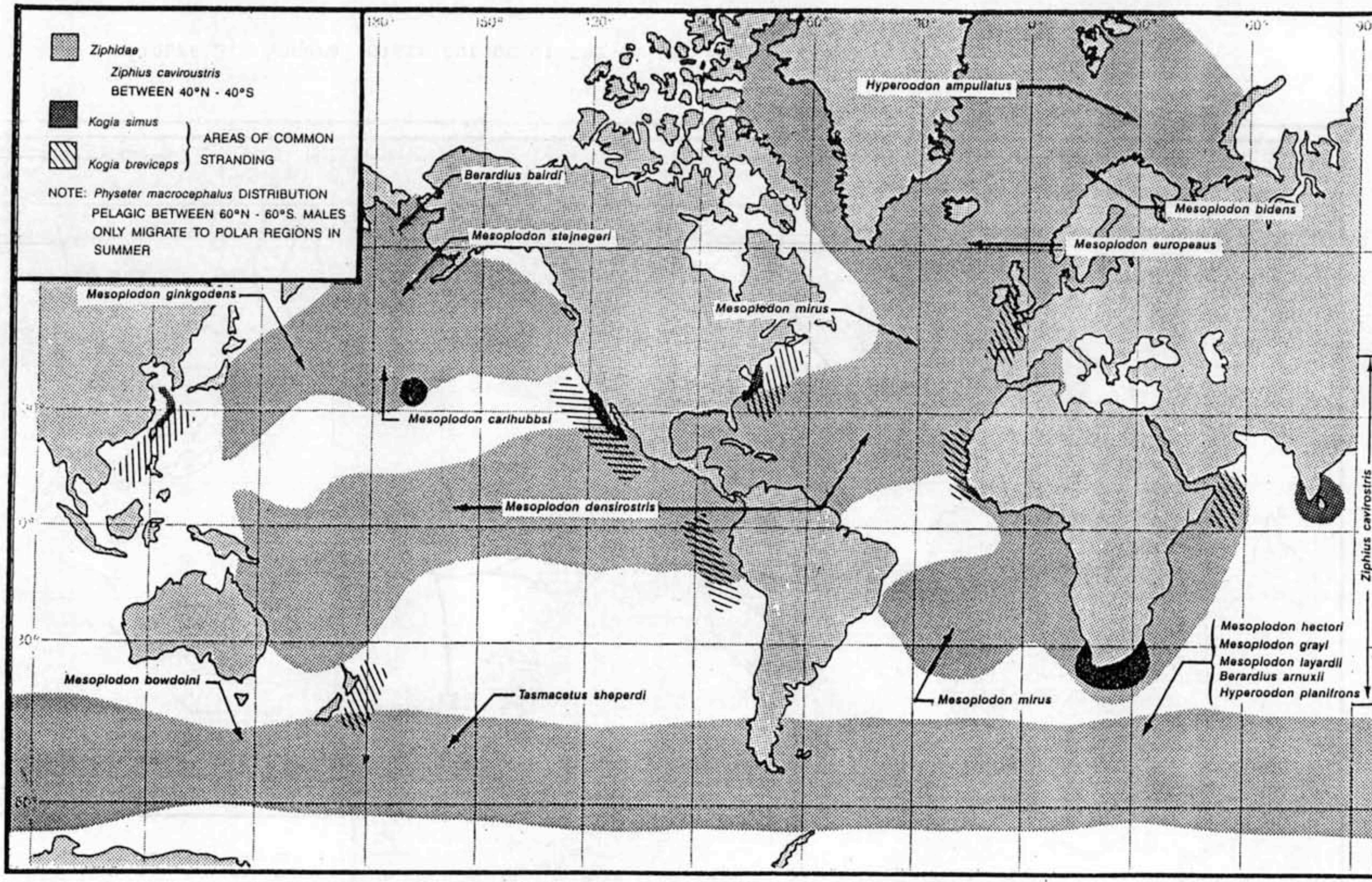


Figure 4a. General distribution of the pelagic toothed whales (Category 4).

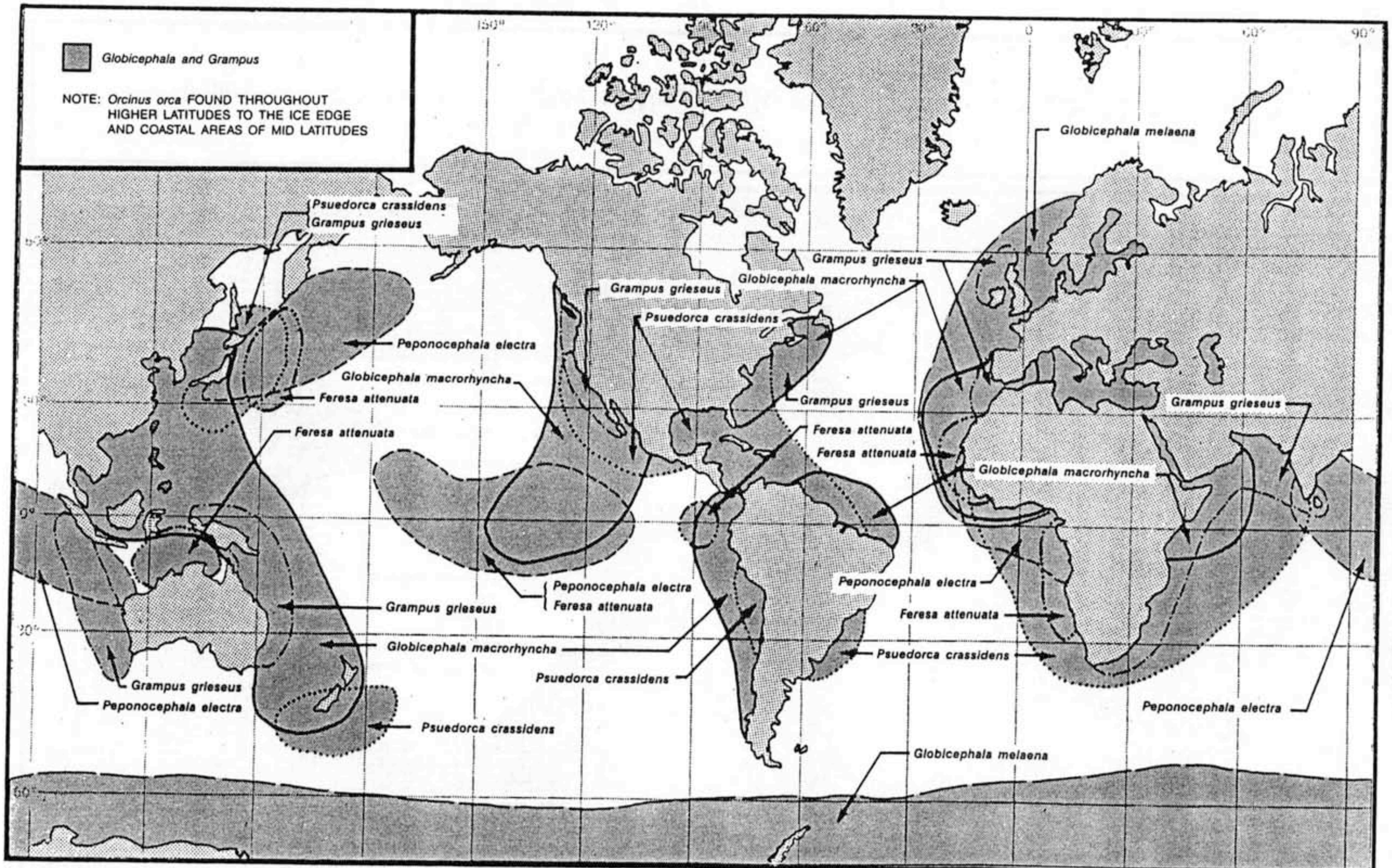


Figure 4b. General distribution of the pelagic toothed whales (Category 4).

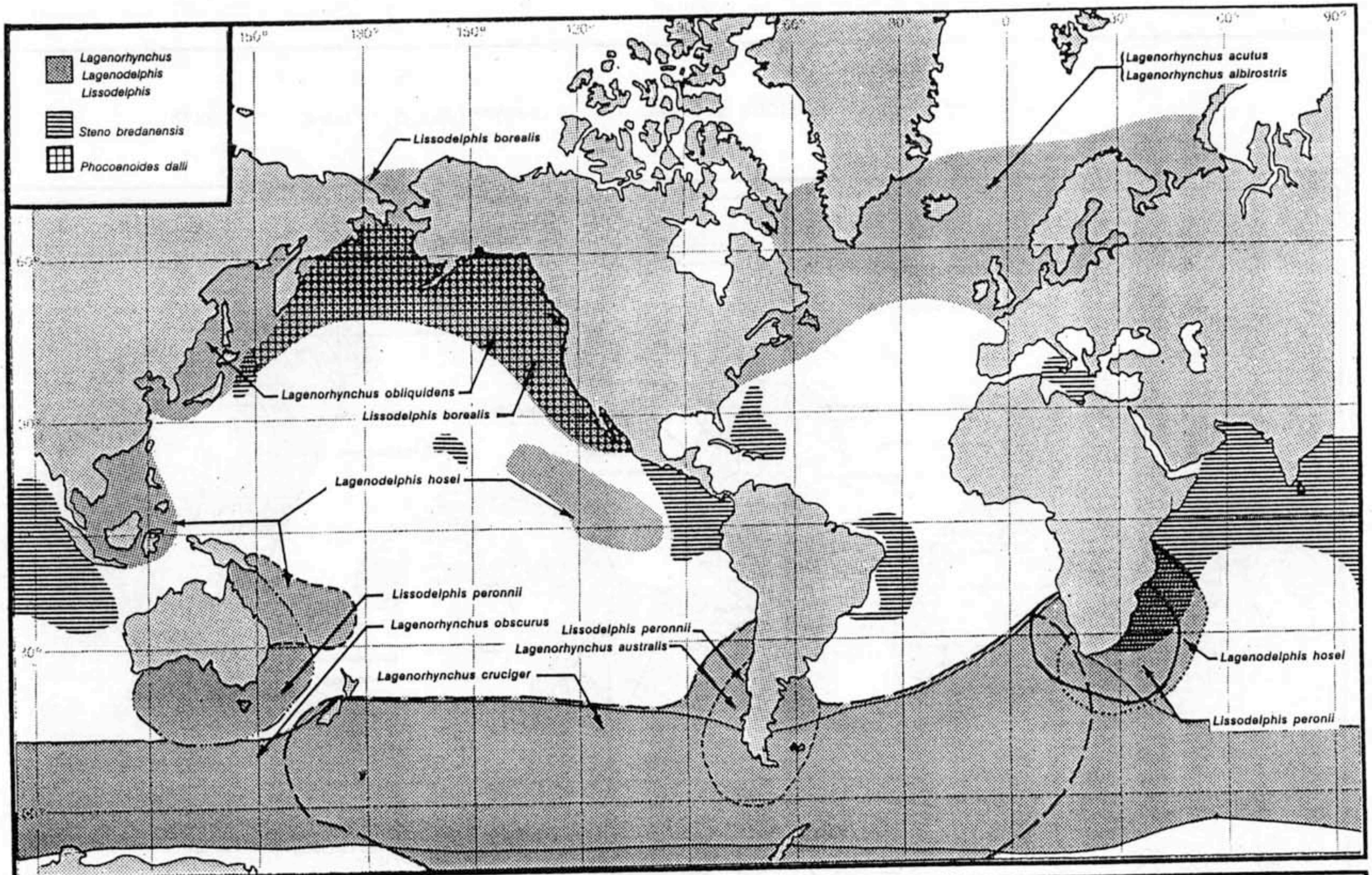


Figure 4c. General distribution of the pelagic toothed whales (Category 4).

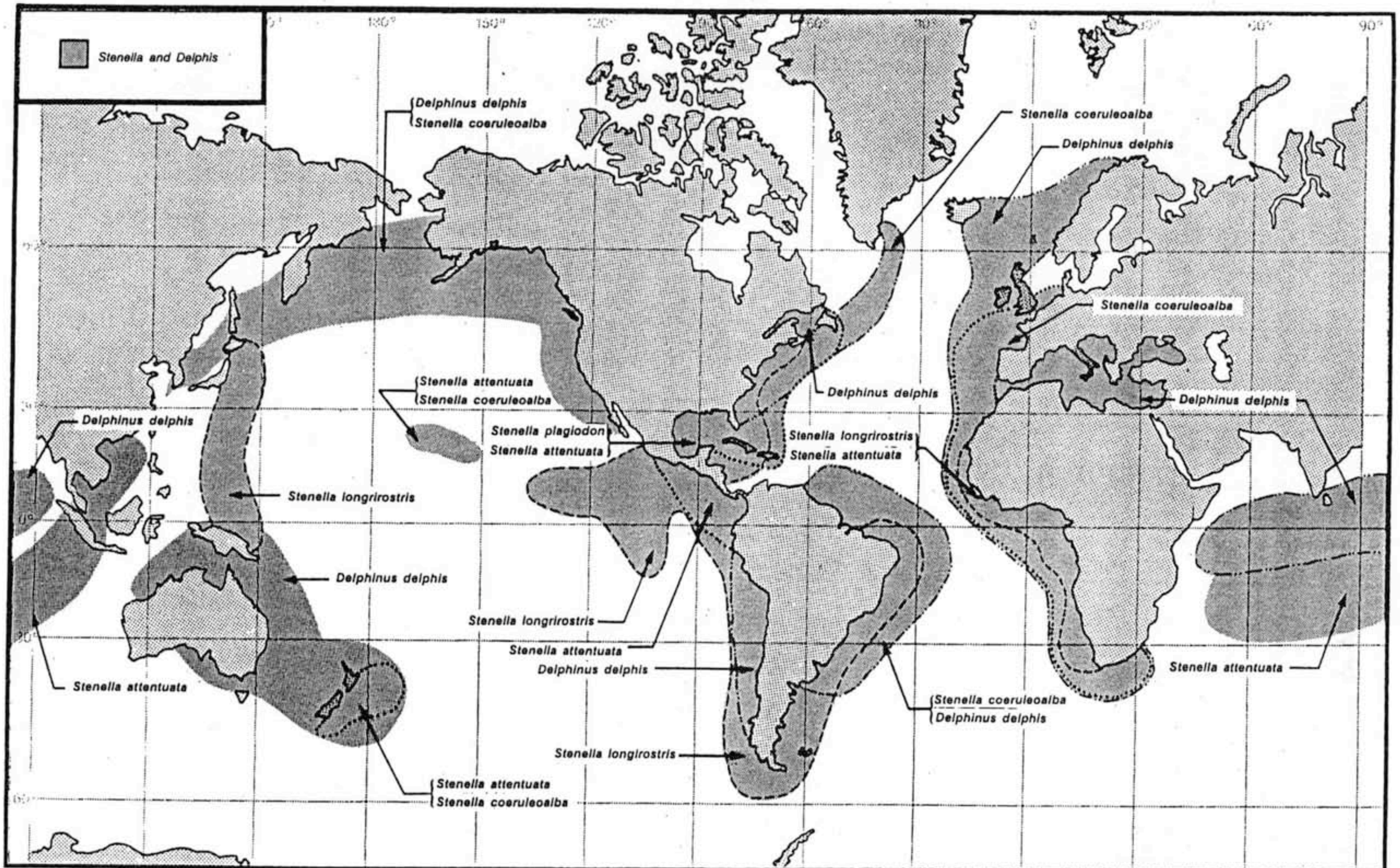


Figure 4d. General distribution of the pelagic toothed whales (Category 4).

However, only those populations that are severely reduced in size and/or can be found in aggregations are vulnerable to population-level impacts as a result of combined impacts with other activities, which cumulatively affect their survival. Those species considered susceptible to population impacts are listed under their taxonomic families within their respective categories of vulnerability (Table 1). The otters and fur seals (Figure 1), Sireniads (Figure 2a), monk seals (Figure 2b), sea lions (Figure 2c), and migratory baleen whales (Figure 3) listed in Table 1 are to be given the most consideration (e.g., accommodation of times of maximum vulnerability such as molting, breeding, pupping) when deciding location and timing of drilling sites.

REFERENCES

* Brown, S.G., R.L. Brownell, Jr., A.W. Erickson, R.J. Hofman, G.A. Llano, and N.A. MacKintosh. 1974. Antarctic mammals. Folio 18. American Geographical Society, New York, NY.

Brownell, R.L. 1978. Ecology and conservation of the marine otter (L. felinan) In: Otters. Proceedings of the First Working Meeting of the Otter Specialist Group. Nicole Duplaix (ed). IUCN Morgas, Switzerland.

Calambokidis, J., J. Pearl, G.H. Steiger, and J.C. Cubbage. 1984. Chemical contaminants in marine mammals from Washington state. NOAA Technical Memorandom NOS OMS 6 Rockville, MD.

Carpenter, C.P., D.L. Geary, Jr., R.C. Myers, D.J. Nachreiner, L.J. Sullivan, and J.M. King. 1978. Petroleum hydrocarbon toxicity studies XVII. Animal response to n-nonane vapor. Toxicol. Appl. Pharmacol. 44:53-61.

Davis, J.E., and S.S. Anderson. 1976. Effects of oil pollution on breeding grey seals. Mar. Pollut. Bull. 7:115-118.

Englehart, F.R., J.R. Geraci, and T.G. Smith. 1977. Uptake and clearance of petroleum hydrocarbons in the ringed seal, Phoca hispida. J. Fish. Res. Board. Can. 34:1143-1147.

* Erickson, A.W. 1977. Marine mammalogy notebook. School of Fisheries, University of Washington, Seattle, WA. 149 pp.

* Evans, W.E. 1983. Distribution and differentiation of stocks of Delphinus delphis in the northeastern Pacific. In: Mammals of the Sea. Vol. IV. FAC Fisheries Series No. 5. Rome, Italy.

Fletcher, J.L. 1971. Effects of noise on wildlife and other animals. EPA-NTID 300.5. U.S. Environmental Protection Agency, Washington, DC. 74 pp.

* Gaskin, D.E. 1982. The ecology of whales and dolphins. Heinemann, Exeter, NH. 459 pp.

Geraci, J.R., and T.G. Smith. 1979. Direct and indirect effects of oil on ringed seals (Phoca hispida) of the Beaufort Sea. J. Fish. Res. Board Can. 33:1976-1984.

Geraci, J.R., and D.J. St. Aubin. 1980. Offshore petroleum resource development and marine mammals: a review and research recommendations. Mar. Fish. Rev. Nov. 12 pp.

* Hammond, P.S., and J.L. Laake. 1983. Trends in abundance of dolphins in purse-seine fishery in the eastern tropical Pacific, 1977-1981. 32nd Rep. Int. Whal. Comm., Cambridge, UK.

Hodgins, H.O., B.B. McCain, and J.W. Hawkes. 1977. Marine fish and invertebrate diseases, host disease resistence and pathological effects of petroleum. pp. 95-173. In: Effects of Petroleum on Arctic and Subartic Marine Environments and organisms. Vol. II. Biological Effects. D.C. Malins (ed). Academic Press, New York, NY.

Husar, S.L. 1977. Trichechus inunguis. pp. 1-4. In: Mammalian Species. No. 72. American Society of Mammalogists.

Husar, S.L. 1978a. Dugong dugong. pp. 1-7. In: Mammalian Species. No. 88. The American Society of Mammologists.

Husar, S.L. 1978b. Trichechus manatus. pp. 1-5. In: Mammalian Species. No. 93. The American Society of Mammologists.

Husar, S.L. 1978c. Trichechus senegalensis. pp. 1-3. In: Mammalian Species. No. 89. The American Society of Mammologists.

* Jones, L., G.C. Bouchet, D.W. Rice, and A.A. Wolman. 1984. Progres report on studies of the incidental take of marine mammals, particularly Dall's porpoise, by the Japanese salmon fisheries 1978-1983. National Marine Mammals Laboratory. Seattle, WA. 63 pp.

Kenchington, R.A. 1972. Observations on the digestive system of the dugong (Dugong dugong). J. Mammal. 53:884-887.

Kenyon, K.W. 1978. Sea otter. pp. 226-235. In: Marine Mammals of Eastern North Pacific and Arctic Waters. Delphine Haley (ed). Pacific Search Press, Seattle, WA.

King, J.E. 1964. Seals of the world. Trustees of the British Museum, London, UK. 154 pp.

King, J.E. 1983. Seals of the world. (2nd edition). Cornell University Press, Ithaca, NY. 240 pp.

Kooyman, G.L., R.W. Davis, and M.A. Castelini. 1977. Thermal conductance of immersed pinniped and sea otter pelts before and after oiling with Prudhoe Bay crude. pp. 151-157. In: Fate and Effects of Petroleum Hydrocarbons in Marine Ecosystems and Organisms. D.A. Wolfe (ed). Pergammon Press, Oxford, UK.

Lentfer, J.W. 1978. Polar bear. pp. 218-225. In: Marine Mammals of Eastern North Pacific and Arctic Waters. D. Haley (ed). Pacific Search Press, Seattle, WA.

Ling, J.K. 1974. The integument of marine mammals. pp. 1-44. In: Functional Anatomy of Marine Mammals, Vol. 2. R.J. Harrison (ed). Academic Press, London, UK.

Moore, S.F., and R.L. Dwyer. 1974. Effects of oil on marine organisms: a critical assessment of published data. Water Res.:819-827.

Nishiwake, M., and A. Sasao. 1977. Human activities disturbing the natural migration routes of whales. Sci. Rep. Whales Res. Inst. 29:113-120.

Norris, K.S. 1969. The ecolocation of marine mammals. pp. 391-423. In: The Biology of Marine Mammals. H.T. Anderson (ed). Academic Press, New York, NY.

* Perrin, W.F., T.D. Smith, and G.T. Sakagawa. 1983. Status of populations of spotted dolphin Stenella attentuata and spinner dolphin S. longirostris in the Eastern tropical Pacific. In: Mammals of the Sea. Vol. IV. FAO Fisheries Series #5. Rome, Italy.

Raumprashad, F., S. Corey, and K. Ronald 1973. The harp seal, Pagophilus groenlandicus XIV. The gross and microscopic structure of the middle ear. Can. J. Zool. 51:589-600.

* Ridgway, S., and R.J. Harrison. 1981a. Handbook of marine mammals. Vol. I. The Walrus, Sea Lions, Fur Seals, and Sea Otter. Academic Press, New York, NY. 235 pp.

* Ridgway, S., and R.J. Harrison. 1981b. Handbook of marine mammals. Vol. II. Seals. Academic Press, New York, NY. 359 pp.

Roesijadi, G., J.W. Anderson, and J. W. Blaylock. 1978. Uptake of hydrocarbons from marine sediments contaminated with Prudhoe Bay crude oil: influence of feeding type of test species and availability of polycyclic aromatic hydrocarbons. J. Fish. Res. Board Can. 35:608-614.

Salter, R.E. 1979. Site utilization, activity budgets, and disturbance responses of Atlantic walruses during terrestrial haul-out. Can. J. Zool. 57: 1169-1180.

Smith, T.G., and J.R. Geraci. 1975. The effect of contact and ingestion of crude oil on ringed seals of the Beaufort Sea. Beaufort Sea Tech. Rep. 5. 67 pp.

Stegeman, J.J., and J.M. Teal. 1973. Accumulation, release, and retention of petroleum hydrocarbons by the oyster (Crassostrea virginica). Mar. Biol. (Berl.) 22:37-44.

* U.N. Food and Agriculture Organization. 1978. Mammals in the seas. Vol. I. Report of the FAO advisory committee on marine resources research - working party on marine mammals. FAO Fisheries Series No. 5. Rome, Italy.

* U.N. Food and Agriculture Organization. 1979. Mammals in the Seas. Vol. II. Pinniped species summaries and report on sirenians. FAO Fisheries Series No. 5. Rome, Italy. 151 pp.

U.S. Department of Commerce. 1983. Draft management plan and environmental impact statement for the proposed Hawaii Humpback Whale National Marine Sanctuary. NOAA, Washington, DC. 172 pp.

U.S. Department of Commerce. 1984. Marine Mammal Protection Act of 1972. Annual Report 1983/84. Washington, DC. 146 pp.

U.S. Fish and Wildlife Service. 1985. Endangered Species. Technical Bulletin Vol. X, No. 2. Washington, DC. pp. 1-12.

Watson, L. 1981. Sea guide to whales of the world. E.P. Dutton, New York, NY. 302 pp.

Williams, T.D. 1978. Chemical immmobilization, baseline hematological parameters and oil contamination in the sea otter. U.S. Marine Mammal Commission Report MMC-77/06 NTIS, Springfield, VA. 27 pp.

* References were used to compile the marine mammal distribution maps only.

APPENDIX B

PROCESSES AFFECTING WEATHERING AND CHEMICAL FATE
OF OIL IN THE MARINE ENVIRONMENT

APPENDIX B

PROCESSES AFFECTING WEATHERING AND CHEMICAL FATE OF OIL IN THE MARINE ENVIRONMENT

The fate of spilled oil can be affected by several processes: advection, spreading, evaporation, dissolution, emulsification, dispersion, auto-oxidation, biodegradation, and sinking/sedimentation (Huang 1983). The composition of the spilled oil and its temperature will determine the manner in which the physical phenomena will act on the oil under the prevailing weather and sea state. The following characteristics of crude oil are of primary interest:

- Specific density - determines rate of slick expansion
- Ratio of light vs. heavy molecular weight components - determines evaporation and weathering rates
- Pour point/waxiness/naphthenes contnet of weathered crude - determines stability of water-in-oil emulsions.

Figure 1 schematically shows the effects of natural weathering processes on oil.

PHYSICAL PROCESSES

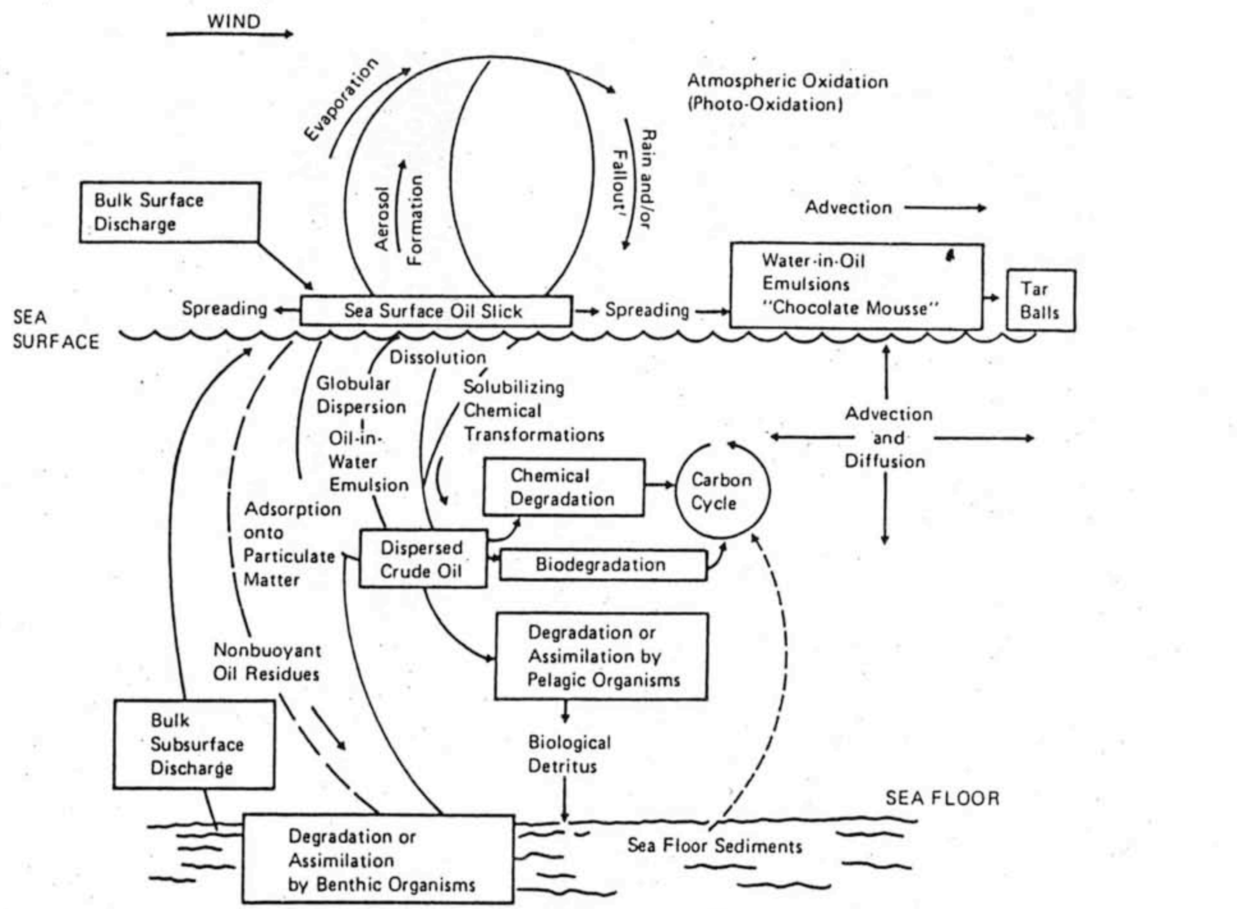
During a drilling operation blowout, oil can enter the marine environment in two ways: at the surface, by rising through the apparatus, or more likely at the borehole on the seafloor. Once in contact with seawater, the oil is subject to the physical weathering processes of spreading, drift, evaporation, dissolution, emulsification, dispersion, and sedimentation.

Spreading

Oil begins spreading horizontally due to gravitational forces (Fay 1969). This movement is first counterbalanced by inertial forces, and then by viscous or frictional forces. When the slick thins sufficiently, surface tensions at the oil-air and oil-water interfaces become dominant and overcome the viscous forces. This continues until the slick ceases to spread. The spreading process is enhanced by warmer water temperatures and increased wave action. Crude oil has been observed to form two distinct phases: a thick oil phase [1-20 mm (0.04-0.8 in) thick], consisting of highly viscous emulsified oil, and a thin oil or blue sheen phase [0.01-0.001 mm thick]. The thick oil appears on the surface as several small slicks or strips, which continue to break down into smaller and smaller patches of oil (Audunson et al. 1980).

Drift

Wind, waves, and surface currents control the drift, or advection of an oil slick. The ability to predict the drift behavior of an oil slick



REFERENCE: NATIONAL RESEARCH COUNCIL 1985

Figure 1. Weathering and dispersion effects on oil in the marine environment.

depends on the availability of accurate wind and current data, and on a good empirical model. Several drift models exist, but they may only be realistically used to assess the risk of impacts to shorelines (Wheeler 1978). The use of such models is generally limited to nearshore spills, and would probably be of little value for predicting the fate of an open ocean spill.

Evaporation

Oil released to the water surface is immediately subject to evaporation. Because evaporation can account for the loss of approximately 60 percent of spilled crude oil (Wheeler 1978), it is an extremely important process affecting the lifetime of the spill and the extent to which environmental resources might be impacted. The amount and rate of evaporation depend primarily on the percentage of volatile components in the oil. In general, the volatile components are more toxic to marine organisms than are the non-volatile components. Thus, weathering protects marine organisms against exposure to the potentially damaging, toxic components in crude oil.

Dissolution

Dissolution is the process whereby oil is dissolved into the water column by natural or chemically induced dispersion. Typically, the volatile crude oil components that are toxic to marine organisms (i.e., aromatics and low molecular weight alkanes) are also the most readily soluble. Fortunately for marine biota, the volatile components are likely to evaporate at a much greater rate when they are dissolved.

Emulsification

During emulsification, water droplets are dispersed into the oil medium, turning the oil into a thick mixture commonly referred to as "chocolate mousse." This mixture may contain up to 75 percent water. The emulsification process is controlled by wave mixing action and water temperature. Emulsification is important because emulsions spread much more slowly than do pure oil slicks and, as a result, are less susceptible to other forms of weathering.

Oil escapement at the seafloor results in a greater degree of initial emulsification than does a similar event on the water surface. The degree of emulsification depends primarily on water depth, oil type, and the amount of gaseous emissions. In general, the extent of emulsification increases with water depth and amount of gaseous emissions. Experimental evidence suggests, however, that a blowout occurring at depths greater than 800 m (2,625 ft) would be devoid of gas. Oil from such a well would rise slowly in large drops and appear at the surface as combination of a slick, an emulsion, and in suspension as small droplets (Wadhaus 1981).

Dispersion

Dispersion of oil particles into the water column is important because it largely determines the lifetime of a slick. Wave action is thought to be the primary factor controlling dispersion rates. It is likely that the dispersion rate is a function of the oil slick thickness, oil-water interfacial tension, sea state, and, especially, the fraction of the sea that is covered by breaking waves (Huang 1983). The dispersion mechanisms change with slick thickness (McKay et al. 1980). A relationship was developed between the probabilities of breaking waves and oil droplets remaining dispersed in the water column (Aravamudan et al. 1982). Breaking waves are thought to cause the oil layer to be propelled into the water column, thus forming a "shower" of oil droplets. Most of the oil particles rise again to the slick and coalesce there, but some of the smaller oil droplets diffuse downwards and become permanently incorporated into the water column. When oil is released from the sea bottom, dispersion is also a function of depth and current velocity.

Sinking/Sedimentation

As oil weathers, its specific gravity may exceed that of water, causing it to sink. However, weathering is probably a factor of minor importance. A more important factor is probably adhesion to particulate matter, and subsequent sinking. Type, size, and load of sediment; salinity; concentrations of sulphur and organic matter in the oil; and degree of agitation affect the adsorption-desorption process. Zooplankton and other organisms may also contribute to sedimentation by ingesting and excreting oil droplets and bits of tar.

CHEMICAL/BIOCHEMICAL PROCESSES

Long-term degradation of crude oil is accomplished by chemical and biochemical action. The two major chemical/biochemical degradation processes are described below.

Auto-Oxidation

The term auto-oxidation includes chemical oxidation and photo-oxidation. Photo-oxidation is the more important of the two. During both processes, hydrocarbons are oxidized through the formation of water-soluble intermediate or end products. The rate of oxidation depends primarily on the intensity and amount of sunlight, degree of emulsification, and the type of oil. Oxidation may occur over weeks or months with only a minor reduction in oil volume. Oxidation products (e.g., acids, alcohols, carbonyl compounds, or metal salts) are usually water-soluble and subject to dilution.

Biodegradation

Biodegradation proceeds slowly, but it is the main process by which spilled oil is removed from the marine environment. Species of bacteria that biodegrade oil are ubiquitous, and use the crude oil as a metabolic energy source. Since bacteria also need oxygen, biodegradation takes place mainly at the oil-water interface. Because it is a slow process, biodegradation is often neglected when assessing the short-term (i.e., 15-30 days) fate of spilled oil.

REFERENCES

Fay, J.A. 1969. The spread of oil slicks on a calm sea. pp. 53-63. In: Oil on the Sea. D.P. Hoult (ed). Plenum Press, New York, NY.

Huang, J.C. 1983. A review of the state-of-the-art of oil spill fate/ behavior models. pp. 313-322. In: Proc. 1983 Oil Spill Conference, San Antonio, Texas. API Publ. No. 4356. American Petroleum Institute, Washington, DC.

Mackay, D., and P.J. Leironen. 1977. Mathematical model of the behavior of oil spills on water with natural and chemical dispersion. EPS-3-EC-77-19. Environmental Protection Service, Fisheries and Environment, Canada.

National Research Council 1985. Oil in the sea: impacts, fates, and effects. Steering Committee for the Petroleum in the Marine Environment Update. National Academy Press, Washington, DC. 601 pp.

Wadhaus, P. 1981. Oil and ice in the Beaufort Sea- the physical effects of a hypothetical blowout. pp. 299-318. In: Petroleum in the Marine Environment: PETROMAR 80. Association Europeene Oceanique. Billing and Sons, London, UK. 788 pp.

Wheeler, R.B. 1978. The fate of petroleum in the marine environment. Special report. Exxon Production Research Company. 32 pp.

APPENDIX C

LIST OF AGENCIES, ORGANIZATIONS, AND INDIVIDUALS
WHO REQUESTED OR RECEIVED THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

APPENDIX C

LIST OF AGENCIES, ORGANIZATIONS, AND INDIVIDUALS
WHO REQUESTED OR RECEIVED THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

The National Science Foundation
1800 G Street, NW
Washington, DC 20550

M. Grant Gross, DD/OCE, Rm. 609
Lou Brown, OCE, Rm. 609
Robert Wall, Head/OSRS, Rm. 611
Curt Collins, PO/OSRS, Rm. 606
Dick Lambert, PO/OSRS, Rm. 606
John Morrison, PO/OSRS, Rm. 606
Don Heinrichs, MG&G/OSRS, Rm. 606
Bruce Malfait, MG&G/OSRS, Rm. 606
Ed Houde, BO/OSRS, Rm. 611
Mary Tyler, BO/OSRS, Rm. 611
Joan Mitchell, BO/OSRS, Rm. 606
Phil Taylor, BO/OSRS, Rm. 611
Neil Andersen, CO/OSRS, Rm. 609
Rodger Baier, CO/OSRS, Rm. 611
Adair Montgomery, CEM, Rm. 641-B
James Callahan, BBS, Rm. 1140
Richard Morrison, PRA, Rm. 1229
Edward Hayes, OBAC, Rm. 425
Paul Herer, ENG, Rm. 1110

Garry Brass, ODP/OCFS, Rm. 613
Charles Myers, DDP, Rm. 627
Allen Shinn, OLPA, Rm. 527
Cecilia Spearing, MPS, Rm. 305
H.L. Clark, OT/OCFS, Rm. 613
Dick West, OT/OCFS, Rm. 613
Peter E. Wilkniss, DD/DPP, Rm. 620
Joseph Bennett, Head/PCIS/DDP, Rm. 628
Ronald LaCount, Manager/POS/DDP, Rm. 627
Francis Williamson, Chief Scientist/DDP, Rm. 620
James F. Hayes, DD/EAR, Rm. 602
Ian MacGregor, (D)DD/EAR, Rm. 602
Bill Bruning, DGC, Rm. 630
Bill Bryant, DGC, Rm. 630
Art Kusinski, OGC, Rm. 501

Dr. John Knauss
Graduate School of Oceanography
University of Rhode Island
Narragansett, RI 02882-1197

Dr. Friedrich Bender
Bundesanstalt fur Geowissenschaften und Rohstoffe
D-3000 Hannover 51
Postfach 510153
Federal Republic of Germany

Dr. Alan Berman
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

Dr. Bernard Biju-Duval
IFREMER
66, Avenue d'Iena
Paris 75116, France

Dr. John Bowman
Natural Environment Research Council
Polaris House, North Star Avenue
Swindon, Wilts SN2 1EU, U.K.

Dr. Douglas Caldwell
Oregon State University
College of Oceanography
Corvallis, OR 97331

Dr. G. Ross Heath
College of Ocean and Fishery Sciences, HA-40
University of Washington
Seattle, WA 98195

Dr. Charles E. Helsley
Hawaii Institute of Geophysics
University of Hawaii
2525 Correa Road
Honolulu, HI 96822

Dr. William W. Hutchison
Department of Energy, Mines, and Resources (EMR)
Earth Sciences Sector
580 Booth Street
Ottawa, Ontario K1A 0E4, Canada

Dr. Akihiko Hattori
University of Tokyo
1-15-1, Minamidai
Nakano-Ku, Tokyo 164, Japan

Dr. Arthur Maxwell
Institute for Geophysics
University of Texas at Austin
4920 North I.H. 35
Austin, TX 78751

Dr. William J. Merrell
Department of Oceanography
Texas A&M University
College Station, TX 77843

Dr. William A. Nierenberg
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, CA 92093

Dr. Barry Raleigh
Lamont-Doherty Geological Observatory
Palasades, NY 10964

Dr. John Steele
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Dr. Jan Stel
Netherlands Council of Oceanic Research
P.O. Box 19121
NL-1000 GC Amsterdam
Netherlands

Dr. Roger Larson
Graduate School of Oceanography
University of Rhode Island
Narragansett, RI 02882-1197

Ms. Joyce M.T. Wood, Chief
Ecology and Conservation Division
Office of Policy and Planning
National Oceanic and Atmospheric Administration
Department of Commerce - Rm. H6111
Herbert Hoover Building
14th Street and Constitution Avenue, NW
Washington, DC 20230-0001

Director
Environmental Protection and Occupational Safety and Health Division (OP-453)
Office of the Chief of Naval Operations
Department of the Navy
Building 200, Rm. S-3
Washington Navy Yard
Washington, DC 200374-0001

Director
Office of Environmental Compliance (PE-25)
Department of Energy
Room 4G-085
Forrestal Building
1000 Independence Avenue, SW
Washington, DC 20585-0001

Departmental Environmental Officer
Office of Management Analysis and Systems
Department of Health and Human Services, Rm. 542E
Hubert H. Humphrey Bldg.
200 Independence Avenue, SW
Washington, DC 20201-0001

Director
Office of Environmental Health
Department of State
Rm. 4325 - State Department Building
21st and C Streets, NW
Washington, DC 20520-0001

Head
Environmental Activities Group (MAR-700.4)
Maritime Administration
Room 2120 - Nassif Building
400 Seventh Street, NW
Washington, DC 20590-0001

Chief
Environmental Compliance and Review Branch (C-WP-3)
Office of Marine and Environment Systems
U.S. Coast Guard
2100 Second Street, SW
Washington, DC 20593-0001

Director
Office of Federal Activities
Environmental Protection Agency
Rm. 2119-I
401 M Street, SW
Washington, DC 20460-0001
Attn: Mrs. Jan Shaw (A-104)

Director
Office of Energy and Environmental Impact
Federal Maritime Commission
1100 L Street, NW
Washington, DC 20573-0001

General Counsel
Marine Mammal Commission, Rm. 307
1625 I Street, NW
Washington, DC 20006-3054
Attn: David Laist

Environmental Compliance Officer
Facilities Engineering Division
National Aeronautics and Space Administration
Code NXG, Room 5031
100 Maryland Avenue, SW
Washington, DC 20546-0001

Staff Director
Environmental Studies Board
National Academy of Sciences
Rm. JH-804
2101 Constitution Avenue, NW
Washington, DC 20418-0001

Chief
Division of Environmental Coordination
Fish and Wildlife Service
Department of the Interior
Rm. 402, Hamilton Building
1375 K Street, NW
Washington, DC

Chief
Review Unit
Environmental Affairs Program (MS-423)
U.S. Geological Survey
Department of the Interior, Rm. 2D318
12201 Sunrise Valley Drive
Reston, VA 22092-9998

Chief
Offshore Environmental Assessment Division
Minerals Management Service
Department of the Interior
Interior Building, Rm. 2044
18th and C Streets, NW
Washington, DC 20240-0001

Mr. Douglas W. Beach
Northeast Region
National Marine Fisheries Service
U.S. Department of Commerce
14 Elm Street
Gloucester, Mass. 01930

Ms. Patricia A. Carter, FM 412
Office of Protected Species and Habitat Conservation
National Marine Fisheries Service
U.S. Department of Commerce
Washington, DC 20235

Oceanic Society
1536 16th Street, NW
Washington, DC 20036
Attn: Cliff Curtis

Center for Environmental Education
1624 9th Street, NW
Washington, DC 20001

Defenders of Wildlife
1244 19th Street, NW
Washington, DC 20036

Friends of the Earth
530 Seventh Street, SE
Washington, DC 20003

Greenpeace
1611 Connecticut Avenue, NW
Washington, DC 20009

National Audubon Society
645 Pennsylvania Avenue, SE
Washington, DC 20003

National Parks and Conservation Association
1701 18th Street, NW
Washington, DC 20009

National Wildlife Federation
1412 16th Street, NW
Washington, DC 20036

Natural Resources Defense Council
1350 New York Avenue, NW
Suite 300
Washington, DC 20005

Nature Conservancy
1800 N. Kent Street, #800
Arlington, VA 22209

Resources for the Future
1755 Massachusetts Avenue, NW
Washington, DC 20036

Sierra Club
330 Pennsylvania Avenue, SE
Washington, DC 20003

The Wilderness Society
1400 I Street, NW, 10th Floor
Washington, DC 20005

International Associate of Fish and Wildlife Agencies
1412 16th Street, NW
Washington, DC 20036

American Fisheries Society
5410 Grosvenor Lane
Bethesda, MD 20814

American Cetacean Society
P.O. Box 2639
San Pedro, CA 90731

Antarctic and Southern Ocean Coalition
1845 Calvert Street, NW
Washington, DC 20009

American Environmental Safety Council
1090 Vermont Avenue, NW
Washington, DC 20036

Conservation Foundation
1717 Massachusetts Avenue, NW
Washington, DC 20036

Union of Concerned Scientists
1346 Connecticut Avenue, NW
Suite 1101
Washington, DC 20036

Center for Law and Social Policy
1751 N Street, NW
Washington, DC 20036

International Institute for Environment and Development
1717 Massachusetts Avenue, NW
Suite 302
Washington, DC 20036

American Society of International Law
2223 Massachusetts Avenue, NW
Washington, DC 20008

Environmental Defense Fund
1525 18th Street, NW
Washington, DC 20036

Mr. Reid T. Stone
Assistant Associate Director for International Programs and Strategic/ Critical Minerals
Minerals Management Service
Department of the interior
Pacific OCS Region
1340 West Sixth Street
Los Angeles, CA 90017

Mr. Craig C. Thompson
Deputy Attorney General
Department of Justice
State of California
1515 K Street, Suite 511
Sacramento, CA 95814

Dr. D. James Baker, Jr.
President
Joint Oceanographic Institutions, Inc.
2100 Pennsylvania Avenue
Suite 316
Washington, DC 20037

Mr. Dan Hunt
Joint Oceanographic Institutions, Inc.
2100 Pennsylvania Avenue
Suite 316
Washington, DC 20037

Mr. John H. Clotworthy
Vice President and General Manager
Joint Oceanographic Institutions, Inc.
2100 Pennsylvania Avenue
Suite 316
Washington, DC 20037

Dr. Philip D. Rabinowitz
Ocean Drilling Program
Texas A&M University
College Station, Texas 77843

Dr. Louis E. Garrison
Deputy Director
Ocean Drilling Program
Texas A&M University
College Station, Texas 77843

Dr. George Claypool
Chairman, PPSP
U.S. Geological Survey, MS 977
Box 25046 Denver Federal Center
Denver, Colorado 80225

Dr. June Lindstedt-Siva
Manager, Environmental Sciences
Atlantic Richfield Company
515 South Flower Street
Los Angeles, CA 90071

Sam Dixon
Sea Technology Magazine
Suite 1000
1117 N. 19th Street
Arlington, VA 22209

Fred Jones
IMCO Services
Environmental
5950 North Course Drive
Houston, TX 77072

GSI
P.O. Box 225621
Mail Station 3930
Dallas, TX 75265
Attn: Larry G. Bowles

John Splettstoesser
Minnesota Geological Survey
2642 University Avenue
St. Paul, MN 55114-1057

Robert L. Riouix
Office of Energy & Marine Geology
U.S. Geological Survey
915 National Center
Reston, VA 22092

C.V. Chapman
31-100 DAB
P.O. Box 2819
Dallas, TX 75221

West Lovess
ONR NSTL Station
Bay St. Louis, MS 39529-5004

American Petroleum Institute
1220 L Street, NW, Rm. 876
Washington, DC 20005
Attn: Mrs. Pat Paske

Director
Office of Environmental Project Review
Department of the Interior
Interior Building, Rm. 4241
18th and C Streets, NW
Washington, DC 20240-0001
Attn: Gail Rainey.

Department of Commerce
Ecology and Conservation Division
NOAA
Herbert C. Hoover Building, Rm. 6121
Washington, DC 20230
Attn: Laurie Givens

U.S. Environmental Protection Agency
A-104
401 M Street, SW
Washington, DC 20460
Attn: Dale Manty

Ms. Lee Kimball
International Institute for Environment
and Development
1601 Connecticut Avenue, NW
Suite 202
Washington, DC 20009

Alex Holser
Office of Strategic and International
Minerals
Minerals Management Service
Department of the Interior
(Address incomplete)

Paul Glasoe
Bureau of Oceans and Scientific
Affairs
Office of Food and Natural Resources
Department of State
(Address incomplete)

McClelland Engineering
2140 Eastern Avenue
Ventura, CA 93003
Attn: Ms. Marie Finey

Colorado State University
Libraries
Fort Collins, CO 80523
Attn: Fred Schmidt, Documents
Librarian

Bob Samuels
Minerals Management Service
Mail Stop 645
12203 Sunrise Valley Drive
Reston, VA 22091

R.M. Robinson
Conoco, Inc.
P.O. Box 2197
Houston, TX 77252

Mr. W. Franklin Guy
Environmental Sciences Dept.
UNOCAL
461 S. Boylston Street
Los Angeles, CA 90017

Dr. Paul Johnson
University of Washington
School of Oceanography WB-10
Seattle, WA 98195

Fred Felleman
University of Washington
Cooperative Fishery Research Unit
WH-10
Seattle, WA 98195

Dr. Erdogan Ozturgut
Ozturgut Oceanographics
3006 NE 194th Street
Seattle, WA 98155

Terry Wahl
3041 Eldridge
Bellingham, WA 98225

Mr. J. Sanchez
2615 South Mission
Tucson, AZ 85713

APPENDIX D

COMMENTS RECEIVED ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

UNITED STATES GOVERNMENT

memorandum

DATE: 8 July 1985

REPLY TO ATTN OF: James T. Callahan, APD, Ecosystem Studies Program, NSF

SUBJECT: Review of DEIS for ODP

TO: Adair F. Montgomery, Chairman, CEM, NSF

I have reviewed the subject DEIS and have, in fact, very little to say about it. The overall job is a good one. The analysis and consideration is a good, healthy cut above the average in terms of quality. Like many others it suffers somewhat from verbosity and redundancy, much of which cannot be easily avoided due to accepted standards for format and content.

The only negative comment I feel inclined to make (and it is really more of a suggestion) relates to the disposition of exotic wastes generated aboard the drill ship. Would it not be possible to preempt criticisms of the current plan to dump them over the side by incorporating less controversial means (more expensive to be sure) as a programmatic cost of doing business?

James T. Callahan

OPTIONAL FORM NO. 10 (REV. 1-80) GSA FPMR (41 CFR) 101-11.6 5010-114

7/10/85

U.S. G.P.O. 1983-381-526/8401

SEP 24 1985

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

SEP 23 1985

In Reply Refer To:
ER-85/1069

Mr. Thomas N. Cooley
Project Officer for Environmental Impact Assessment
Ocean Drilling Program, Room 613
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dear Mr. Cooley:

We have reviewed the draft environmental impact statement for the National Science Foundation Ocean Drilling Program and generally concur that interference with DOI mineral resource development activities would likely be insignificant. The drilling activities proposed in the three identified locations in or near U.S. waters other than the Georges Bank Site would not, in our view, likely affect biological resources under the jurisdiction of this Department. The statement recognizes the marine bird resources that nest and forage regularly in the Georges Banks environments and the program undoubtedly will seek to avoid any such conflicts.

In this regard, we suggest that a useful mitigation measure minimizing the effects of aircraft disturbance on seabirds would be to maintain a minimum 1,500-feet altitude when passing over any colonies. We suggest also that formal biological and ecological input to the committee selecting final drilling sites is needed and should be considered. No provision seems to be made to routinely have such information available to the site selection process. It would be particularly relevant for high-latitude areas where critical animal use and "weather windows" for drilling may coincide. Indeed, the entire site selection process could be more fully elaborated in the EIS. The anticipated numbers of drill sites that will be undertaken by the program for the full scale of the program over the long term, we feel, should be projected so that the public has a complete understanding of the overall magnitude of the program.

We would note to NSF's attention also that any assurance that DSDP will not encounter reservoired oil is not as firmly founded as may be assumed. For example, the GLOMAR CHALLENGER brought oil on deck from DSDP Site 2 on Challenger Salt Dome in the Gulf of Mexico in August 1969.

Some specific items that possibly should be considered and further explained include: explanation of how any radioactivity to be cored and exposed on the seafloor and in the laboratory will be handled, what might be expected from the albedo effects of oil spills at high-latitudes, the geochemical monitoring of the composition of pore fluid exchanges from deep crustal drill holes over time, and ice buildup effects and deicing procedures contemplated in Section 4.3 of the EIS. These may be unimportant environmental issues, but perhaps the EIS should establish that by discussing more fully what is known or intended as controls.

DOI (CONTINUED)

Mr. Thomas N. Cooley

We note for your information that the U.S. Geological Survey (USGS) is incorrectly referenced as the regulatory agency for offshore drilling in U.S. waters. The Conservation Division of the USGS was the responsible entity until the Minerals Management Service (MMS) was formed in January 1982. The MMS is now the responsible agency for the OCS program. References to USGS rather than MMS were noted on pages vii, 38, and 213, but an exhaustive search for such references was not made.

We hope this information proves helpful to you and thank you for the opportunity to review this DEIS.

Sincerely,

Bruce Blanchard, Director
Environmental Project Review

United States Department of State

Washington, D.C. 20520

September 11, 1985

Mr. Thomas N. Cooley
Project Officer for Environmental
Impact Assessment
Ocean Drilling Program
National Science Foundation
1800 G Street, N.W., Room 613
Washington, D.C. 20550

Dear Mr. Cooley:

Thank you for giving the Department of State a chance to review the draft Environmental Impact Statement for the Ocean Drilling Program. Interested offices have reviewed the statement and we have a small number of suggested changes. For simplicity's sake, I have indicated all of them on photocopies of the pages where we think they belong, and I enclose these for your reference.

You will note that we have inserted references to E.O. 12114 which "furthers the purpose of the National Environmental Policy Act with respect to the environment outside the United States, its territories and possessions." It is E.O. 12114 which actually sets forth the requirement and establishes the criteria for conducting various types of environmental reviews of government activities which have or might have environmental impacts outside of U.S. jurisdiction, as the ocean drilling program certainly might. The NEPA environmental review procedure only applies to impacts within the U.S.

A change which is required in several places is to drop the word "Consultative" from the name of the International Maritime Organization (IMO). I hope we have caught all the citations, but trust that your final editor will pick up any which we have missed.

Thanks again for the opportunity to review and comment on the draft EIS.

Sincerely,

Paul J. Glasoe
Environmental Assessment Coordinator
OES/ENR

Enclosure: as stated.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

RECEIVED
OCT 29 1985
BELLEVUE, WASHINGTON

OFFICE OF
EXTERNAL AFFAIRS

OCT 24 1985

Dr. Garrett Brass, Director
Ocean Drilling Program
Division of Ocean Sciences
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dear Dr. Brass:

In accordance with our responsibilities under Section 309 of the Clean Air Act and the National Environmental Policy Act (NEPA), we have reviewed the National Science Foundation's (NSF) draft Environmental Impact Statement (DEIS) for the proposed Ocean Drilling Program (ODP).

In general, we believe that the document provides an accurate description of the proposed action. We do, however, have some suggestions regarding the proposed ocean drilling activities and impacts described in the DEIS.

NPDES Regulations: In the second full paragraph on page 38, the DEIS states that EPA has established "regulations for the discharge of pollutants such as sewage, solid wastes, oil, and drilling mud (which regulations) may apply to the ODP operations." This sentence and the remainder of that paragraph appear to be a reference to effluent limitations guidelines promulgated by EPA and/or to the National Pollutant Discharge Elimination System (NPDES) regulations. To characterize the applicability of the NPDES regulations to ODP operations more accurately, the last sentence in the paragraph should be deleted, and the second to last sentence should be revised as follows:

> "For example, the National Pollutant Discharge Elimination System (NPDES) provisions of the amended FWPCA apply to point source discharges from vessels engaged in drilling operations."

Sediment deposition: In discussing the impacts of solids deposition and water column suspended solids, the DEIS predicts rapid dilution in the water column and only localized bottom/sediment accumulations of solids no greater than 1.0 cm. We suggest that the discussion in the DEIS should clearly establish why this sediment deposition will result in only negligible environmental impacts. Sediment deposition could be of some importance for drilling depths less than 100m and for many of the probable drill sites in the Georges Bank area.

Mitigation: The proposed mitigation of possible adverse environmental impacts is handled through discussions of program engineering and planning. While we support the concept of avoidance of likely impacts through design and planning, there may be cases where total avoidance may not be possible. In those cases, we recommend that NSF consider using operating orders to mitigate possible adverse effects. For example, an operating order may stipulate that helicopter flights maintain a horizontal distance of one mile and a vertical distance of 1500 feet from the vicinity of a rookery. Another example may be to establish procedures for temporary cessation of operations when migratory whales or threatened or endangered species are known to be in the impact area.

Hydrothermal Vent Communities/Spreading Centers: We believe that hydrothermal vent communities near spreading center sites should be specifically considered as biologically significant communities. Although these areas are not listed as critical habitat for threatened or endangered species, they are of great biological interest and require special precautions (e.g., pre-drilling examination of spreading center drill sites through underwater camera surveillance, or use of a riser drilling system) to assure that hydrothermal vent communities will not be disturbed. We recommend that Section 4.5, "Impact of the ODP on the Biological Environment", be expanded to include a discussion of hydrothermal vent communities as Biologically Sensitive Areas and the special precautions to be used in the vicinity of these communities.

On a minor technical issue, we suggest that Table 24 (p. 166) include new EPA water quality criteria for four-day and one-hour averages in lieu of "maximum allowable" Federal Saltwater Criteria (See 50 FR 30784, July 29, 1985).

We have rated the DEIS "LO", Lack of Objections. (See attached rating definition for a complete description of EPA's classification system). If you have any questions regarding EPA's comments, please contact Dr. Dale Manty of my staff at FTS 382-5078.

Sincerely,

Allan Hirsch

Allan Hirsch, Director
Office of Federal Activities

Enclosure

cc: Tom Cooley
National Science Foundation
Ocean Drilling Program
1800 G Street, N.W.
Washington, D.C. 20550

MARINE MAMMAL COMMISSION
1625 EYE STREET, N.W.
WASHINGTON, DC 20006

29 August 1985

Mr. Thomas N. Cooley
Project Officer for Environmental
  Impact Assessment
Ocean Drilling Program, Room 613
National Science Foundation
1800 G Street, N.W.
Washington, D.C. 20550

Dear Mr. Cooley:;

The Marine Mammal Commission, in consultation with its Committee of Scientific Advisors on Marine Mammals, has reviewed the "Draft Environmental Impact Statement for the Ocean Drilling Program" and offers the following comments and recommendations.

GENERAL COMMENTS

The Draft Environmental Impact Statement (DEIS) provides a description and assessment of potential impacts associated with an action proposed by the National Science Foundation to initiate and support a long-term (ten or more years) ocean drilling research program that would succeed the recently completed Deep Sea Drilling Project. The new program would make use of a more modern research vessel (the JOIDES RESOLUTION) capable of drilling safely into deep sedimentary sequences on continental margins. Drilling would take place throughout the world's oceans and provide core samples and data necessary to improve current understanding of seafloor spreading, plate tectonics, the structure of the earth's interior, and related geological conditions and phenomena.

To facilitate consideration of potential impacts, the DEIS evaluates four representative drilling areas including the Georges Bank, East Pacific Rise, Mid-American Trench, and the Weddell Sea. Several mitigating measures are identified including: compliance with certain applicable U.S. laws and regulations as well as the Antarctic Treaty; site reviews by the JOIDES Pollution Prevention and Safety Panel and the Texas A&M Research Foundation Safety Panel; avoiding sites with potential hydrocarbon reserves; and suspending drilling operations immediately if any petroleum hydrocarbons are discovered. The DEIS indicates that the National Science Foundation has initiated consultations concerning the proposed action's potential effects on endangered and threatened species with both the National Marine Fisheries Service and the Fish and Wildlife Service pursuant to the provisions of section 7 of the Endangered Species Act, but that the results of these

consultations were not available at the time the DEIS was completed.

The analysis of potential environmental impacts associated with drilling operations in the four representative areas appears to provide a useful approach for identifying and assessing possible adverse effects likely to be associated with the proposed ocean drilling program. Analyses in the DEIS indicate that potential adverse effects on endangered and non-endangered marine mammals from activities associated with the proposed Ocean Drilling Program would be negligible. While these analyses seem reasonably complete and accurate, it also appears possible that drilling activities which might be conducted at certain times and locations could have a significant adverse effect on some endangered marine mammal populations. For example, as discussed below, the Great South Channel in the Georges Bank area is used by a significant portion of the endangered North Atlantic right whale population each spring. If drilling operations were to be conducted in or adjacent to this area during the spring, it is possible that disruption of normal feeding or migratory behavior of right whales dependent on this habitat could have significant adverse effects on the recovery of the population. Such effects on endangered, as well as non-endangered, marine mammals should be identified in the DEIS.

With respect to possible effects on endangered and non-endangered marine mammals, the description of the planning process for scheduling and selecting specific drilling sites should be expanded to identify the steps that would be taken to ensure that spatial and temporal considerations, as noted above, will be identified in an appropriate and timely manner throughout the course of the Ocean Drilling Program. Presumably, this need, as it relates to endangered species, will be addressed during the course of section 7 consultations with the National Marine Fisheries Service and the Fish and Wildlife Service. If it is not, the Marine Mammal Commission recommends that the National Science Foundation reinitiate consultations with the two Services to discuss this issue. With respect to non-endangered marine mammals, as discussed below, we are uncertain as to whether the Foundation has considered the need for obtaining authorization from the Secretary of Commerce pursuant to section 101(a)(5) of the Marine Mammal Protection Act for the incidental, but unintentional, taking of non-depleted marine mammals during the course of project related activities and, if you have not already done so, we recommend that you consult with the National Marine Fisheries Service to determine the applicability of this provision and its requirements to the proposed Ocean Drilling Program.

SPECIFIC COMMENTS

<u>Pages 37 to 39, Applicable Laws and Regulations:</u> This section of <u>the DEIS, which identifies laws and regulations</u> applicable to the

proposed Ocean Drilling Program, should be expanded to identify relevant provisions of the Convention for the Conservation of Antarctic Seals, the Endangered Species Act, and the Marine Mammal Protection Act. Among other things, The Convention for Antarctic Seals prohibits the capturing or killing of Ross seals, elephant seals and Antarctic fur seals and provides area, season, and quota restrictions for the capturing and killing of crabeater, Weddell and leopard seals. The Endangered Species Act requires that all Federal agencies ensure that their activities and programs are not likely to jeopardize the continued existence of any listed endangered[1] or threatened species or to destroy or adversely modify any habitat critical to the survival of such species.

The Marine Mammal Protection Act establishes a moratorium, with certain limited exceptions, on taking any marine mammal and defines the term "take" to include "harass, hunt, capture, or kill" or to attempt to engage in such activities. The limited exceptions for the taking of marine mammals include a provision under section 101(a)(5) of the Act, which directs the Secretary of Commerce to authorize, upon request, the incidental, but unintentional, taking of small numbers of non-depleted marine mammals by U.S. citizens engaged in a specified activity other than commercial fishing. As noted earlier, we recommend that the National Science Foundation consult with the National Marine Fisheries Service, if it has not already done so, to determine whether and how an exemption can be obtained.

Page 39: The meaning of the third sentence on this page, which states that the conservation standards set forth in Article II of the Convention on Conservation of Antarctic Marine Living Resources (CCAMLR) "...are utilized to scrutinize the proposed drilling activity in the Antarctic," is not clear. The CCAMLR conservation standards provide the basis for assessing and avoiding the possible adverse effects of fishery and associated activities, but may not be appropriate for evaluating possible impacts from the Ocean Drilling Program. As an example, there is good justification for allowing fisheries to reduce fish stocks to their maximum net productivity or maximum sustainable yield levels, as described in paragraph 3 (a) of Article II, but no justification for allowing similar reductions due to the Ocean Drilling Program or other non-fisheries activities. Therefore, this paragraph should be expanded to explain how the CCAMLR conservation standards have been or will be used to "...scrutinize the proposed drilling activity in the Antarctic."

In addition, something like the words "and December 1984, respectively" should be added to the end of the parenthetical in the second sentence of the paragraph on page 39 since the U.S.

1 Unless otherwise indicated, the term "endangered" as used in these comments is synonymous with the term "endangered" as defined in the U.S. Endangered Species Act.

legislation implementing the CCAMLR took effect on this date rather than 1982.

Page 54, first paragraph: The last sentence of this paragraph notes that drilling in the Weddell Sea is scheduled for mid January through December 1987. Page iii notes that drilling in this area would be between December 1986 and February 1987. The starting date for drilling activity either in this paragraph or on page iii should be corrected.

Page 59, second complete paragraph: The penultimate sentence of this paragraph indicates that the Antarctic Bottom Water is colder and "slightly less saline" than water higher in the water column. For reasons discussed in the third paragraph on the page, it would seem that the word "less" in the aforementioned sentence should be changed to "more."

Page 85, second complete paragraph: Something like the words "at least" should be inserted between the words "of" and "32" in the first sentence of the paragraph since there may be additional species of diatoms in the epontic community that have not been identified.

Page 93, Table 8: Footnote "a" of this Table, which lists species of seals found in the Weddell Sea, indicates that Antarctic fur seals, Sub-Antarctic fur seals, and Ross seals are "species designated as specially protected under the Agreed Measures for the Conservation of Antarctic Fauna and Flora (Public Law 95-541)". This footnote should be expanded, or a new footnote should be added, to indicate that these species plus the southern elephant seal and the Weddell seal also are treated as "protected species" pursuant to Article 3 of the Convention for the Conservation of Antarctic Seals.

Pages 96 to 97, Table 9: This Table identifies species of whales and dolphins found in the Weddell Sea. Footnote "a" to this Table indicates that the blue, fin, sei, humpback, southern right, and sperm whales are designated as specially protected species under the Agreed Measures for the Conservation of Antarctic Fauna and Flora and Public Law 95-541. Although these species of whales are listed as "endangered" under the U.S. Endangered Species Act, we are unaware of their listing as "specially protected species" under the Agreed Measures. Therefore, we suggest that this footnote be checked for accuracy and that it be revised or expanded, as appropriate, to indicate that the identified species of whales are listed as "endangered" under the U.S. Endangered Species Act.

Pages 100 to 102, Endangered Species: This section should be expanded to identify those species that are listed as endangered or threatened in the IUCN Red Data Book and that are listed under Appendices I and II of the Convention on International Trade of Endangered and Threatened Species of Wild Fauna and Flora. In addition, the first paragraph of this section notes that six species of "endangered" whales may occur in the Antarctic region. The meaning of the term "endangered" is not self evident and, if the paragraph is intended to indicate that these species are listed as "Endangered" under the U.S Endangered Species Act, the beginning of the first sentence of the paragraph should be changed to read something like the following: "Five cetaceans listed as 'Endangered' under the U.S. Endangered Species Act are known ...". If some other meaning of the term is intended, it should be explained. This comment also applies to the "Endangered Species" sections which appear on pages 121 and 141 of the DEIS.

Pages 113 to 114, Table 13: This Table provides information on species of cetaceans found in the Georges Bank region. In order to clarify the meaning of the term "endangered species" in footnote "a," the footnote should be changed to read something like "Species listed as 'Endangered' under the U.S. Endangered Species Act."

Page 121, second complete paragraph: This paragraph, which discusses endangered whales in the Georges Bank area, notes that the right whale is probably the most endangered marine mammal in the area and that the Bay of Fundy supports a breeding population of this species. Figure 41 on page 122 of the DEIS illustrates the location of important right whale habitats at the mouth of the Bay of Fundy and east of Cape Cod in the Great South Channel area. Because of the extremely small size of the the surviving right whale population, information concerning seasonal habitat use patterns for this species is particularly important. To provide a more complete and accurate description of available habitat use information for this species, the text of this paragraph and Figure 41 should be expanded to note that Browns Bank off the southern tip of Nova Scotia, as well as the Great South Channel area (approximately 60 miles due east of Nantucket Island) and the mouth of the Bay of Fundy are the most important right whale habitat areas presently known to exist around Georges Bank. In addition, since right whales are concentrated in these areas at particular times of the year, seasonal use pattern in these areas also should be identified (e.g., Great South Channel - March to early July; Bay of Fundy - July to October; and Browns Bank - July to November).

Page 142, Resource Development: Since this section considers only development of mineral resources in the Antarctic (commercial fisheries is discussed separately), the title of this section would be more accurate if it was changed to read something like "Mineral Resource Development". This comment also applies to the "Resource Development" section on page 143 of the DEIS.

Page 180, second complete paragraph: This paragraph, which discusses the effects of noise on marine mammals, notes that: the magnitude of behavioral effects will depend on the species and type of activity; response may include temporary changes in transit course to avoid the noise source and other minor changes of behavior; and since marine mammals will be close to noise

generating activities only a fraction of the operating time and relatively few individuals will be affected by these noises, the overall effect on any population is expected to be negligible. It should be expanded to note that drilling activity in or near important feeding or migratory habitat for endangered whales (e.g., the Great South Channel or Browns Bank which are adjacent to Georges Bank and used by a significant portion of the remaining North Atlantic right whale population) could have a significant adverse effect on one or more endangered whale populations if such activities were to displace whales from these areas during critical periods of seasonal use.

Page 181, Drilling Operations: The fourth sentence of this paragraph states that, with respect to operational drilling discharges, the "...mobility and detection ability of marine mammals allows them to avoid significant discharge plumes." We are unaware of any studies or observations suggesting that marine mammals can detect and would avoid drilling discharge plumes. We therefore recommend that this sentence either be deleted or that the paragraph be expanded to provide the basis for the conclusion. This also applies to similar statements concerning the ability of birds and fish to detect and avoid operational discharges.

Page 182 to 183, Impacts On Endangered Species: The first paragraph of this section notes that it was concluded elsewhere in the DEIS that the ocean drilling program would not have significant adverse impacts on marine mammals and that this would apply to endangered and threatened species. The paragraph should be revised to reflect possible impacts on endangered whale populations as discussed earlier.

Page 183, Impact On Biologically Sensitive Areas: This section should be expanded to identify and discuss at sea marine mammal nursery, feeding and/or migratory habitats (e.g., the Great South Channel, Browns Bank, the mouth of the Bay of Fundy, and Stellwagon Bank in the Georges Bank area) which may be areas of special biological importance.

Page 187, first paragraph: This section notes that Ocean Drilling Program activities will be guided by " a conservation standard" established under the Convention on Conservation of Antarctic Marine Living Resources and U.S. regulations implementing this Convention. To ensure that the relevance of these authorities is understood, a cross-reference should be added to the paragraph to refer the reader to the section of the document on applicable laws and regulations (pages 37 to 39 in the DEIS), which should be revised as suggested above.

Page 201, first paragraph: The last sentence of this paragraph states that "[t]he most effective way to prevent adverse impacts [on marine mammals and birds] is to avoid drilling during periods of maximum vulnerability (e.g., molting, breeding, pupping, migration)." Since it also is true that potential adverse impacts might be eliminated or reduced by avoiding drilling in localized areas of special biological importance, something like the words "in areas of special biological importance and/or" should be inserted between the words "avoid drilling" and "during periods" in the last sentence of the paragraph.

Page 212, Laws and Regulations: This section notes that a number of laws and regulations apply to activities conducted under the Ocean Drilling Program and refers to Table 27 on page 213, for a summary of those laws and regulations. Table 27 should be expanded to identify the responsibilities of the Department of Commerce for the protection of marine mammals and endangered species under the provisions of both the Endangered Species Act and the Marine Mammal Protection Act.

Pages 214 to 215, Site Reviews: This section discusses provisions including review by the "JOIDES Pollution Prevention and Safety Panel (PPSP)" for ensuring that drilling related operations are conducted safely. In order to ensure that environmental factors necessary to avoid or mitigate potential adverse effects on marine mammals and endangered species are considered in an appropriate and timely manner, this section should be expanded or modified to indicate how planning procedures will ensure that operational decisions, such as the selection of drilling sites and drilling schedules, reflect the need to avoid areas of special biological importance and/or periods of possible species vulnerability. For example, the PPSP as described in the first paragraph of this section might be expanded to include marine mammal scientists and/or biological oceanographers, as well as petroleum geologists, geophysicists, and organic geochemists, and the list of "important factors considered in the site selection process," which is included at the end of the second paragraph of the section, might be expanded to include factors such as the presence of potentially vulnerable biological communities or populations.

Page 223, third paragraph: This paragraph notes that formal consultations have been initiated with the National Marine Fisheries Service and the Fish and Wildlife Service pursuant to section 7 of the Endangered Species Act. As necessary and appropriate, the FEIS should describe and discuss any reasonable and prudent alternatives and recommendations provided by the two Services. The results of these consultations should be appended to the FEIS.

I hope that these comments and recommendations are helpful. If you or your staff have any questions concerning them, please do not hesitate to contact either David W. Laist or me. Our phone number should you wish to call is 653-6237.

Sincerely,

Robert J. Hofman, Ph.D.
Scientific Program Director

cc Mr. Anthony J. Calio
Mr. R. Tucker Scully
Peter E. Wilkniss, Ph.D.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Washington, D.C. 20235

F/NER54:DB

AUG 29 1985

Dr. Thomas M. Cooley
Project Officer, Environmental
Impact Assessment, ODP
Division of Ocean Sciences
Oceanographic Centers and
Facilities Sections
National Science Foundation
Washington, D.C. 20550

Dear Dr. Cooley:

This is in response to your letter of May 6, 1985, initiating consultation with the National Marine Fisheries Service (NMFS) pursuant to Section 7 of the Endangered Species Act of 1973, as amended (ESA). Your request pertains specifically to the phase of the National Science Foundation's (NSF) 10-year Ocean Drilling Project (ODP) that is to be carried out near Georges Bank. We have reviewed the Draft Environmental Impact Statement for the Ocean Drilling Program (DEIS) and other information available to the NMFS that pertains to this project.

The ODP is a long-range, world-wide effort. The proposed drilling sites will only be specified 1 year in advance, and will be selected based on scientific merit and environmental and operational safety. Georges Bank is discussed in the DEIS only as one of four representative sites that encompass the scientific goals, geographic positions, and geological and ecological conditions of the ODP. The drilling schedule for the first 3 years, and the long-range plans through 1991, do not involve Georges Bank. The fact that specific areas of geological interest in the Georges Bank area are not identified in the DEIS makes an assessment of effects to endangered species very difficult.

The actual drilling operations that may take place in the Georges Bank area under the ODP have been well defined and are well known. The plans call for the use of a dynamically positioned deep-sea drillship using a riser drilling technique. This drilling technique is familiar to us as it has been used several times in exploratory drilling operations for commercial oil and gas resources along the continental shelf edge. In fact, most of the ODP operations are virtually identical to the OCS oil and gas exploration activities that have been subjected to extensive environmental assessment in the past few years. Therefore, we believe that the data contained in Biological Opinions that NMFS has provided to the Minerals Management Service regarding the potential effects of leasing and exploration activities in the North Atlantic Region (enclosures) can be applied to the ODP-proposed use of Georges Bank.

Specifically, should NSF select a drilling site within the high-use, preferred areas noted for right, humpback, and fin whales in the Great South Channel and along the western edge of Georges Bank, then a full, formal consultation pursuant to Section 7 of the ESA would be necessary. Conversely, the fact that the ODP proposes to use only one dynamically positioned drillship at a time reduces the potential effects to the endangered species in areas outside the high-use or preferred areas identified above and in the enclosed opinions. Therefore, it may be possible to come to a "no effect" determination regarding the ODP on Georges Bank.

We suggest that NSF include more information in the FEIS regarding the use (frequency and seasonal timing) of seismic exploration in the Georges Bank. The potential for ODP site selection within the sensitive high-use areas for endangered whales should also be investigated and discussed in more detail in the FEIS. If this information shows that the high-use areas for whales are of low or no potential value for the ODP, and if seismic exploration can be limited to air gun use and seasonally restricted in certain endangered species high-use areas, then it is possible that a "no effect" conclusion could be stated in the FEIS.

We recommend that you work closely with our Northeast Regional Office regarding development of this aspect of the FEIS, and that you suspend continuation of a formal consultation pending the outcome of the further discussions mentioned above. Please keep Patricia Carter of the Office of Protected Species and Habitat Conservation (FTS 634-7471) and Douglas Beach of our Northeast Regional Office (FTS 837-9288) informed of your progress on the ODP and development of the FEIS.

Sincerely,

James E. Douglas, Jr.
for William G. Gordon
Assistant Administrator
for Fisheries

Enclosures

NOTE: Under the Paperwork Reproduction Act, these public documents (the enclosures, NMFS 1982; 1983) are included only by reference and are not included herein.

OCT 2 1985

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

OFFICE OF THE ADMINISTRATOR

September 30, 1985

Mr. Thomas N. Cooley
Project Officer for Environmental
Impact Assessment
Ocean Drilling Program, Room 613
National Science Foundation
1800 G Street NW
Washington, D.C. 20550

Dear Mr. Cooley:

This is in reference to your draft environmental impact statement for the Ocean Drilling Program. Enclosed are comments from the National Oceanic and Atmospheric Administration.

We hope our comments will assist you. Thank you for giving us an opportunity to review the document.

Sincerely,

David Cottingham
David Cottingham
Ecology and Conservation Division

Enclosure

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
ENVIRONMENTAL RESEARCH LABORATORIES
Pacific Marine Environmental Laboratory
NOAA Building Number 3
7600 Sand Point Way N.E.
Seattle, WA 98115

September 18, 1985 R/E/PM:MRM

TO: PP2 - David Cottingham

FROM: R/E/PM - Martin R. Mulhern

SUBJECT: DEIS 8506.12 - Ocean Drilling Program

PMEL has reviewed the draft environmental impact statement. Basically, the document seems to be well thought out from the perspective of general oceanographic considerations and geological hazards and impacts. We do not however, have particular expertise with operation of blowout preventers and similar equipment and cannot address these aspects of the DEIS.

We have no specific additions or revisions recommended.

cc: R/E/PM - S. Hammond

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Management Division
Habitat Conservation Branch
14 Elm Street
Gloucester, MA 01930

September 18, 1985 F/NER74:BEH

TO: PP2 - David Cottingham

FROM: F/NER74 - Bruce Higgins

SUBJECT: Comments on the National Science Foundation's Draft Environmental Impact Statement for the Ocean Drilling Program (ODP) (DEIS 8506.12)

The Northeast Region and Center of the National Marine Fisheries Service (NMFS), National Oceanic and Atmospheric Administration (NOAA), have reviewed this DEIS and offer the following comments and recommendations:

GENERAL COMMENTS AND RECOMMENDATIONS

The assertion made in the DEIS that research drilling in the Antarctic and Georges Bank areas would result in negligible effects on the ecosystems and on the fisheries resources within the ecosystems may be valid. However, we are concerned that no evaluation is given of the probabilities of detrimental impacts to the Antarctic ecosystem in the event of an accidental blowout caused by the continuous stress on the JOIDES vessel and drilling systems under conditions of extended periods of gale-force winds during the planned January-February operational schedule in the Weddell Sea.

We recommend that an appropriate evaluation of this kind of event be done. To ensure that appropriate measures are taken to protect living resources and habitats in both the Georges Bank and Weddell Sea areas, we recommend that scientific observer teams from NOAA/NMFS be included among the scientific complement during the at-sea operations. These teams would be provided with the shipboard means to conduct appropriate monitoring measurements of environmental impacts based on observations made before, during, and after the drilling operation. We believe that this recommendation is valid in consideration of (1) the critical importance of Georges Bank as a spawning and feeding ground supporting the $1 billion/year fisheries economy of the coastal states from Maine to North Carolina, and (2) the relatively pristine condition of the Antarctic environment, which requires special consideration by fisheries ecologists in assessing any adverse environmental impact on the living marine resource populations, no matter how seemingly insignificant. Because of the ecological and political sensitivity of the Antarctic, special monitoring of potential environmental impacts is warranted, particularly in an effort sponsored largely by the United States.

SPECIFIC COMMENTS

Page 29, paragraph 5. Georges Bank is not even on the schedule as a candidate drill site area up to 1991; however, Figure 8 on page 30 shows a site off New Jersey, not Massachusetts. Is this correct, or is that site supposed to be Georges Bank? Similarly, Figure 9 on page 32 indicates that there is no specific future scientific interest in Georges Bank, although there is interest in an area off Chesapeake Bay. (Also see comment below for page 50 et seq.)

Pages 44-45. Potential effects of exploratory drilling operations on marine mammals are discussed in detail in the Biological Opinions NMFS prepared for the Department of the Interior's Minerals Management Service (MMS) for various oil and gas lease sales. For the Georges Bank area, the statement in paragraph 3 on page 45 indicating that potential effects on endangered and threatened species would be magnified due to these animals' reduced populations is only likely to be true for right whales within the preferred high-use areas noted in NMFS's Biological Opinion for Lease Sale 82. The possibility of collisions between a drillship and sea turtles in the Georges Bank area is virtually zero.

Page 47. Potential impacts of oil spills on marine mammals are correctly stated and are similar to those found in NMFS's Biological Opinions to MMS. However, the probability of an oil spill occurring during the ODP is much less than during oil and gas exploratory drilling activities.

Pages 50 et seq.. Why was George Bank chosen as a "representative site" when there is no mention of it in the ODP schedule in Section 2.2? If, as the maps on pages 30 and 32 indicate, the interest is more likely to be in the New Jersey or Chesapeake Bay areas, then why not discuss either of those as a representative site? Discussing Georges Bank as a representative site would seem to be inadvisable, unless it is an actual proposed site during the life of the project.

Page 110, paragraph 6. The coastal waters of the Gulf of Maine do not provide much habitat for harp seals or hooded seals. They occasionally visit the area but their range is centered to the north in Canadian waters.

Page 111, Table 12. Harbor seals prefer rocky ledges as haulout areas. Sandy beaches are only used by juveniles in the winter on Cape Cod where no rock ledges are available.

Page 112, paragraph 2. The right whale is also found in Cape Cod Bay and the Great South Channel in late winter and spring. Humpback and fin whales are the predominant species in the area, and should also be mentioned in the narrative.

Page 112, paragraph 3. The killer whale is not commonly seen in the area. The pilot whale, the Atlantic white-sided dolphin, and the harbor porpoise are the common small odontocetes in the area year-round. The Risso's dolphin is a common inhabitant of the shelf-edge area.

Page 113, Table 13. We suggest making the following changes: Minke whale should read: "Nearshore northward spring migration . . ." and "offshore southward fall migration . . . ." For fin whale and humpback whale, add ". . . and other available small schooling fishes" to the last sentence. For right whale, begin the first sentence with "Remaining individuals . . . ." For long fin pilot whale, replace the first sentence with: "Pelagic distribution centered around the shelf edge with seasonal spring/summer movement over the shelf." For killer whale, add a new sentence at the end: "Infrequently seen in U.S. waters." For harbor porpoise, insert a new first

sentence: "Most common small cetacean on the shelf." For bottlenose dolphin, insert a new third sentence: "Inshore and offshore stocks possible." For North Atlantic bottlenosed whale, replace "Rhode Island" with "southern New England waters."

Page 121, paragraph 2. With regard to the Atlantic Ridley, we suggest adding at the end of the fourth sentence ". . . the most severely depleted sea turtle species."

Page 121, paragraph 3. With regard to right whales, we suggest inserting "(500)" after "low population . . ." in the fourth sentence.

Page 167. Sperm whales and pilot whales have been reported to congregate around a drillship operating in the Mid Atlantic (presumably to feed on schooling squid). Some of these sperm whales stayed near the drillship even after the presumed food source had dispersed. Vessel noise and dynamic positioning echo sounders may have had something to do with these animals' apparent attraction to the drillship.

Pages 178-179 . ODP activities may disperse endangered whales from high-use areas where feeding conditions are optimal. These effects would be significant only in areas where severely depleted species, such as the right whale, congregate to take advantage of oceanographic conditions that concentrate food sources, such as dense blooms of Calanus spp. in the Great South Channel in the spring. Seismic operations could have the same effects if conducted in high-use areas at certain times.

Page 212. Seismic surveys should be done with airguns only, and should be prohibited in endangered whale high-use areas during known periods of whale use.

Additional Information

Additional information that may be of interest to the NSF in their determination of potential impacts to marine mammals involves recently documented whale behavior in the vicinity of a drill ship. In 1984 NMFS personnel observed endangered sperm whales in the vicinity of the OCS drillship DISCOVERER SEVEN SEAS during exploration drilling operations for Shell Offshore Inc. in 1000 fathoms (f) of water approximately 100 nm east of Cape May, New Jersey. A report documenting the observed behavior is being prepared with cooperation from the Minerals Management Service. The draft report indicates that the observed whales were attracted to the drillship for an undetermined reason. There is speculation that the initial attractant may have been the concentration of squid (a prey species for sperm whales) near the drillship. The attached letter summarizes the data contained in the draft report.

We also want to bring two recent publications on the Antarctic to your attention: Antarctic Ecology edited by R. M. Laws (Academic Press, 1984) and IV SCAR Symposium Proceedings recently published by Springer Verlag.

APPENDIX E

NATIONAL SCIENCE FOUNDATION RESPONSES TO COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

APPENDIX E

NATIONAL SCIENCE FOUNDATON RESPONSES TO COMMENTS ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT

JAMES CALLAHAN

"The only negative comment I [have] relates to the disposition of the exotic wastes generated aboard the drill ship. Would it not be possible to preempt criticisms of the current plan to dump them over the side by incorporating less controversial means ..."

All discharges from the drillship comply with existing regulations and pollution control measures. The laboratory drainage is neutralized in limestone media and milk of magnesia before addition to the 300-gallon domestic waste (gray water) holding tank (see Section 4.2). Thus, all chemicals are pH-neutralized and highly diluted before being discharged. Collection (and thus mixing and concentration) of these chemicals for shore-based disposal does not offer a more environmentally sound method of disposal.

DEPARTMENT OF THE INTERIOR - OFFICE OF THE SECRETARY

"... we suggest that a useful mitigation measure minimizing the effects of aircraft disturbances on seabirds would be to maintain a minimum 1,500-ft altitude when passing over any colonies."

The use of a helicopter is not expected over the course of the program due to the distances of drill sites from land. However, if helicopters are needed, the NSF recognizes that a 1,000-ft overflight over rookeries is required by law, but that 1,500 ft is obtainable, and has brought up the matter with TAMU, the ODP Science Operator (which develops the operational plans for the ODP).

"We suggest also that formal biological and ecological input to the committee selecting final drilling sites is needed and should be considered."

The NSF recognizes this as a valid concern and has brought up the matter with JOIDES (which provides the scientific planning for the ODP). Methods under discussion to incorporate biological considerations into the site selection process include:

- Adding a biological position to the Pollution Prevention and Safety Panel (which reviews all potential sites prior to selection)
- Retaining consultants to review sites for environmental implications.

Either of these methods would help to ensure that potential biological impacts are addressed in advance of final site selection and that adequate consideration is given to issues such as the proximity of sites to areas of biological importance and conflicts with critical periods of seasonal use by endangered species.

"... the entire site selection process could be more fully elaborated in the EIS."

The site review and selection process is outlined in Section 4.8 under Operational Planning and Procedures. After the JOIDES Planning Committee screens proposals for scientific merit, the potential sites undergo a two-tiered pollution prevention and safety review. The major points of this analysis are discussed in the text. The Manual on Pollution Prevention and Safety (JOIDES Pollution Prevention and Safety Panel 1976) discusses the selection criteria and process in detail. Under the Paperwork Reduction Act, this public document is included only by reference and is not reproduced herein.

"The anticipated numbers of drill sites ... [over] the full scale of the program ... should be projected so that the public has a complete understanding of the overall magnitude of the program."

The ODP will probably last 10-20 years, and there is no appropriate method to estimate the number of drill sites that will be occupied during that (as yet undefined) period. However, based on figures compiled during the DSDP (see Table 1), an average of 74 holes drilled per year can be predicted throughout the course of the program. If riser drilling is initiated at some point in the future, this number will be significantly reduced.

"We would note ... that any assurance that [O]DP will not encounter reservoired oil is not as firmly founded as may be assumed. For example, the GLOMAR CHALLENGER brought oil on deck from DSDP Site 2 on Challenger Salt Dome in the Gulf of Mexico in August 1969."

The NSF agrees that this example is a true statement. However, in response to events at Site 2, which was drilled near the beginning of the program, three significant improvements were made. The Pollution Prevention and Safety Panel was formed, the whole site review and safety assessment structure was installed, and the stringent requirements for site selection and operations planning were initiated. Since that time, liquid hydrocarbons have not been brought on deck again, indicating the system's effectiveness in avoiding reservoired oil.

" ... how [will] any radioactivity to be cored and exposed on the seafloor and in the laboratory ... be handled ... [?]"

One of the logging tools measures gamma ray attenuation and has a radioactive source. The ODP staff includes technicians with training in the safe and proper handling and storage of radioactive material and the drillship has proper onboard storage facilities that meet all applicable regulations. In the unlikely event material with sufficient radioactivity to warrant isolation is brought on board, the expertise and facilities exist to properly house the material until it can be turned over to the appropriate authorities for proper disposal. The site would be abandoned and capped if there was potential for retrieving more radioactive material.

"... what might be expected from albedo effects of oil spills at high latitudes ... [?]."

This subject is still open to much debate. There is general agreement that significant albedo reduction will only occur from oil covering the ice surface, which could cause a drastic change in reflectivity. Oil on water can reach the ice surface in two ways. First, freezing of oil covered leads, followed by compression closing the leads, can build hummocks from the newly formed, oily ice. Second, under-ice transport of the oil will leave isolated pockets which are incorporated into the bottom of the ice pack during winter freezing. Both can result in significant, although isolated, areas of oil-coated surface ice that would increase proportional to the volume spilled. However, even in a very large spill, the total area affected and the patchy nature of these areas, would not result in a significant change in the heat balance. Considering the much smaller volumes of even a worst-case spill that could potentially result from the ODP's "off-structure" drilling policy and site review procedures, no significant changes in the albedo at high latitudes is predicted.

"The geochemical monitoring of the composition of pore fluid exchanges from deep crustal drill holes over time ... [should be considered or explained]."

The monitoring of downhole pore waters has been an ongoing program of the DSDP and continues within the ODP. Reentry cones are set at specific sites to allow reoccupation of the hole at a later date. Holes such as 504B on the East Pacific Rise have been reentered and pore waters monitored (among other parameters). Comparison with the previously collected data has not indicated substantial compositional changes. In addition, the estimated rates of exchange have been on the order hypothesized for hydothermal circulation cells in the seafloor. Impacts associated with these exchanges appear to be negligible. However, monitoring will continue.

"... ice buildup effects and de-icing procedures contemplated in Section 4.3 ... [should be explained]."

Ice buildup on the superstructure and derrick affects the weight or amount of drill string that can be deployed. Eventually, ice buildup can force curtailment of drilling operations (dependent on the depth of the hole). In deeper waters, this will occur before vessel stability is substantially affected, allowing the area to be abandoned if ice buildup continues. High-latitude safety and de-icing procedures standard to the arctic drilling and shipping industries are followed by the vessel operator. In addition, high latitude operations are conducted during summer months when icing conditions are at a minimum.

"... the U.S. Geological Survey (USGS) is incorrectly referenced as the regulatory agency for offshore drilling in U.S. waters. ... The [Minerals Management Service] is now the responsible agency for the OCS program."

The appropriate revisions have been made to the text.

DEPARTMENT OF STATE

"[We suggest references be inserted] ... to E.O. 12114 which furthers the purpose of the National Environmental Policy Act with respect to the environment outside the United States, its territories and possessions. .... The NEPA environmental review procedure only applies to impacts within the U.S."

The appropriate revisions have been made to the text.

"A change which is required in several places is to drop the word 'Consultative' from the name of the International Maritime Organization (IMO)."

The appropriate revisions have been made to the text.

ENVIRONMENTAL PROTECTION AGENCY

"NPDES Regulation: In the second full paragraph on page 38 ... To characterize the applicability of the NPDES regulations to ODP operations more accurately, the last sentence in the paragraph should be deleted, and the second to last sentence should be revised as follows:

> **"For example, the National Pollutant Discharge Elimination System (NPDES) provisions of the amended FWPCA apply to point source discharges from vessels engaged in drilling operations."**

The appropriate revisions have been made to the text.

"Sediment deposition: .... We suggest that the discussion in the DEIS should clearly establish why [localized bottom/sediment accumulation of solids no greater than 1.0 cm] will result in only negligible environmental impacts. Sediment deposition could be of some importance for drilling depths less than 100 m and for many of the probable drill sites in the Georges Bank area."

The ODP is a worldwide program of study of the ocean bottom and continental margins. Almost all the potential drilling sites are at depths greater than 1,000 m and most are greater than 3,000 m. Only during the riser phase of drilling does there exist strong potential of drilling in less than 1,000 m of water, and even then no holes are in water depths less than 100 m. The program is designed to sample areas of scientific interest that are not accessible by other means. The reasons that shallower areas (where large quantities of organically rich sediments have accumulated resulting in the potential of oil formation) are not considered, are discussed at various points throughout the text. In addition, these areas can be studied with information retrieved during routine OCS operations.

The results of sediment deposition modeling are presented in Section 4.2. For riserless drilling, accumulations occur in the immediate vicinity of the borehole. Modeling for riser drilling at sites shallower than most potential sites, predicted maximum deposition less than 0.05 mm. The effects of sedimentation on benthos, demersal eggs, and fish are presented in Section 4.5. From this analysis in the text, a conclusion of negligible impacts from sediment deposition is predicted based on short-term and/or localized effects.

"Mitigation: .... While we support the concept of avoidance of likely impacts through design and planning, there may be cases where total avoidance may not be possible. In those cases, we recommend that NSF consider using operating orders to mitigate possible adverse effects. For example, an operating order may stipulate that helicopter flights maintain a horizontal distance of one mile and a vertical distance of 1,500 feet from the vicinity of a rookery. Another example may be to establish procedures for temporary cessation of operations when migratory whales or threatened or endangered species are known to be in the impact area."

The NSF recognizes that this is a valid concern and has brought the matter up with TAMU, the ODP Science Operator (which develops the operational plans for the ODP).

"Hydrothermal Vent Communities/Spreading Centers: We believe that hydrothermal vent communities near spreading center sites should be specifically considered as biologically significant communities. .... We recommend that Section 4.5 ... be expanded to include a discussion of hydrothermal vent communities as Biologically Sensitive Areas and the special precautions to be used in the vicinity of these communities."

The appropriate revisions have been made to the text. Because most of the scientists who study the vent systems are also members of JOIDES, there is an inherent interest to make sure that potential vent areas are not considered as drill sites. Numerous active spreading center regions do not have vent systems and the geophysical mapping from deep-tow systems that are needed to accurately locate an on-ridge site will clearly show the presence or absence of vents.

"... we suggest that Table 24 (p. 166) include new EPA water quality criteria for four-day and one-hour averages in lieu of 'maximum allowable' Federal Saltwater Criteria (See 50 FR 30784, July 29, 1985)."

Modeling of surface drilling mud discharges predicts adequate dilutions to meet four-day average criteria within the 100 m mixing zone. However, the U.S. EPA water quality criteria for one-hour averages are more appropriate for the intermittent and short-term nature of the mud discharges, as is the case for similar discharges from OCS opertions. The appropriate revisions have been made to Table 24 and to the text.

MARINE MAMMAL COMMISSION

"Pages 37 to 39, Applicable Laws and Regulations: ... should be expanded to identify relevant provisions of the Convention of the Conservation of Antarctic Seals, the Endangered Species Act and the Marine Mammal Protection Act."

The appropriate revisions have been made to the text.

MMC (CONTINUED)

"... we recommend that the [NSF] consult with the National Marine Fisheries Service ... to determine whether and how an exemption [for the taking of marine mammals under section 101(a)(5) of the Marine Mammal Protection Act] can be obtained."

The NSF consulted with the National Marine Fisheries Service (NMFS) through a May 6, 1985 letter and received a reply letter dated August 29, 1985. No comments on the taking of marine mammals were received. While the NSF questions the need for research vessels to apply for exemptions, it understands the special considerations of the ODP and recognizes that an exemption may be appropriate. The NSF is in the process of requesting an exemption from the NMFS for the incidental taking of marine mammals under Section 101(a)(5).

"Page 39: The meaning of the third sentence on this page ... is not clear. .... [T]his paragraph should be expanded to explain how the CCAMLR conservation standards have been or will be used to '... scrutinize the proposed drilling activity in the Antarctic'."

The NSF, in consultation with its Division of Polar Programs, recommends that this language be inserted for clarification:

> "Measures under the CCAMLR prohibit harvesting or other associated activities in violation of the Convention. Harvesting is defined as:
>
> (A) The harassing, molesting, harming, pursuing, hunting, shooting, wounding, killing, trapping or capturing of Antarctic marine living resources;
>
> (B) Attempting to engage in any activity set forth in subparagraph (A);
>
> (C) Any other activity which can reasonably be expected to result in any activity described in subparagraph (A); and
>
> (D) Any operations at sea in support of, or in preparation for, any activity described in subparagraph (A) through (C)."

"... the words 'and December 1984, respectively' should be added to the end of the parenthetical in the second paragraph on page 39 since the U.S. legislation implementing the CCAMLR took effect on this date."

The appropriate revisions have been made to the text.

"Page 54, first paragraph: The last sentence ... notes that drilling in the Weddell Sea is scheduled for mid January through [February] 1987. Page iii notes that drilling in this area would be between December 1986 and February 1987."

Occupation of this drill site will be contingent on pack ice conditions, which change yearly. December through early March is typically the period of least ice cover. The exact timing of drilling activities will depend on that season's ice conditions and the completion date of the previous site. However, the most likely period of occupation is January through February. These dates are now consistent throughout the text.

"Page 59, second complete paragraph: The penultimate sentence ... indicat[ing] that the Antarctic Bottom Water is colder and 'slightly less saline' than water higher in the water column ... should be changed to 'more'."

The sentence is technically correct as it stands. The cooled surface water sinks at the ice edge, entraining roughly an equal amount of the slightly warmer, more saline circumpolar deep water as it descends the continental slope (see Figure 14). This produces a bottom water mass that is less saline than the overlying circumpolar deep water, but denser due to the low temperature.

"Page 85, second complete paragraph: [A modifier] should be inserted between the words 'of' and '32' in the first sentence of the paragraph, since there may be additional species of diatoms in the epontic community that have not been identified."

The appropriate revisions have been made to the text.

"Page 93, Table 8: Footnote 'a' ... should be expanded, or a new footnote should be added, to indicate that these species plus the southern elephant seal and the Weddell seal also are treated as 'protected species' pursuant to Article 3 of the Convention for the Conservation of Antarctic Seals."

The appropriate revisions have been made to Table 8.

"Pages 96 to 97, Table 9: ... we suggest that this footnote ['a'] be checked for accuracy and that it be revised or expanded, as appropriate, to indicate that the identified species of whales are listed as 'endangered' under the U.S. Endangered Species Act."

Species are designated as Specially Protected under Public Law 95-541 if classified as Endangered under the U.S. Endangered Species Act. However, when more than one set of conservation measures apply to a species, the more stringent regulations are enforced. Therefore, species that are classified as Engangered are protected under the U.S. Endangered Species Act. The appropriate revisions have been made to Table 9.

"Pages 100 to 102, Endangered Species: This section should be expanded to identify those species that are listed as endangered or threatened in the IUCN Red Data Book and that are listed under Appendices I and II of the Convention on International Trade of Endangered and Threatened Species of Wild Fauna and Flora."

The appropriate revisions have been made to the text.

MMC (CONTINUED)

"Page 100 to 102, Endangered Species: In ... the first paragraph of this section ... the term 'endangered' is not self evident. .... This comment also applies to ... pages 121 and 141 of the DEIS."

The term Endangered was intended to indicate that the species are listed as Endangered under the U.S. Endangered Species Act. The appropriate revisions have been made to the text.

"Pages 113 to 114, Table 13: ... clarify the meaning of the term 'endangered species' in footnote 'a' ..."

The term Endangered is used in the same context as stated in the previous response. The appropriate revisions have been made to Table 13.

"Page 121, second complete paragraph: ... the text of this paragraph and Figure 41 should be expanded to note that Browns Bank off the southern tip of Nova Scotia, as well as the great South Channel area ... and the mouth of the Bay of Fundy are the most important right whale habitat areas .... In addition, ... seasonal use pattern in these areas should be identified ...."

Revisions noting the common names of the preferred habitat areas and their seasonal use patterns have been made to the text. The preferred area for right whales around Browns Bank has been added to Figure 41. Common names have been left off Figure 41 to facilitate presentation of the data. By comparison with the detailed base map of Georges Bank (Figure 19), one can compare regions of preferred habitat with the common names of geographic features.

"Page[s] 142 [and 143], Resources Development: Since [these] section[s] considers only development of mineral resources (commercial fisheries is discussed separately), the title of this section would be more accurate if it was changed to read something like 'Mineral Resource Development'."

A statement has been added to clarify that fisheries resources are discussed earlier. The purpose of this section is to discuss resources under development in the representative area. Although only fisheries and minerals are currently under development, other resources may be developed in the future. Altering the subtitle as suggested would be inappropriately restrictive.

"Page 180, second complete paragraph: This paragraph ... should be expanded to note that drilling activity in or near important feeding or migratory habitat for endangered whales ... could have a significant adverse effect on one or more endangered whale populations if such activities were to displace whales from these areas during critical periods of seasonal use."

These revisions have been added to the text. In addition, it was noted that proposed drill sites would be occupied through only one season by a single ship (stations are occupied for substantially less than 1 year) in the worst-case, thereby reducing the potential of population level impacts.

"Page 181, Drilling Operations: The fourth sentence of this paragraph states ... '... mobility and detection ability of marine mammals allows them to avoid significant discharge plumes.' We ... recommend that this sentence either be deleted or that the paragraph be expanded to provide

the basis for the conclusion. This also applies to similar statements concerning the ability of birds and fish to detect and avoid operational discharges."

The appropriate revisions have been made to the text.

"Page 182 to 183, Impacts on Endangered Species: ... The paragraph should be revised to reflect possible impacts on endangered whale populations as discussed earlier."

The appropriate revisions have been made to the text.

"Page 183, Impact on Biologically Sensitive Areas: This section should be expanded to identify and discuss at sea marine mammal nursery, feeding and/or migratory habitats ... which may be areas of special biological importance."

The NSF agrees that these are areas that may be of special biological importance. Therefore, discussion of potential impacts to these areas have been included in the document.

"Page 187, first paragraph: This section notes that Ocean Drilling Program activities will be guided by 'a conservation standard' established under CCAMLR and U.S. regulations implementing this Convention. ... [A] cross-reference should be added to the paragraph to refer the reader to the section of the document on applicable laws and regulations...."

The appropriate revisions have been made to the text.

"Page 201, first paragraph: ... [We suggest] the words 'in areas of special biological importance and/or' should be inserted between the words 'avoid drilling' and 'during periods' in the last sentence of the paragraph."

The appropriate revisions have been made to the text.

"Page 212, Laws and Regulations: ... Table 27 should be expanded to identify the responsibilities of the Department of Commerce for the protection of marine mammals and endangered species under the provisions of both the Endangered Species Act and the Marine Mammal Protection Act."

The appropriate revisions have been made to the text.

"Pages 214 to 215 Site Reviews: ... the PPSP as described in the first paragraph of this section might be expanded to include marine mammal scientists and/or biological oceanographers, and the list of 'important factors considered in the site selection process' ... might be expanded to include factors such as presence of potentially vulnerable biological communities or populations."

Please refer to the response to a similar concern expressed by the Department of the Interior discussed earlier in this appendix. It would be inappropriate to change the text concerning the site review process in this document until a final decision is made on a system that will address biological concerns in the site selection process.

MMC (CONTINUED)

"Page 223, third paragraph: This paragraph notes that formal consultations have been initiated with the National Marine Fisheries Service and the Fish and Wildlife Service pursuant to Section 7 of the Endangered Species Act. ... The results of these consultations should be appended to the FEIS."

The results of these consultations have been added to the FEIS under Chapter Five--Consultation and Coordination with Others.

NATIONAL MARINE FISHERIES SERVICE - DEPARTMENT OF COMMERCE

"We suggest that NSF include more information ... regarding the use (frequency and seasonal timing) of seismic exploration in the Georges Bank."

There are no present plans to drill on Georges Bank. This site was chosen as a representative site to facilitate impact assessment of oil and gas blowout, fisheries, marine mammals, and birds. If proposals to drill in the region are made, the appropriate environmental assessment will be pursued prior to any activities, including the frequency and seasonal timing of seismic exploration and potential for interaction with high-use areas of endangered whales.

"The potential for ODP site selection within the sensitive high-use areas for endangered whales should also be investigated and discussed in more detail in the FEIS."

Please refer to the response to a similar concern (biological considerations input into the site selectin process) expressed by the Department of the Interior discussed earlier in this appendix.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION - OFFICE OF THE ADMINISTRATOR - DEPARTMENT OF COMMERCE

"[We recommend that appropriate consideration] ... is given of the probabilities of detrimental impacts to the Antarctic ecosystem in the event of an accidental blowout caused by the continuous stress on the JOIDES vessel and drilling systems under conditions of extended periods of gale-force winds during the planned January-February operational schedule in the Weddell Sea."

The JOIDES RESOLUTION was chosen as the drillship for the ODP, in part, because its drilling and ice capabilities (Table 4 and Section 4.3) allowed expansion of the program to higher latitudes. The redesigned drill string and load handling equipment can handle extreme conditions. When weather conditions approach the drillship's capabilities, operations will be ceased and the hole will be abandoned. With its bow to weather, the ship has sufficient power to stay on-station during gusts above the normal weather limits. In the unlikely event that a freak wave or gust displaced the ship too far off station while drilling, the drill string would most likely fail either at the seafloor or at the stress reduction device in the moonpool. Failure at the seafloor would result in the loss of the downhole assembly. Failure at the stress reduction device would result in loss of the entire drill string. Impacts from the loss of the drill string and the resulting potential release of formation fluids were discussed in Section 4.7. An accidental blowout would not occur unless potential blowout conditions had developed downhole at the time of the drill string loss. Based on the extemely low probabilities projected for blowouts with release of oil (Section 4.7) and loss of the drill string, the likelihood that both conditions will occur simultaneously appears to be negligible.

"To ensure that appropriate measures are taken to protect living resources and habitats in both the Georges Bank and Weddell Sea areas, we recommend that scientific observer teams from NOAA/NMFS be included among the scientific complement during the at-sea operations."

Due to the remoteness from land of most ODP operations, an observer team would not be able to helicopter at will to and from the ship on-station, and would therefore be required to meet the vessel at the appropriate port of call at the start of the leg in question. The team would have to stay on board throughout the 2-month leg, with the majority of the time spent in a stationary mode on site. If these conditions are acceptable for an observation team, the NSF will initiate consulting with JOIDES and NMFS on the matter. The NSF feels that these conditions are an excellent opportunity for certain types of field studies and is actively publicizing the availability of the platform.

"Page 29, paragraph 5: Georges Bank is not ... on the schedule as a candidate drill site area ... however, Figure 8 on Page 30 shows a site off New Jersey, not Massachusetts. Is this correct, or is that site supposed to be Georges Bank? Similarly, Figure 9 on Page 32 indicates that there is no specific future scientific interest in Georges Bank, although there is interest in an area off Chesapeake Bay."

Information updated at the time of publication is provided in the EIS on potential drilling locations for this long-term program. Specific drilling plans are available 1 year in advance of the drilling operations, thus they are discussed. Figure 8 presents identified candidate drill sites for the first 2 years of the drilling program as known at the time of EIS publication. Long-range drilling plans are tentative, and thus are difficult to address. However, Figure 9 is presented to indicate areas where scientific interest to drill has been identified, although this is not necessarily inclusive of all future drill sites.

"... the statement in paragraph 3 on Page 45 indicating that potential effects on endangered and threatened species would be magnified due to these animals' reduced populations is only likely to be true for right whales within the preferred high-use areas noted in NMFS's Biological Opinion for Lease Sale 82. The possibility of collisions between a drillship and sea turtles in the Georges Bank area is virtually zero."

This additional information is noted. However, no change to the document is required.

NOAA (CONTINUED)

"Page 47. Potential impacts of oil spills on marine mammals are correctly stated and are similar to those found in NMFS's Biological Opinions to MMS. However, the probability of an oil spill occurring during the ODP is much less than during oil and gas exploratory drilling activities."

This concurrence is noted. However, no change to the document is required.

"Pages 50 et seq. Why was Georges Bank chosen as a 'representative site' when there is no mention of it in the ODP schedule in Section 2.2? ... Discussing Georges Bank as a representative site would seem to be inadvisable, unless it is an actual proposed site during the life of the project."

As discussed in Section 3.1-Introduction, representative sites were selected to encompass the full range of scientific goals, geographic positions, and geologic and ecologic conditions expected during the ODP. In this way, the full range of potential effects is addressed. The Georges Bank area was selected because of data availability that would allow the assessment of oil and gas blowout, fisheries, and landfall/shore impacts.

"Page 110, paragraph 6. The coastal waters of the Gulf of Maine do not provide much habitat for harp seals or hooded seals. They occasionally visit the area but their range is centered to the north in Canadian waters."

This additional information is noted. However, no change to the document is required.

"Page 111, Table 12. Harbor seals prefer rocky ledges as haulout areas. Sandy beaches are only used by juveniles in the winter on Cape Cod where no rock ledges are available."

The appropriate revisions have been made to Table 12.

"Page 112, paragraph 2. The right whale is also found in Cape Cod Bay and the Great South Channel in late winter and spring. Humpback and fin whales are the predominant species in the area, and should also be mentioned in the narrative."

This information is presented under the discussion on Endangered Species later in the section on the Georges Bank region. In the interest of brevity, no change to the document will be made.

"Page 112, paragraph 3. The killer whale is not commonly seen in the area. The pilot whale, the Atlantic white-sided dolphin, and the harbor porpoise are the common small odontocetes in the area year-round. The Risso's dolphin is a common inhabitant of the shelf-edge area."

The appropriate revisions have been made to the text.

"Page 113, Table 13. We suggest making the following changes: Minke whale should read: 'Nearshore northward spring migration ...' and 'offshore southward fall migration ....' For fin whale and humpback whale, add '... and other available small schooling fishes' to the last sentence. For right whale, begin the first sentence with 'Remaining individuals ....' For long fin pilot whale, replace the first sentence with: 'Pelagic distribution

centered around the shelf edge with seasonal spring/summer movement over the shelf.' For killer whale, add a new sentence at the end: 'Infrequently seen in U.S. waters.' For harbor porpoise, insert a new first sentence: "Most common small cetacean on the shelf.' For bottlenose dolphin, insert a new third sentence: 'Inshore and offshore stocks possible.' For North Atlantic bottlenosed whale, replace 'Rhode Island' with 'southern New England waters.'"

The appropriate revisions have been made to Table 13.

"Page 121, paragraph 2. With regard to the Atlantic Ridley, we suggest adding at the end of the fourth sentence '... the most severely depleted sea turtle species.'"

The appropriate revisions have been made to the text.

"Page 121, paragraph 3. With regard to right whales, we suggest inserting '(500)' after 'low population ...' in the fourth sentence."

The appropriate revisions have been made to the text.

"Page 167. Sperm whales and pilot whales have been reported to congregate around a drillship operating in the Mid Atlantic (presumably to feed on schooling squid). Some of these sperm whales stayed near the drillship even after the presumed food source had dispersed. Vessel noise and dynamic positioning echo sounders may have had something to do with these animals' apparent attraction to the drillship."

This additional information is noted. However, no change to the text is required. Other observed effects of noise on marine mammals are presented in Section 4.5.

"Pages 178-179. ODP activities may disperse endangered whales from high-use areas where feeding conditions are optimal. These effects would be significant only in areas where severely depleted species, such as the right whale, congregate to take advantage of oceanographic conditions that concentrate food sources, such as dense blooms of Calanus spp. in the Great South Channel in the spring. Seismic operations could have the same effects if conducted in high-use areas at certain times."

Please refer to the response to a similar concern expressed by the Marine Mammals Commission earlier in this appendix. It is appropriate that impacts to areas of special biological importance be addressed. Although the right whale is Endangered, the potential for impacts is significant only in certain areas such as those listed above. Therefore, the discussion is located under Impacts on Biologically Sensitive Areas.

"Page 212. Seismic surveys should be done with airguns only, and should be prohibited in endangered whale high-use areas during known periods of whale use."

NOAA (CONTINUED)

Please refer to the response to a similar concern expressed by the National Marine Fisheries Service discussed earlier in this appendix. Although the comment was specific for Georges Bank, similar procedures apply to other areas. As stated earlier in the appendix, the NSF is pursuing methods to incorporate such biological considerations into the site selection process.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

BULK RATE
POSTAGE & FEES PAID
National Science Foundation
Permit No. G-69
SPECIAL FOURTH CLASS BOOK