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Management of Living Marine Resources:

A Research Plan for the Washington and Oregon Continental Margin

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CONTENTS

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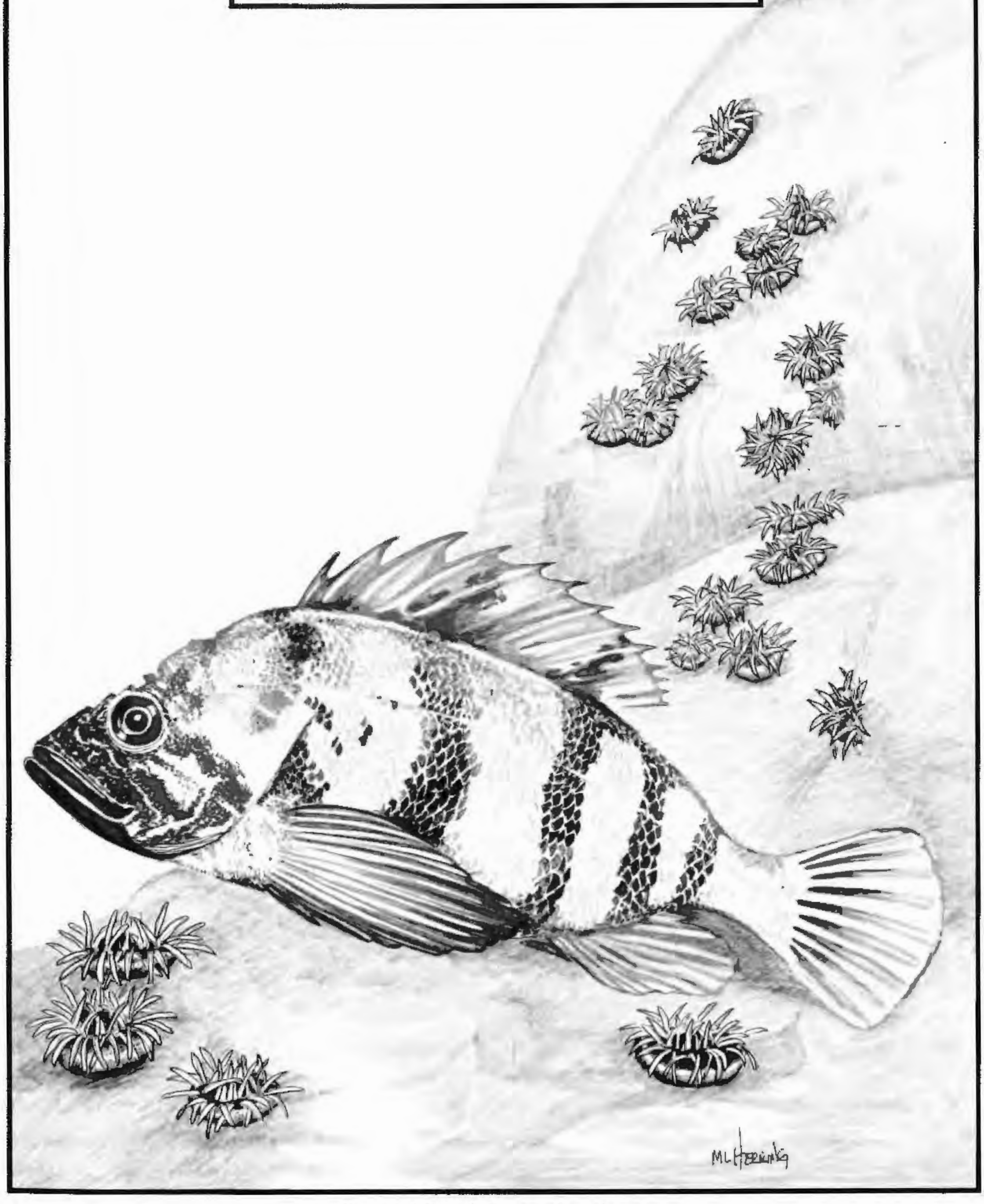
Conclusions and Recommendations



Tiger rockfish, *Sebastes nigrocinctus*

CONCLUSIONS AND RECOMMENDATIONS

The scale of human impact on the world's oceans is expanding at a rate that greatly exceeds our capacity to foresee the consequences. Despite progress in environmental assessment during the past several decades, prediction of the effects of human disturbances in large marine ecosystems remains an elusive goal. The inability to forecast ecological change is, in part, a practical limitation; the complexity of physical and biological interactions superimposed by a myriad of human disturbances often overwhelms available information and understanding. However, the uncertainty may be more absolute; chance events may cause irreversible changes in the structure of complex ecosystems that defy prediction (May 1977; Beddington 1986) .

Whatever the cause, uncertainty is fundamental to our understanding of the behavior of large marine ecosystems. Accordingly, a primary function of environmental assessment is not to develop precise predictors of ecological response but rather to minimize the risk that human disturbance will produce large-scale and irreversible change (Bella and Overton 1972). The purpose of this research plan is to improve environmental assessment in a large marine ecosystem so that appropriate actions can be taken to minimize the risks of human disturbance.

Strategies to Minimize Environmental Risk

The prospect that oil and gas and placer mineral resources may be extracted from the Washington and Oregon continental margin raises a large number of questions about environmental risks in this region. Some of these are technical questions that will require additional research to answer. Others are management questions that will decide which technical issues are most important to address and how the results will be applied to decisions about resource use. It is thus difficult to discuss research needs outside the context of the management program that will set the priorities and use the results. We conclude that the following strategies for research and management are needed to improve environmental assessment and to minimize environmental risks in the Washington-Oregon offshore region:

1. Conduct research on natural variability.

Potential development of mineral resources off the Washington and Oregon coast has stimulated a familiar array of environmental questions about an unfamiliar marine ecosystem. The ecological effects of offshore development will be influenced by many factors unique to this region. Examples include the cold water environment, strong tidal and wave energies, a seasonally active coastal upwelling system, and large-scale variation in the strength of currents that transport water and organisms from adjacent subarctic and subtropic biomes. Application of environmental studies from other marine locations will be hampered by the lack of basic inventory information for many populations and communities in the Washington-Oregon region. Oceanographic information has not been collected consistently through time or space, so that it is difficult or impossible to compare results of many surveys. Regional scales of variability, therefore, are poorly understood, and stable equilibrium conditions for many populations and communities, if they occur, have not been described. Such deficiencies will undermine areawide assessment and detection of the effects of human disturbances.

Four major types of disturbance will be associated with oil and gas and mineral development in this region: noise, chemical contamination, dredging and habitat alteration, and interference with established offshore fisheries. Although one objective of this plan is to evaluate the sensitivity of selected populations and communities to these disturbances, we conclude that environmental assessment will be advanced most significantly through a better understanding of natural variability throughout the region. This will require more consistent monitoring of representative populations and communities. Expanding the number of habitats and communities for which there are data on population fluctuations should be emphasized. Concurrently, research on physical processes at a variety of spatial and temporal scales will be needed to interpret biological fluctuations. In particular, the interactive effects of local upwelling events and large-scale climatic change on biological production should be investigated. Satellite imagery may assist researchers in these studies by providing a synoptic view of regional oceanographic conditions through time.

Future research should emphasize variability of entire aggregations of species. Much of the biological information for Washington and Oregon is analyzed and reported for single species of economic importance and has limited application to many broader ecological questions. For example, stock-recruitment models for single populations provide little insight whether a disturbance will cause an ecosystem to become unstable or the species composition and abundance of component populations to dramatically change. On the other hand, simulation models of entire ecosystems may offer little guidance about effects on individual species or the reversibility of observed changes (Beddington 1986). Trends in abundance and distribution of the many components of the ecosystem may provide the appropriate middle ground to evaluate ecological change. At the same time, interactions among species should be studied to understand the possible consequences of shifts in population abundance or to distinguish natural from man-induced effects.

The results of oceanographic surveys should be analyzed and presented in a geographic format. Environmental decisions will usually focus on the development of specific geographic areas and will affect not only single populations but entire aggregations of species that share a region or habitat. Surveys should be analyzed to describe the composition of species assemblages and their associated habitats. Assemblage-habitat distributions should be evaluated through multivariate analysis of previous biological surveys off Washington and Oregon as well as new surveys designed at the multiple species level. Survey information should be entered into a computerized mapping system to describe geographic relationships among species, environmental factors, and proposed development activities.

Obviously, understanding variability among the diverse components of a large marine ecosystem is not a simple undertaking. The classification of species assemblages and habitats and the definition of keystone or indicator species within them would help to establish research priorities. We recommend that a conceptual model of the ecosystem be developed, not as a means of prediction, but to classify the diversity of subsystems, habitats, and communities and to identify the processes that are believed to control biological variability. The model should include the entire northern California Current region (continental margin from Cape Mendocino, California to Vancouver Island, British Columbia) as an ecological unit. Such a model would help to identify the components of the ecosystem that may be most sensitive to disturbance and the deficiencies in existing knowledge that most severely restrict understanding of population fluctuations.

2. Establish information standards for environmental decisions.

Timeliness of research is critical if results are to keep pace with development proposals. All too often environmental studies are a response to decisions that already have been made. As a result, environmental studies may become a means of legitimizing rather than making decisions. Standards for information collection must be built into a decision process to assure that results are timely and beneficial to ocean management.

The prelease phase of the oil and gas leasing program is a crucial period for decision-making because it is during this time that risks to the entire region are evaluated. The capacity to minimize these risks decreases during subsequent phases of the management program as attention shifts to the regulation of individual development sites. Although the federal leasing program follows a detailed series of admininistrative steps that precedes an oil and gas sale, there are no specific standards that define the quality or quantity of environmental information necessary to make prelease decisions.

Very few of the prelease studies recommended in this plan can be completed prior to 1992 when oil and gas leasing is scheduled for the Washington-Oregon region. Existing oceanographic information for this region can support only a superficial evaluation of environmental risks. As noted above, previous biological surveys do not adequately describe the diversity of communities, habitats, and environmental conditions that are represented throughout a very large sale area. There is little information about nearshore circulation processes that will influence the distribution and movement of contaminants in coastal waters. Much of the existing data has not been analyzed in geographic and multiple species formats that are needed to identify environmentally sensitive areas prior to the lease sale. Very little time remains to collect, analyze, and interpret new information for areas and communities not previously studied.

The importance of prelease decisions and the lack of basic inventory information for this region suggest that the states of Washington and Oregon should define a minimum standard for prelease environmental studies. We recommend that the leasing schedule be adjusted as needed to synchronize leasing decisions with the collection and analysis of environmental information needed to support them.

An important factor that contributes to the lack of information needed to support leasing decisions is the large geographic extent of the Washington-Oregon sale area. As a general rule, management decisions that are broken into small, incremental stages with careful environmental evaluation required at each stage will tend to minimize risk. Management decisions that occur over short temporal and spatial scales are usually less likely to have large-scale consequences. In this regard, the federal leasing program, which opens very large regions to oil and gas development for a period that may last several decades, appears inconsistent with prudent management of environmental risks. This becomes a particular concern in the Pacific Northwest where the lack of previous development activity and inconsistent biological monitoring seriously undermine environmental assessment for a large and heterogeneous region.

In contrast to the oil and gas leasing program, placer mining activity should allow adequate time for environmental evaluation. No immediate proposals or schedules exist for mineral mining off the Washington or Oregon coast. In addition, the area of development interest and the potential environmental risks are more localized than the proposed oil and gas leasing program. This should allow more detailed environmental surveys to be focused in areas with commercial potential.

The effects of marine placer mining have not been widely studied. While there has been considerable research on the effects of channel maintenance dredging in estuaries and bays, no continuous dredging operations for marine minerals have been tested in the United States. In addition, very little physical or biological information has been collected in the nearshore region off southern Oregon (south of Cape Blanco) where mining activity is most likely to occur. We recommend a standard protocol for environmental assessment be incorporated into state leasing programs for mineral exploration and development. In the first phase of such a protocol, inventories of biological resources and habitats in the southern Oregon region should be conducted concurrently with ongoing exploratory surveys for placer minerals.

A critical interpretive step should follow completion of environmental research and precede planning for offshore development; that is, the results of many unrelated studies (often conducted for reasons other than environmental assessment) must be compiled, analyzed collectively, and translated into a management program for ocean resources. The results of such an analysis should be documented so that the rationale for decisions is clearly understood. Synthesis of environmental information should be repeated periodically and the management program updated to reflect the evolution of scientific understanding that will result from new research. Through this iterative process, safety factors applied to management decisions may be adjusted as research improves understanding of environmental risks.

Before the Washington-Oregon continental margin is opened to leasing for petroleum or placer minerals, we recommend the states prepare an interpretive report that synthesizes all available oceanographic data in a format that is needed to make prelease environmental decisions. We suggest the report be organized as an atlas that summarizes results in a geographical or ecological hierarchy (system, subsystem, habitat, etc.). Such a format should define the distribution of species assemblages and habitats and describe the processes that influence biological variability at each hierarchical level. The implications of these results and recommendations for managing specific offshore habitats and subsystems should be discussed.

3. Designate the ecosystem as the primary unit of environmental planning and management.

In the United States, environmental regulations in marine environments are primarily implemented on a case-by-case basis. State and federal permits and procedures focus on individual development proposals and local environmental effects. Off-site effects and the ecosystem-wide implications of individual or cumulative actions are rarely understood and often disregarded. However, if a fundamental goal of environmental management is to avoid large-scale consequences of human disturbance (Bella and Overton 1972), then the appropriate unit of management is an entire region or ecosystem. For the Pacific Northwest, the appropriate unit of management is the northern California Current ecosystem.

Regional management requires planning to direct local resource uses. Management plans should describe the activities that will be allowed and the locations where they will occur to acheive a desired regional effect (Regier and Baskerville 1986). Since the consequences of development activities on an ecosystem are usually unpredictable, management strategies based on general ecological principles (rather than "hard data") will be a primary means to minimize large-scale risks. Examples of such strategies might include: (1) maintain biological and habitat diversity region-wide by limiting the total area of any one habitat, community, or population that is dedicated to development; (2) separate environmental disturbances in time and space; (3) limit or prohibit specific categories of use to protect highly diverse or productive habitats and communities; (4) minimize or prohibit disturbances in shallow or poorly flushed areas; (5) protect keystone species that tend to regulate community structure and stability. A combination of broad policies, offshore management zones, and performance standards may be used to direct local actions consistent with regional strategies.

Interest in total ecosystem management has grown steadily worldwide for several decades (Sherman 1986). Increasing signs of oceanic stress from pollution, intensive fishery harvest, and global warming underscore the need for coordinated management at national and international levels. Unfortunately, jurisdictional boundaries remain a major impediment to ecosystem management. Within the United States, a complex array of state and federal agencies share responsibility for managing ocean resources. Separate agencies are responsible for managing marine mammals, marine birds, sport and commercial fisheries, pollutant discharges, ocean dredging and disposal, oil and gas and mineral development. Management is further segregated geographically between adjacent states and along the 3-mile boundary of the Territorial Sea that divides state and federal jurisdictions. The concept of total ecosystem management becomes even more complicated where international boundaries are involved.

A hopeful step toward integrated resource management in the Pacific Northwest is the development of an Oregon Ocean Resources Management Plan scheduled for completion in June 1990 (Oregon Ocean Resources Management Task Force 1988). Although the plan will not address the entire northern California Current ecosystem, it will develop policies for the use of living and nonliving resources in federal as well as state waters of the Oregon continental margin. We recommend that a regional mechanism be established to coordinate resource planning and management in Oregon with northern California (north of Cape Mendocino) and the State of Washington. Coordinated management plans may also provide the impetus needed to develop an ecosystem-wide focus to environmental studies.

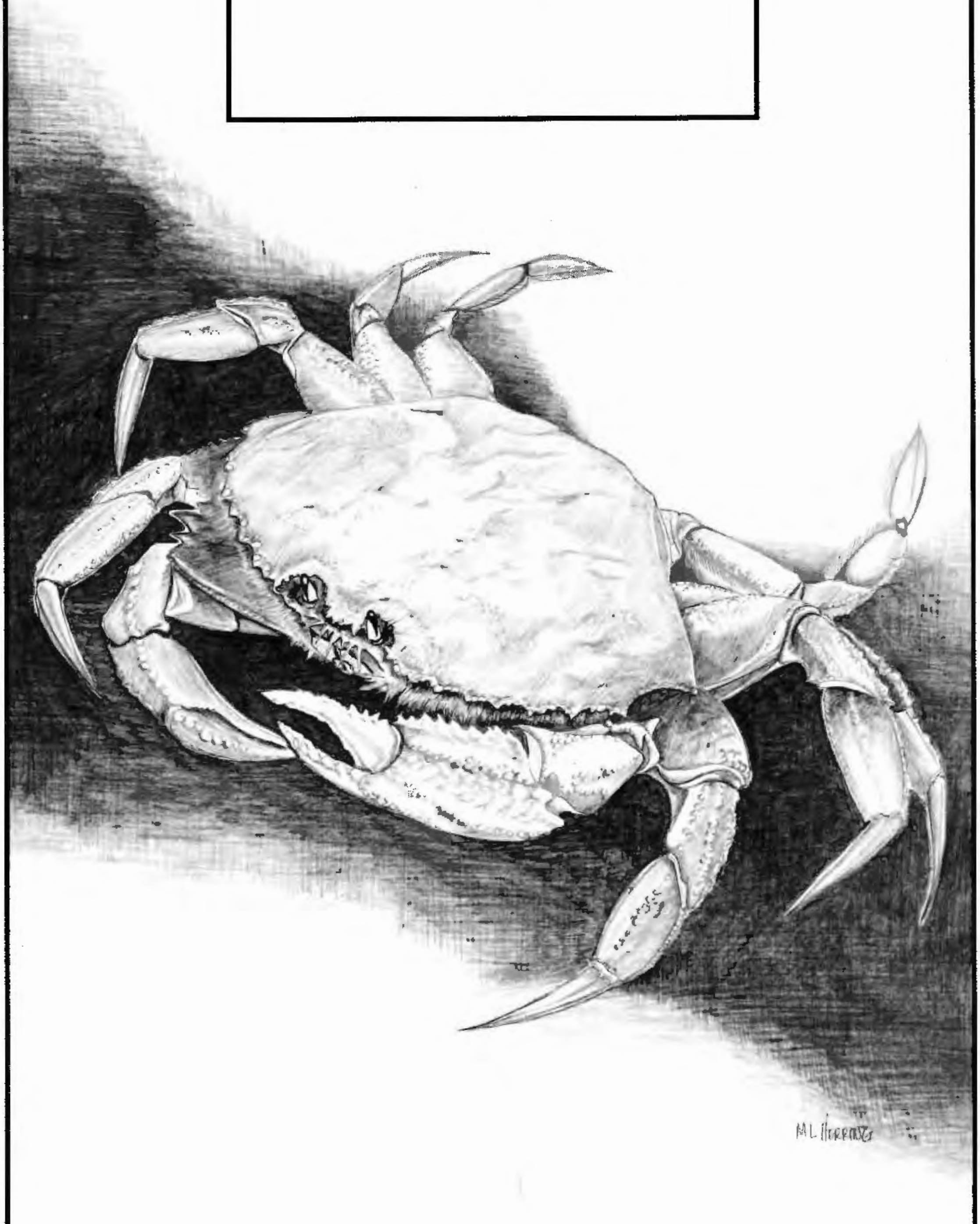
4. Develop a cooperative environmental research program for the northern California Current ecosystem.

Interests in environmental studies in the Pacific Northwest are as divergent as the management functions of the many resource agencies that fund or conduct oceanographic research. Research by fishery management agencies, for example, primarily involves individual populations of commercial interest. Harvest statistics maintained by these agencies provide valuable time series, but similar data for noncommercial species and prey organisms or environmental factors needed to interpret these trends are rarely collected. Environmental studies related to oil and gas leasing are administered through the Minerals Management Service of the U.S. Department of Interior. Most surveys are short-term and often focused on specific issues or legal requirements that might impede leasing activities. Study priorities are established annually with no strategic plan to integrate individual studies into a cohesive, regional program. Washington and Oregon universities have conducted much of the basic ecological research in the region, but funding has been inconsistent, and studies are frequently short-term and limited in geographic coverage. Results thus describe a limited range of environmental conditions.

In conclusion, institutional interests and the high costs of ocean research have diffused research activities into an array of individual, short-term, and local issues. This is contrary to the long term and large scale of information that is needed to support regional management and to minimize environmental risks. Ironically, the lack of basic ecological understanding that has resulted from research on a series of unrelated issues is universally limiting to the management capabilities of the many resource interests in the region. We recommend that a cooperative program of research institutions and state and federal resource agencies be organized to plan, review, and coordinate environmental research throughout the northern California Current region.

This research plan was prepared without consideration of any single agency that might fund or implement our recommendations. This has allowed us the luxury of a regional and long-term approach to environmental studies. The obvious disadvantage is that no single entity exists to assure that these recommendations will be implemented. Formation of a regional clearinghouse for reviewing research proposals or development of a cooperative studies program among agencies and universities could encourage the ecosystem perspective that is sorely needed. In the absence of such a structure for implementing our recommendations, we are nonetheless hopeful that this plan will direct research toward those subjects and locations that will most benefit environmental assessment throughout the region.

Introduction



Dungeness crab, *Cancer magister*

Need for a Research Plan

In the future, an increasing proportion of the world's minerals will be extracted from the ocean floor. Interest in these resources has been stimulated by decades of improvement in offshore drilling technology, worldwide demand for energy and strategic minerals, and discovery of significant offshore deposits of oil, gas, and valuable metals (e.g., manganese, copper, nickel, chromium, cobalt). The United States Congress amended the Outer Continental Shelf Lands Act in 1978 to expedite the development of offshore resources "in order to achieve national economic and energy policy goals, assure national security, reduce dependence on foreign sources, and maintain a favorable balance of payments in world trade." In 1983, the President of the United States signed a proclamation that extended United States jurisdiction to 200 nautical miles from the coast. Within this Exclusive Economic Zone, the United States claims all rights to the mineral resources on or below the seabed.

Within the next decade, resource demand in the United States could stimulate oil and gas exploration and mineral mining in many areas of the Exclusive Economic Zone. The Washington-Oregon outer continental shelf is one of 38 areas proposed for lease in the U.S. Department of Interior's 1987-92 oil and gas leasing program (MMS 1987). In addition, chromite-bearing black sands off the southern Oregon coast and titanium-rich sands off the northern Oregon and southern Washington coasts are under consideration for future mining (U.S. Bureau of Mines 1987). These placer deposits, extractable with hopper dredges, are of significant interest because of their strategic importance and the lack of alternative domestic supplies. Nearshore deposits of sand and gravel may also be dredged off the Oregon and Washington coast as local onshore supplies in some coastal areas are depleted and the costs to transport materials from remote inland locations are high.

The potential development of nonrenewable resources off the Washington and Oregon coast raises a large number of environmental issues that previously have not been a concern in this region and with which the natural resource agencies of the two states have had little experience. Fish, shellfish, and other living marine resources support a large commercial fishing and seafood processing industry and are vital to tourism and recreation in the Pacific Northwest. Although universities, state and federal agencies, and commercial fishermen have contributed to a large body of oceanographic and fisheries data for this region, available information is insufficient to evaluate the risks of offshore mineral development to many important marine habitats, populations, and communities.

The large number of issues and the very high cost of ocean research will require careful planning and coordination of future research activities among state and federal resource agencies. In anticipation of these needs, the Oregon Department of Fish and Wildlife (ODFW) received federal funds to prepare this plan of biological research for the Washington and Oregon continental shelf. The plan defines research that is most needed to understand and minimize the environmental risks of coastal mineral development.

This report describes our study methods, summarizes the principal data gaps, and recommends research to address the management concerns of this region. Because the area from the U.S.-Canada border to Cape Mendocino, California represents a single zoogeographic region, some of the literature we reviewed and most of the research we recommend for Washington and Oregon also apply to northern California.

In the last 13 years, several literature reviews have been written to summarize what is known about the biology and oceanography of the marine and estuarine waters off Washington and Oregon and to identify research needs (Oceanographic Institute of Washington 1977; Stander and Holton 1978; Bottom et al. 1979; Proctor et al. 1980; Harvey and Stein 1986). In 1976, the U.S. Bureau of Land Management held a 3-day conference to discuss research needs in relation to potential oil and gas leasing off the Washington and Oregon outer continental shelf (U.S. Bureau of Land Management 1977). Research recommendations were identified by more than 150 scientists from the Pacific Northwest. Stander and Holton (1978) mapped general distributions for key marine species, discussed data gaps, and endorsed the Bureau of Land Management recommendations for research. Good et al. (1987) reviewed mineral, oil, and gas resource potential, development technology, and environmental effects as part of an evaluation of Oregon agency rules and programs for management of the nearshore ocean. In May 1988, the U.S. Department of Interior's Minerals Management Service (MMS) sponsored another 3-day conference and workshop "to develop a clear understanding of research needs and priorities with respect to the...oil and gas 5-year lease sale scheduled for the Washington and Oregon Planning Area" (MMS 1988b).

Despite the ackowledged need, little biological research has occurred off the Washington and Oregon coast since the early 1970s, so that many of the research priorities recognized in 1976 (U.S. Bureau of Land Management 1977; Stander and Holton 1978) are still applicable today. However, the results of previous workshops and many reviews of research needs for this region are long "wish lists" of activities organized by scientific discipline. These lists offer little context to indicate why particular recommendations were chosen over others or which studies are most relevant to environmental evaluation and management. An important purpose of this plan is to provide a logical rationale for environmental research that is directly tied to management and information requirements related to potential mineral development in coastal Washington and Oregon.

Defining an appropriate level of detail was among the most difficult decisions we had to make for this plan. We chose the middle ground between a long-term strategic plan and more detailed research activities to address immediate management issues. At the strategic level, we tried to anticipate the full range of ocean management issues that may arise in the next several decades. This required that we evaluate potential environmental conflicts associated with each phase of exploration and development for oil and gas and placer minerals. We considered this broad overview a necessary prerequisite for defining objectives among an endless array of marine research topics that could be proposed and undertaken. On the other hand, present development plans, and, in particular, the scheduled 1992 Washington-Oregon oil and gas lease sale, dictate immediate attention be given to specific research topics needed to support prelease decisions. We have attempted to offer sufficiently detailed recommendations in this report to encourage research that is most needed before the continental shelf is opened to oil and gas or minerals leasing.

As is true for any plan, this document is not an endpoint but a beginning. It is a roadmap that will need revision as new territory is charted. Priorities for study will undoubtedly change. Additions and modifications will be necessary as the specific development plans for this region unfold and as research provides new information. We have tried to present a general rationale and structure that can accommodate other research activities as new information requirements are identified.

Approach and Methods

Figure 1 illustrates the steps we followed to identify objectives and tasks for the research plan. In the first phase of our analysis, we reviewed the types of development that are most likely to occur and the environmental implications of these activities for the Washington-Oregon study region. Second, we considered whether existing technical information is adequate to evaluate environmental risks and devise measures to minimize adverse effects.

Specifically, we evaluated whether existing information is sufficient to describe:

(A) patterns of distribution for the principal species, communities, and habitats off Washington and Oregon,

(B) the possible environmental effects of each phase of marine mineral exploration and development, and

(C) the critical processes that affect biological production and natural variability in the region.

From this review, we identified major categories of environmental research that are needed to support decisions about the use of ocean resources. Our conclusions are represented by the objectives, tasks, and activities that are listed in the plan.

We established an interagency advisory panel to provide information for the plan and to coordinate our activities with representatives from state and federal resource agencies and Sea Grant institutions in Washington, Oregon, and California (*Table 1*). Between January and March 1987, we met with panel advisors in each of the states to review development potential for oil and gas and minerals, discuss environmental issues, and define key species and groups of species for the research plan. We also sent questionnaires to agencies and Sea Grant institutions in other coastal states throughout the United States to obtain additional information about the environmental issues that have been raised where mineral and oil and gas development have occurred or are proposed. From April through June 1987, we interviewed technical experts from universities and resource agencies in Washington and Oregon (*Table 2*). Through these meetings, we identified biological and oceanographic data sets available for the study area and developed a list of information needs.

For practical reasons, it was necessary to limit the geographic area and subject matter of this plan. Our literature review focused primarily on the marine environment

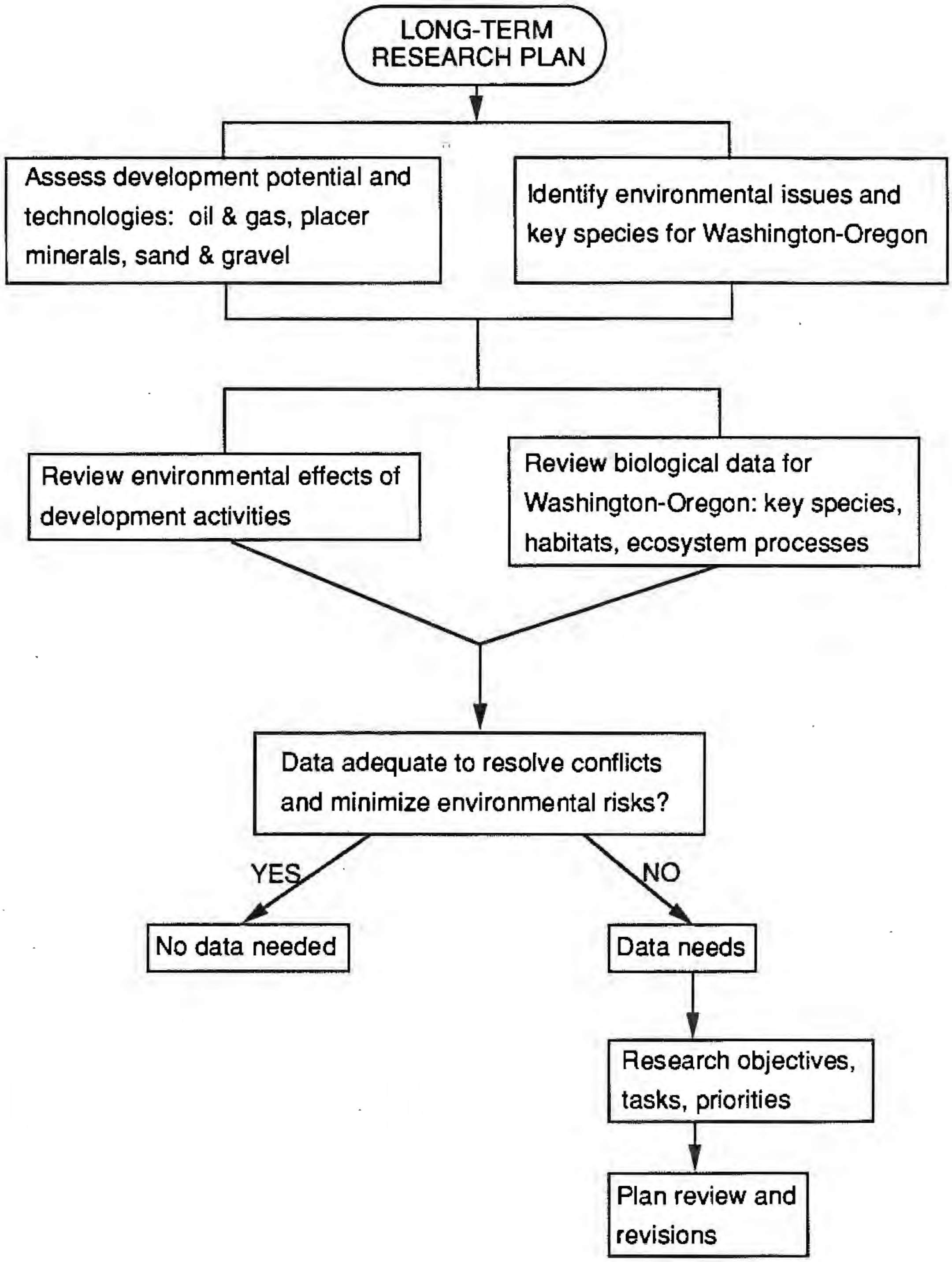


Figure 1. Methodology used to prepare a research plan for biological resources of the Washington and Oregon continental margin.

from the beach to the upper continental slope (approximately 900 m depth). Secondarily, we evaluated research needs that apply to most Washington and Oregon estuaries, but more detailed review for individual estuaries may be necessary in the future when specific development proposals are defined. We evaluated information available for biological resources and fisheries. We also reviewed reports in the physical sciences related to the transport of pollutants and production of biological populations, but we did not consider other types of research in geological, chemical, or physical oceanography. Although parts of this plan will apply to many other marine development activities, we emphasized biological and fisheries issues that could accompany development of oil and gas and nearshore mining for placer minerals or sand and gravel. Research needs for deep ocean mining are evaluated in several literature reviews for the Gorda Ridge region (Boudrias and Taghon 1986; Ellis and Garber 1986; Harvey and Stein 1986; Krasnow 1986) and are not described in this report. Air quality impacts; onshore environmental effects resulting from construction and operation of pipelines, processing plants, or other support facilities; and the various social or economic effects of offshore development (other than effects on coastal fisheries) were beyond the scope of this research plan.

Table 1. Members of the interagency panel for the research plan.

Robert Bailey	Oregon Department of Land Conservation and Development
Thomas Dark	National Marine Fisheries Service
Joseph Easley	Otter Trawl Commission
Louis Echols	Washington Sea Grant
James Glock	Pacific Marine Fisheries Commission
Cadet Hand	California Sea Grant
Susan Hansch	California Coastal Commission
Buford Holt	Minerals Management Service
Gregory McMurray	Oregon Department of Geology and Mineral Industries
Mary Lou Mills	Washington Department of Fisheries
Fred Piltz	Minerals Management Service
Monique Rutledge	National Marine Fisheries Service
Robert Tasto	California Department of Fish and Game
Brian Walsh	Washington Department of Ecology
Jay Watson	US Fish and Wildlife Service
William Wick	Oregon Sea Grant

Goal and Rationale

Lewis (1980) describes two primary goals of environmental management that are the focus of this plan: maintenance of ecological diversity and the overall health and productivity of the marine ecosystem. To satisfy the first goal, selected habitats, areas, or species may be protected to avoid piecemeal loss of diversity from physical destruction or misuse. Designation of protected areas cannot prevent exposure to pollutants transported in water, but judicious placement of management zones, preserves, buffer areas, and the like can help to minimize the threat of exposure. Classification of habitats and communities, therefore, is a fundamental tool to define and maintain ecological diversity. The second goal—overall health and productivity of the marine ecosystem—is a much more difficult problem that requires other management and research strategies. The causes of variability for many marine populations and communities are poorly understood so that effects of man-induced changes in the ocean may not be distinguishable from natural cycles. Understanding ecological processes and the dynamics of natural populations and communities are critical to environmental evaluation and management.

Unfortunately, research cannot provide all the answers to assure these two goals are achieved. A principal problem is the environmental predicament described by Bella and Overton (1972): the human capacity to alter ecosystems has progressed at a much faster rate than our ability to foresee the consequences. Accurate forecasting of these consequences will likely remain an unrealistic goal if, as theory and experience suggest, ecosystems do not behave in a predictable manner but may exhibit irreversible changes that are the result of chance events in history (May 1977; Beddington 1986). For disturbances that affect complex ecosystems, not only are the probabilities of a particular outcome uncertain, but often a large number of the possibilities are unknown (Bella and Overton 1972).

Table 2. Technical advisors who provided information for the assessment of research needs.

David Armstrong, University of Washington	Crab
Carl Banse, University of Washington	Benthic invertebrates
Steven Barry, Washington Department of Fisheries	Crab
Jerry Butler, Oregon Department of Fish and Wildlife	Ocean sport fish
Drew Carey, Oregon State University	Benthic invertebrates
D. W. Chamberlain, Atlantic Richfield Co.	Environmental science
Robert Demory, Oregon Department of Fish and Wildlife	Groundfish
Darrell Demory, Oregon Department of Fish and Wildlife	Crab
Tina Escheverria, National Marine Fisheries Service	Rockfish
David Fluharty, University of Washington	Policy and management
Robert Francis, University of Washington	Groundfish
Robert Garrison, Oregon Department of Fish and Wildlife	Salmon
James Golden, Oregon Department of Fish and Wildlife	Groundfish
James Good, Oregon State University	Policy and management
Donald Gunderson, University of Washington	Crab, groundfish
Danil Hancock, Oregon State University	Benthic invertebrates
Barbara Hickey, University of Washington	Physical oceanography
Adriana Huyer, Oregon State University	Physical oceanography
Charles Janda, US National Park Service	Coastal Management
Steven Jeffries, Washington Department of Game	Marine mammals
Kenneth Jenkins, California State Long Beach	Molecular ecology
LaVerne Kulm, Oregon State University	Geological oceanography
Michael Landry, University of Washington	Zooplankton
William Lingley, Washington Dept. of Natural Resources	Geology
Roy Lowe, US Fish and Wildlife Service	Birds
Nancy MacHugh, Oregon Department of Fish and Wildlife	Steelhead
Don Maurer, California State Long Beach	Benthic invertebrates
Charles Miller, Oregon State University	Zooplankton
Thomas Northrup, Washington Department of Fisheries	Crab
William Pearcy, Oregon State University	Fish, shellfish
Ellen Pikitch, Oregon State University	Groundfish
James Ray, Shell Oil Co.	Environmental science
Douglas Simons, Washington Department of Fisheries	Razor clams
Charles Simenstad, University of Washington	Fish, Benthos
Lawrence Small, Oregon State University	Phytoplankton
Richard Starr, Oregon Department of Fish and Wildlife	Shellfish
Ted Strub, Oregon State University	Physical oceanography
Jack Tagart, Washington Department of Fisheries	Groundfish
Malcom Zirges, Oregon Department of Fish and Wildlife	Salmon

The uncertainty inherent in the behavior of large marine ecosystems has important implications for environmental assessment and management: research can provide understanding of the risks but it will not lead to absolute predictability of the outcome of environmental decisions. Ultimately, policy makers must decide the magnitude of risk and uncertainty that is acceptable and the environmental safety factors (Bella 1979) that are appropriate for decisions that affect complex ecosystems.

The goal of this research plan is to improve assessment of environmental risks in order to devise measures that will avoid or minimize damage to ecological diversity and to the general health and productivity of the marine ecosystem. In this goal, "risk" can be defined as the possibility of harm or exposure to a disturbance that could cause harm. This definition implies that risk is comprised of three principal components that are fundamental to environmental assessment and management *(Figure 2)*:

(1) What is the likelihood that a population, community, or ecosystem will be exposed to a disturbance that could cause harm?

(2) How sensitive is a particular organism, population, or community to exposure?

(3) What are the possible outcomes in the natural environment if organisms, populations, or communities are sensitive and they are exposed?

In the case of oil pollution, for example, the chance of exposure is the likelihood that a spill will occur and the chance that certain populations or communities might encounter the oil; the sensitivity of an organism, population, or communtity to exposure is an evaluation of the sublethal or toxic effects of hydrocarbons; and finally, the outcome is a particular response of the marine ecosystem that could result given, for example, the sensitivities of each population or community that is exposed, the persistence of oil that is released into the marine environment, the long-term changes in the biological community that might result.

Environmental restrictions that regulate offshore development are intended to decrease the chances of an undesirable outcome by reducing one or more of these three components of risk. The severity of restriction lessens with each successive decision point in the assessment of risk (*Figure 2*). For example, the surest method to minimize risk is to limit the chance of exposure. In the most extreme case, this can be accomplished by a complete prohibition of the activity. A less restrictive approach is to limit the specific location of the activity to minimize the likelihood that critical or sensitive areas or organisms will be exposed. Once the decision is made to allow an activity in an area, then risk must be regulated by controlling the extent or magnitude of exposure. This may be based on an assessment of the sensitivity of organisms or communities to the activity.

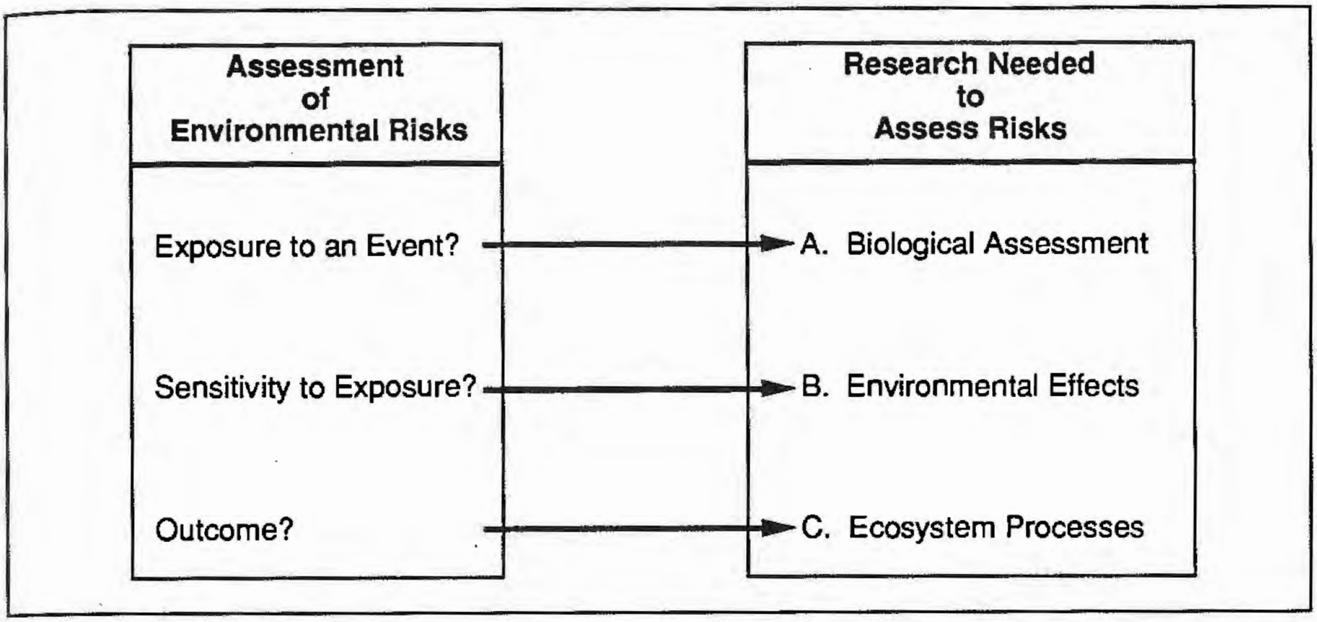
For example, stipulations to a lease agreement may regulate the timing of operations to protect critical life history events. Waste discharge permits may regulate the composition or volume of contaminants within some limits of biological sensitivity that are deemed acceptable. Once an action is permitted and stipulations have been established, little can be done to affect the third component of risk—the ecological outcome of exposure to a disturbance. At this stage of the decision process, research may be designed to monitor certain indicators of the outcome, and in some instances, changes in the management program may be possible to prevent the continuation of an adverse effect.

Although the leasing procedures differ for placer mining and the geographic areas of interest will be much smaller than for oil and gas, planning for both activities will involve a similar sequence of decisions about each of the components of environmental risk (*Figure 2*). In both cases, the leasing program proceeds from planning for a relatively large area to development of the resources at a specific site. Information requirements change as the focus of the program shifts from consideration of the entire planning area (e.g., should there be a Washington-Oregon lease sale or are the ecological risks of oil and gas development too great?) to subareas with development potential (e.g., should selected areas be excluded from the lease sale to protect ecological diversity and avoid the risk of exposure to certain activities or contaminants?) and, finally, to specific activities within a particular lease tract (e.g., should conditions be placed on an activity in order to protect sensitive species, habitats, or communities?).

There is a built-in paradox to this sequential screening process: uncertainty is greatest during the prelease period when decisions that may have the most significant ecological implications are made. The decision whether to open an entire region to oil and gas development, for example, is usually made very early when there has been little lead time for environmental studies. Furthermore, because subtle, large-scale effects of disturbance on an entire ecosystem are the most difficult to anticipate or measure, the tendency is to ignore them and move on to the protection of selected areas or control of discharge at a development site (Lewis 1980). The ability of management programs to avoid widespread environmental consequences, however, decreases as each decision point is passed and the focus shifts to operational standards at a local site. The adequacy of these standards for maintaining environmental health is poorly understood because, as noted above, ecological effects are the most difficult to measure and are often ignored. This circularity points to the importance of regional planning and research prior to leasing, when the earliest decisions focus on risks to the entire ecosystem and over the largest geographic area. Although this plan provides recommendations for research during all phases of offshore mineral exploration and development, we emphasize information needed during the critical prelease period. Ultimately, a long-term commitment to study the dynamics of natural marine communities and processes is needed to better understand the risks of human disturbance to the health of marine ecosystems.

The rationale and organization of this plan reflect three principal categories of information (Program Elements A, B, C) needed to evaluate and minimize environmental risks associated with development of the Washington and Oregon continental margin. These categories address the three types of questions (listed above) in an evaluation of environmental risk (*Figure 2*):

Figure 2. Three principal components in an assessment of environmental risk. Program Elements A, B, and C of this plan represent three categories of information needed to evaluate each of these components of risk (see text).

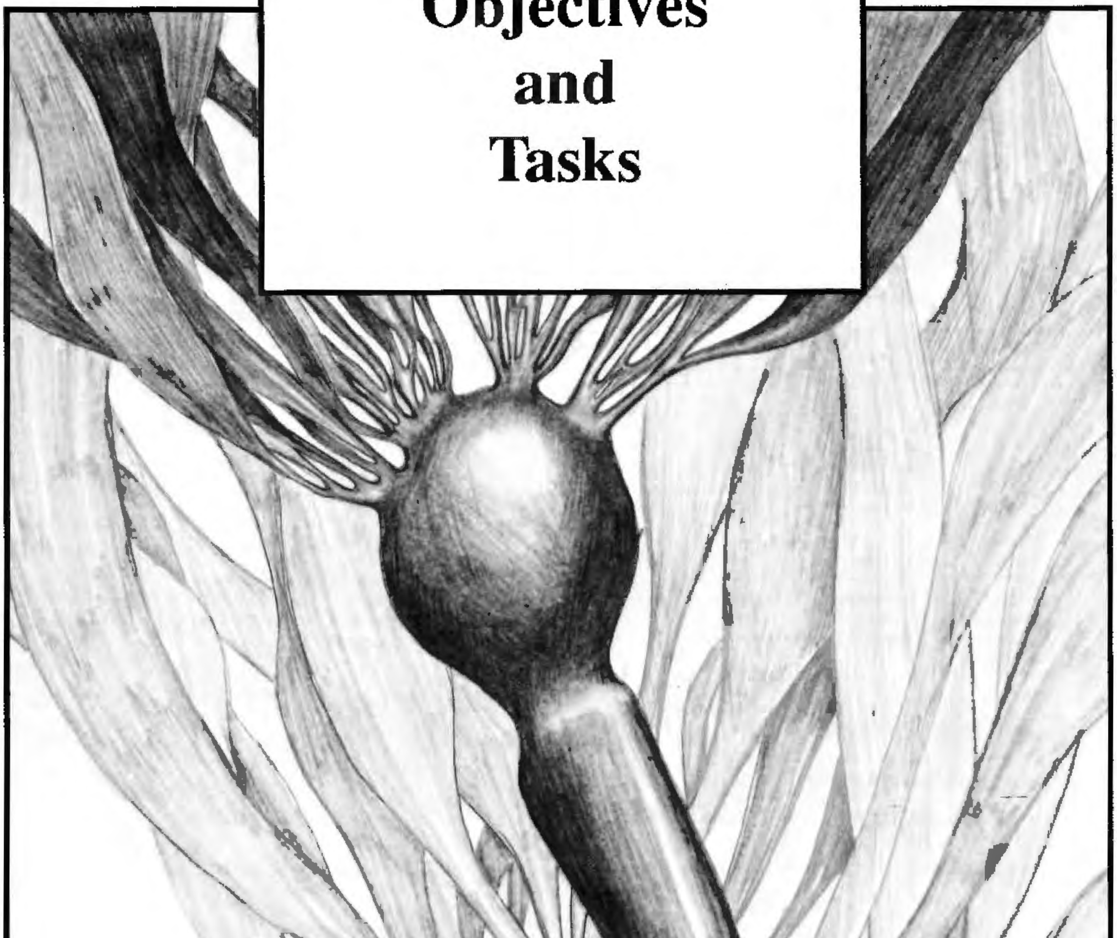


1. Program Element A: Biological Assessment. The environmental risk of exposure to a development activity can be minimized and biological diversity can be protected if development is restricted from regions that are critical to important or representative populations and communities. The Biological Assessment Program Element of the research plan identifies information needed to describe the distribution of habitats and communities that could be at risk from proposed mineral development. During the prelease phase of oil and gas development, for example, decisions are made regarding which sites should be included or excluded from a lease sale. So-called "Areas of Special Biological Significance" may be deferred from sale to avoid potential resource conflicts. Survey information will be needed prior to a lease sale to classify the diversity of habitats and associated communities and describe the distribution and abundance of important or susceptible populations.

2. Program Element B: Environmental Effects. The sensitivity of organisms, populations, or communities to development activities should be understood to establish appropriate operating standards that will minimize environmental risks. Experimental research in the laboratory or the field may be needed to test the effects of a particular activity or to understand the biological processes of a specific response. Baseline and monitoring studies may be necessary to evaluate the effects of development in the natural environment, particularly if an activity is permitted despite a high degree of uncertainty about its effects. Such studies may provide a measure of the effectiveness of lease stipulations so that necessary changes can be made in existing or future operations. We include baseline and monitoring studies in this program element if the effects of a development activity have not been widely studied or are poorly understood for the natural environment off Washington and Oregon. We identified four major categories of environmental effects that may require research to manage placer mining or oil and gas operations: noise and disturbance, contaminants, dredging and habitat alteration, and fisheries conflicts.

3. Program Element C: Ecosystem Processes. The ecological outcome of a development action is the most difficult component of risk to assess. Some environmental effects cannot be easily defined as a series of site-specific disturbances to one or more species or habitats of interest. Pollutants are transported beyond a local site by ocean currents so that the deferral of critical habitats from a lease sale cannot guarantee that they will be free from exposure to contaminants. Biological effects are transferred via food chains or magnified by shifts in community structure that accompany changes in the abundance of one or more important species. The cumulative or synergistic effects of many small activities, therefore, may be much greater than the sum of their parts. Information is needed about the natural processes that control transfer of materials, community dynamics, and production and flow of energy through the ecosystem. This research is essential to interpret the results of experimental studies and apply them to natural systems. This research is also cost effective, because it applies to a broad range of environmental issues whether the specific concern is oil spills, dredge spoils, mining discharges, or ocean outfalls.

Objectives and Tasks



Bull kelp, *Nereocystis luetkeana*

OBJECTIVES AND TASKS

We reviewed whether existing information is adequate to assess environmental risk as defined in each of the three research categories (*Figure 2*). From these reviews, we developed a list of proposed research objectives, tasks, and activities for the Washington and Oregon region (*Figure 3*). In many cases, tasks and activities are relevant to more than a single objective. We have made frequent use of cross references in the text to indicate areas of overlap.

The plan combines environmental studies related to oil and gas development and mineral mining activities. It includes several surveys specific to the nearshore region of the southern Oregon coast where there is considerable interest in potential development of placer minerals.

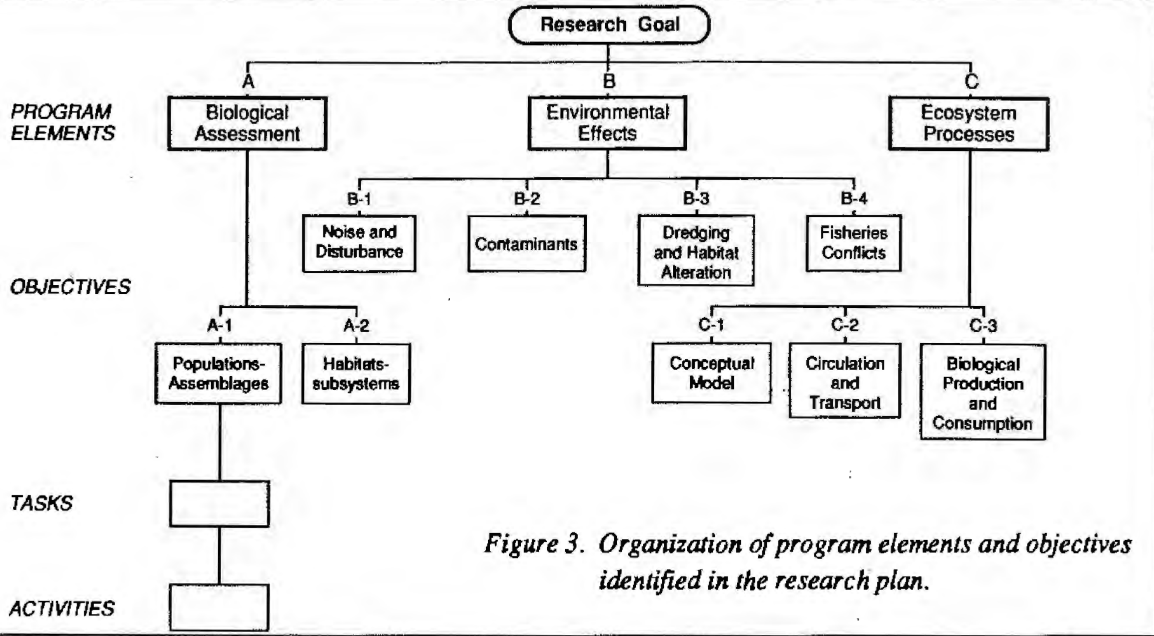


Figure 3. Organization of program elements and objectives identified in the research plan.

Program Element A. Biological Assessment:

Describe important populations, communities, and habitats that could be at risk from future offshore development and identify critical areas where resource conflicts should be avoided. Monitor trends among populations and communities representative of the diversity of hahitats in the region.

The research in this program element is intended to provide basic inventory information to describe distribution, abundance, and habitat use by key species or species assemblages (*Figure 4*). Areawide life history and distribution information will be needed to identify critical areas for key species during sensitive life history stages. We developed a list of key species and assemblages for the Washington and Oregon region as a guide to review whether existing inventory data are adequate. The plan lists research needs for many key species or groups of species for which little life history or distributional information is available.

It is impractical to evaluate the potential effects of each development activity on each life history stage of each important species or biological group. Offshore activities will tend to impact entire aggregations of species that co-occur in specific geographic areas or similar types of habitat. However, much of the biological and fisheries information for Washington and Oregon has been collected to estimate abundance and manage harvest of single species or stocks of commercial interest. A major challenge of an environmental studies program will be to shift from an entirely single- and commercial-species perspective to evaluate risks to entire assemblages of commercial and noncommercial species and habitats. In this program element, we suggest two approaches to describe the structure of species assemblages and to evaluate the importance of specific geographic areas or habitats. First, we suggest that multivariate statistical methods be used to reanalyze results of previous surveys that have been presented primarily in a single species format. Second, we suggest new surveys to target assemblages and habitats that have not been widely studied and may be sensitive to future development.

Temporal fluctuations among many populations and communities in this region have not been described, which limits interpretation of environmental risks or effects of future environmental activities. Many of the areawide distributional surveys in this program element should logically lead to long-term monitoring programs for representative communities and habitats. In some instances, keystone or indicator species may be selected to describe population trends. Long-term monitoring is needed to improve understanding of the causes of natural variability (*see also* Program Element C) that will influence the possible consequences of development activities.

Objective A-1. Populations and Assemblages:

Describe distribution, abundance, and feeding or rearing habitats for important life history stages, populations, or assemblages of species.

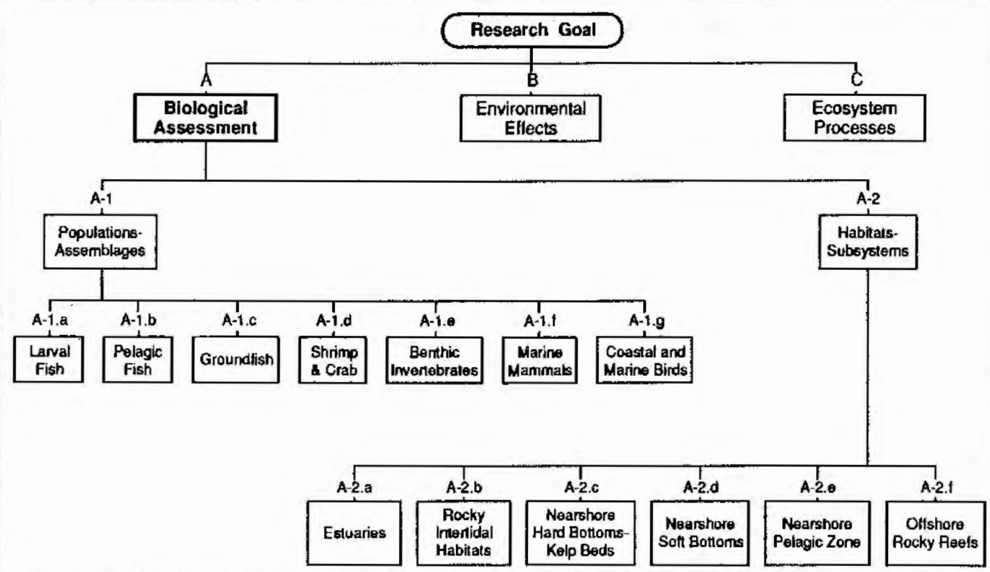


Figure 4. Research objectives and tasks in the Biological Assessment Program Element.

Task A-1.a. Larval Fish

Describe the temporal and spatial distribution of pelagic larval fishes and assemblages off the Washington and Oregon coast, and identify physical factors that influence observed patterns of abundance.

Early life history stages of most organisms are more sensitive than adults to acute or chronic exposure to contaminants such as hydrocarbons or drilling fluids. A number of larval fish surveys have been conducted off Washington and Oregon but these do not address all geographic areas or seasons. We recommend the following research activities:

(1) *Analyze existing National Marine Fisheries Service (NMFS) survey data to test the hypothesis that there are persistent assemblages of larval fishes on the continental margin that co-occur within specific water masses or classes of physical habitat.*

A series of annual reports (e.g., Clark 1986a, 1986b) summarize the results of NMFS larval fish surveys in this region. The data are reported for the appropriate months of each survey year, and distributions are plotted for single species. We recommend that these data be combined and analyzed to describe interannual variations in the distribution and abundances of key species and assemblages. Multivariate techniques should be used to describe associations of species and to test the hypothesis that community structure is a response to specific physical factors. Annual and combined data sets should be compared with available satellite and other survey information for surface currents, temperature, and chlorophyll. Research to understand the physical processes that affect recruitment of larval fishes is described in Activity C-3.b.(2).

Task A-1.b. Pelagic Fish: **Describe the temporal and spatial distribution of pelagic species and assemblages and assess physical factors that may influence observed patterns of abundance.**

Sediments released during dredging for placer minerals or contaminants associated with oil and gas development could degrade water quality and displace pelagic fishes from preferred feeding or rearing areas. In general, the habitats and conditions required by pelagic fishes and assemblages have not been widely studied. A series of purse seine surveys off the Washington and Oregon coast provide general information about the distribution of pelagic assemblages and species including salmon, herring, and anchovy (e.g., Brodeur and Pearcy 1986; Pearcy and Fisher 1988). Task A-2.e of this plan recommends a survey of pelagic fishes in shallow, nearshore and neritic habitats.

The potential effects of offshore development on adult salmon and fisheries for salmon are a critical issue in the Pacific Northwest. Unlike groundfish species [*see* Activity A-1.c.(1)), however, there are no commercial logbook data to describe the coastwide distribution of catch and effort for adult salmon. This information is needed to determine critical habitats and to avoid conflicts between offshore development activities and the conduct of fisheries. We recommend the following research activity:

*(1) Describe offshore movements and abundances of adult chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon and correlate distribution with temperature, cholorophyll, or other environmental factors.*

A pilot study in 1973 indicates that harvest rate and, presumably, ocean distribution of adult coho salmon are correlated with water temperature (O'Brien et al. 1974). We recommend further research be conducted to compare temperature, chlorophyll, currents or other environmental data with the distribution of commercial catch and effort for both chinook and coho salmon. Distribution of catch information could be estimated from a sample of fishing boats. Aerial boat counts would allow expansion of on-board estimates based on coastwide distribution of fishing effort. These results could be compared with surface temperature, chlorophyll, or other physical data available from satellite imagery. Information for several years and a variety of oceanographic conditions would describe geographic areas and habitats potentially important to adult salmon and commercial fisheries [*see also* Activity B-4.a.(3)].

Task A-1.c. Groundfish: **Describe the temporal and spatial distribution of juvenile and adult groundfish species and assemblages; assess physical factors that may influence observed patterns of abundance.**

Demersal habitats may be altered by numerous activities associated with oil and gas or minerals exploration and development. Commercially important groundfish species are among the fishes that could be most directly affected by alteration or contamination of benthic habitats. Demersal fishes are often less tolerant of short-term acute exposures to hydrocarbons than intertidal or pelagic species (National Research Council 1985). There is a need for information on the life history, distribution, and feeding and spawning habitats of key species and assemblages of rockfish and flatfish off Washington and Oregon. We recommend the following research activities to better understand potential risks to groundfish species:

(1) Compile and analyze logbook records, and map seasonal and spatial distribution of catch, effort, and catch per unit effort for groundfish species collected by commercial fishermen off Washington, Oregon, and northern California.

Logbooks maintained by commercial fishermen in Washington, Oregon, and northern California contain a wealth of information that could be analyzed to describe adult groundfish distributions. A recent pilot project by ODFW (Starr and Saelens 1987) developed computer programs to summarize from logbook records the distributions of shrimp and groundfish catch and effort. Computer programs will allow calculation of catch, effort, and catch per unit effort for any chosen time period. These data can be mapped to define important production areas or economic value of specific regions to commercial fisheries. A geographic information system is being developed by ODFW as a mapping tool to allow direct comparison with the location of proposed lease tracts or other development activities.

At the time this research plan was prepared, the Oregon pilot project was expanded to analyze Washington and northern California databases. Further analyses are planned to describe coastwide the temporal and spatial distribution of harvest for key commercial groundfish species [and pink shrimp, *see* Activity A-1.d.(1)] and an aggregate of all species. Depth, temperature, and substrate data should be compared with catch information to evaluate the influence of physical factors on the spatial and temporal distributions of key species or assemblages. Several years of analysis should provide an indication of interannual variability, although available data will be limited to recent years for which logbook information has been recorded and may not represent a wide range of oceangraphic conditions.

(2) *Analyze the results of NMFS scientific groundfish surveys to test the hypotheses that (a) distribution of commercial catch (above) is a valid indicator of the distribution of fish abundance, and (b) groundfish species are organized into persistent assemblages that reflect preferences for specific types of physical habitat.*

Every three years since 1977, NMFS has conducted trawl surveys to assess abundance and distribution of groundfish species off the West Coast. These data should be compared with appropriate years (and months) of commercial catch information [Activity A-1.c.(1) above] to determine whether target fisheries and scientific surveys yield similar patterns of distribution for individual groundfish species. Agreement between the data sets will support the use of catch and effort data to describe distribution of groundfish species. Disagreement will require a value judgement as to which data set is the better indicator.

Single and combined years of the NMFS trawl surveys should be analyzed to describe the structure of species assemblages. Multivariate methods similar to those employed by Gabriel and Tyler (1980) and Gabriel (1982) should be used to determine whether recognizable associations of groundfish species persist between years and exhibit specific habitat or geographic preferences. Distributions should be compared with existing temperature, depth, and substrate data.

(3) *Identify important spawning habitats for adult groundfish species.*

There is little or no information on important spawning areas for adult groundfish species. Trawl surveys have generally occurred during periods when adult groundfish are not in spawning condition. Scientific surveys during the winter months or an observer program to collect life history data from commercial fishing vessels are needed to determine the distribution of spawning adult groundfish species and to identify important spawning habitats.

(4) *Describe distribution, food, and feeding habitats of juvenile rockfish* (Sebastes) *species.*

Rockfish are not recruited to fisheries until the age of 4 to 10 years. Scientific surveys off Washington and Oregon have also targeted adults. Consequently, very little information is available to describe the early life history and ecology of rockfish species on the West Coast. NMFS has begun a long-term study in the region between Point Sur and Cape Mendocino to gain a better understanding about factors that influence recruitment and the ecology of juvenile rockfish (Lenarz and Moreland 1985). Similar studies are needed for the California Current region north of Cape Mendocino to evaluate both nearshore and offshore habitats preferred by juvenile rockfish species. SCUBA surveys will be needed for shallow nearshore hard-bottom habitats (*see also* Task A-2.c). Concurrent sampling with nets may be necessary to also obtain quantitative samples for stomach analysis. Midwater trawl and submersible surveys will be needed to sample offshore pelagic and rocky reef habitats (*see also* Task A-2.f).

Task A-1.d. Shrimp and Crab: **Describe the temporal and spatial distribution of key species of shrimp (*Pandalus jordani*) and Dungeness crab (*Cancer magister*), and assess physical factors that influence recruitment and observed patterns of abundance.**

Pink shrimp and Dungeness crab are among the most valuable shellfish harvested in the Pacific Northwest. Larval, juvenile, and molting crustaceans tend to be most vulnerable to contaminants such as hydrocarbons and drilling discharges (National Research Council 1983; 1985). There is presently little published information on the distribution, abundances, and life history of pink shrimp or Dungeness crab needed to assess or minimize potential risks of offshore development. We recommend the following research activities:

(1) Compile, analyze, and map seasonal and spatial distribution of catch, effort, and catch per unit effort for pink shrimp collected by commercial fishermen off Washington, Oregon, and northern California.

The pilot project to map commercial logbook data for groundfish [*see* Task A-1.c.(1)] also compiled data for 3 years of pink shrimp harvest off Oregon. At the time this research plan was prepared, the pilot project was expanded to analyze shrimp data for northern California and Washington and to add the remaining years of information available for Oregon. Computer programs have been developed that will allow calculation of catch, effort, and catch per effort for any chosen time period. Annual and interannual variations in catch rate should be compared to assess whether there are consistent patterns of abundance. Results should be correlated with environmental variables (e.g., substrate type) to test for factors that may influence distribution patterns. A geographic information system will allow computer mapping of results for direct geographic comparison with the location of proposed lease tracts or other development activities.

(2) Describe distribution, abundance, and life history of Dungeness crab off Washington and Oregon.

There is no commercial logbook program to provide coastwide information about the distribution of Dungeness crab. In addition, only large males are harvested by the fishery, so that commercial catch information may not be an indicator of total abundance. Abundances of males alone will not provide adequate life history information or identify important reproductive regions or the factors that control reproductive success.

A major data gap that has limited the interpretation of larval recruitment studies is the lack of information on adult stock sizes that produce observed larval densities. In addition, except for the offshore region of southern Washington and in Grays Harbor and Willapa Bay (Gunderson et al. In Press), there has been little research to define distributions of adult, juvenile, or larval Dungeness crab or to identify important rearing habitats. Large estuaries on the southern Washington coast are among important rearing areas for juvenile stages of crab (Armstrong and Gunderson 1985; Armstrong et al. 1986; Gunderson et al. In Press), but this raises questions about the specific rearing habitats used by Oregon crab, since sizeable adult populations exist but available estuarine rearing area is much less.

Surveys are needed to describe large-scale patterns of abundance, distribution, and habitat use by various age classes of adult, juvenile, and larval Dungeness crab off Oregon and Washington. Crab larvae are a major component of the plankton in the surface (neuston) layer (Shenker 1988). Surveys of larval abundance and distribution in the offshore neustonic community may be particularly important because larval stages are most sensitive to hydrocarbon contamination and may be directly exposed when oil from a spill spreads in a thin layer on the water's surface [*see also* Activity B-2.e.(2)]. Small beam and otter trawls should also be used to collect juvenile and adult crab and may provide concurrent information on flatfish abundances and distribution [*see also* Activity A-2.d.(2)]. Survey results for adults should be compared with catch data from observers placed on commercial vessels to determine whether the harvest of large male Dungeness crab can serve as an indicator of total population distribution or abundance.

Task A-1.e. Benthic Invertebrates: **Describe the distribution of key species and assemblages of benthic macroinvertebrates and the physical factors that influence observed patterns of abundance.**

Benthic invertebrate communities are important secondary producers that support commercial populations of demersal fish and shellfish. The food habits and structure of demersal fish assemblages may be directly related to the distribution of benthic invertebrate communities and their associated habitats. Dredging operations for placer minerals or placement of pipelines or platforms will alter benthic habitats. Contaminants from oil and gas operations can have sublethal or toxic effects on benthic populations, and some toxins can be passed on to higher trophic levels through food chains. Information on the composition and distribution of invertebrate assemblages is needed to identify important feeding habitats for higher trophic levels and to classify the categories of benthic habitat that could be at risk from offshore development activities. Invertebrate surveys recommended for specific subsystems or habitats are discussed in Objective A-2.

(1) From existing data, test the hypothesis that benthic invertebrate populations are organized into assemblages that reflect preferences for specific classes of physical habitat. Map distributions of key species and assemblages.

There has been little research on benthic invertebrate communities of the Washington and Oregon continental shelf since the 1960s. Existing data should be compiled into a single database for the Washington and Oregon region. New data also may be available from recent surveys of dredge spoil disposal sites near the mouths of a number of estuaries. Existing data should be analyzed to provide an overview of the distribution of benthic invertebrates and the organization of species assemblages. Results of these analyses should be used to (1) develop a classification system for benthic habitats and communities on the continental shelf and slope and (2) identify any additional research needs.

Task A-1.f. Marine Mammals: **Monitor distribution, abundance, population status, and food habits for key species of marine mammals along the Washington and Oregon coast.**

Potential effects of offshore development activities on marine mammals include acute or sublethal effects of hydrocarbons or other contaminants; changes in the quality or availability of food from contamination or alteration of habitat; and disturbance of feeding, migratory, and reproductive behavior from the cumulative effects of noise and activity associated with offshore development. The legal status afforded under the Marine Mammal Protection Act and the Endangered Species Act will require special consideration be given to mammal populations to avoid adverse effects during offshore development activities. The following research is needed for mammal populations off Washington and Oregon:

(1) Describe distribution, abundance, population status, and food habits of sea otters (Enhydra lutris) *off the Washington coast.*

Sea otter populations off the Washington coast can be surveyed from shore to a distance of 1 mile (1.6 km) offshore. From Cape Flattery to Destruction Island, Washington, aircraft observations will be necessary to determine offshore feeding areas out to approximately the 20 fathom (36.6 m) contour [*see also* Activity A-2.c.(2)].

(2) *Describe food habits, food requirements, and feeding habitats—particularly nursing females during reproductive periods—for northern sea lions* (Eumetopias jubatus) *at Rogue and Orford Reefs on the southern Oregon coast.*

Significant declines in northern sea lion populations in Alaska and California have caused concern about the stability of the reproductive stock at Rogue and Orford reefs on the southern Oregon coast. Prior to placer mining, information will be needed about habitat use by northern sea lions in this region [*see also* Activity B-1.b.(2)].

(3) *Describe distribution, abundance, and population trends of common nearshore and offshore marine mammals.*

Little information exists about the predevelopment population status or distribution of many marine mammals that occur off Washington and Oregon. During the prelease phase of oil and gas development, coastwide surveys will be needed to document the distribution and abundances of offshore mammals (e.g., northern elephant seals *Mirounga angustirostris*, northern fur seals *Callorhinus ursinus*, baleen whales, and other cetaceans). Similar surveys and population status of common nearshore mammals (Pacific harbor seals *Phoca vitulina*, California sea lions *Zalophus californianus*, northern sea lions, harbor porpoises *Phocoena phocoena*) are also needed [*see also* Activity B-1.b.(1)].

Task A-1.g. Coastal and Marine Birds:

Monitor distribution and population status of key species and assemblages of coastal and marine birds off Washington and Oregon.

Potential effects of offshore development activities on bird populations include disruption of breeding activity from vessel and aircraft traffic or other noise and activity, direct mortality or sublethal effects from oil spills, or indirect effects from loss of food or habitat. Predevelopment data are needed to define existing distribution patterns, habitat use, or population status for several groups of marine and coastal birds. Specific data are also needed for populations of species listed as threatened or endangered. We recommend the following surveys to fill data gaps for coastal and marine birds in the Washington and Oregon planning area:

(1) *Determine at-sea distribution of local breeding species and seasonal and pelagic species of marine birds in the off-breeding season, particularly in the area 3 to 6 miles (4.8 to 9.7 km) offshore. A minimum of 3 or 4 years of survey data may be necessary to provide a reasonable indication of natural variation in distribution patterns.*

(2) *Analyze existing data on location and sizes of seabird breeding colonies and the feeding habitats for these birds during nesting and fledgling periods.*

(3) *Determine distribution, abundance, and habitat use by endangered brown pelicans* (Pelacanus occidentalis).

(4) *Survey abundance and population status of black brant* (Branta bernicla) *off Washington and Oregon. Monitor onshore and offshore movement and use of eelgrass beds for feeding.*

(5) *Survey abundance and population status of endangered Aleution Canada geese* (Branta canadensis leucopareia). *Determine use of offshore islands for roosting and feeding.*

Objective A-2. Habitats and Subsystems: **Describe community structure and trophic relationships within selected marine and estuarine habitats or ecological subsystems.**

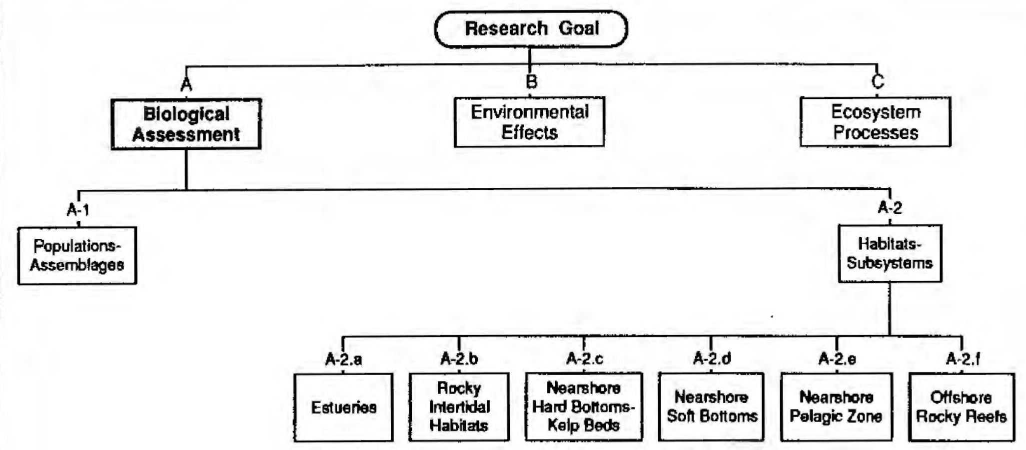


Fig. 4a. Research tasks in the Biological Assessment Program Objective A-2.

Task A-2.a. Estuaries: **Describe the composition, distribution, and abundance of fish and invertebrate assemblages and classify and map habitat types in Washington and Oregon estuaries.**

Estuaries are among the most productive coastal ecosystems. They are also highly vulnerable to oil pollution effects or habitat modifications that could result from dredging and filling for pipelines or various facilities needed to support offshore operations. Research needed to assess oil spill movements in estuaries is described in Activity B-2.d.(2). Research on the chronic effects of hydrocarbon pollution in estuaries is discussed in Task B-2.g.

The quality and quantity of biological research has varied considerably among estuaries in the Pacific Northwest. The larger estuaries in the region (e.g., Grays Harbor, Puget Sound, Columbia River, Yaquina Bay, Coos Bay) are more likely to experience the effects of onshore support facilties, pipelines, or increased vessel traffic. However, accidental oil spills offshore could enter any estuary in Washington or Oregon. As a first step, we recommend the following assessments be made:

(1) *Update existing habitat maps for Oregon estuaries, and classify and map estuarine habitats in Washington.*

Intertidal and subtidal habitats in Oregon estuaries were mapped in 1979 based on aerial photos and field surveys (Bottom *et al.* 1979). These maps were recently digitized to provide information on the distribution and acreages of each habitat type (Oregon Department of Land Conservation and Development 1987). However, habitat distribution in estuaries may have changed substantially in the decade that has passed since these maps were produced. New surveys should be conducted for Oregon estuaries to update previous maps and to describe significant changes in habitat distribution or extent. Total areas of intertidal and subtidal habitats in each Oregon estuary should be calculated and compared with previous estimates. Similar habitat maps should be prepared and digitized for Washington estuaries.

(2) *From existing survey data, classify estuaries according to the composition and structure of their fish communities. Define the physical factors that may influence community structure in each class of estuary and the implications for habitat management.*

Fish communities have been studied in many estuaries in Washington and Oregon, but most surveys have not been published. Results of surveys should be further analysed and compared to develop hypotheses about the factors that control the structure of estuarine fish assemblages in the Pacific Northwest. Such a comparison would be consistent with the large scale of information needed to make decisions during the early prelease phase of offshore development.

The sampling methods used to survey fish communities in Washington and Oregon have varied among estuaries and prevent quantitative analysis. However, it should be possible to classify estuaries according to their fish communities, relative abundances, and habitats. Physical factors that may affect community structure in different classes of estuaries should be evaluated. Important factors may include river discharge and salinity distribution, tidal prism, and the areal extent and composition of habitat types within each estuary [*see* Activity A-2.a.(1) above]. Key fish species and, to the extent possible, important food chain relationships in each class of estuary should be described.

Task A-2.b. Rocky Intertidal Habitats:

Describe and classify rocky intertidal habitats and associated communities along the Washington and Oregon coast.

Rocky intertidal habitats support extremely rich and diverse plant and invertebrate communities important for ecological research and valued for their productivity and recreational, educational, and aesthetic benefits. Rocky intertidal areas are also highly visible and vulnerable to oil spills that move onshore. Although oil on exposed rocky shores may be quickly cleansed, diverse rocky communities are often dominated by long-lived and slowly recruiting species and may suffer long-term damage (Detheir 1988). Selected rocky intertidal areas have been the subject of intensive research in community ecology (Paine 1974; Paine and Levin 1981), but basic inventory information has been lacking to describe and categorize rocky intertidal habitats and communities that exist along most of the Washington and Oregon coast. Such information will be needed to evaluate the ecological risks of oil spills or other disturbance to intertidal communities coastwide or to apply results of intensive research and monitoring to similar types of habitats in other areas. We recommend the following research activity:

(1) Describe composition and relative abundance of plant and invertebrate species, and classify rocky intertidal habitats in Washington and Oregon according to their dominant physical features and community structure. Describe long-term trends in community structure for representative geographic locations and habitat types.

Dethier (1988) recently classified habitats and established sites for continued monitoring in the Pacific Coastal Area of the Olympic National Park. The tremendous diversity, pristine character, and extent of rocky intertidal habitats in the park indicates this should be a high priority location for future research and monitoring. Long-term monitoring should continue at study sites established in the park (Dethier 1988). Comparable inventories should be conducted at representative locations in Washington and Oregon to develop a coastwide classification of rocky intertidal habitats and to establish representative monitoring sites. Long-term trends in community structure and the relative vulnerability of representative habitats to offshore development and disturbance should be described.

Task A-2.c. Nearshore Hard Bottoms-Kelp Beds:

Map the distribution and extent of nearshore rocky reef-kelp bed ecosystems and describe species composition, abundance, distribution, and trophic relationships among mammals, fishes, and invertebrates.

Kelp beds are known to be highly productive ecosystems that support diverse assemblages of mammal, fish, and invertebrate species. Disturbance of kelp beds, whether through natural causes, oil spills, or other factors can alter community structure for long periods of time. An inventory is needed of the biological resources associated with these areas to understand potential risks associated with offshore development. We recommend the following research activities:

(1) *Inventory and map beds of* Macrocystis integrifolia *and* Nereocystis luetkeana *off Washington and Oregon.*

Kelp bed habitats along the entire Oregon coast have not been inventoried since the early 1950's when Waldron (1955) surveyed bull kelp (*N. luetkeana*) distribution, concentration, and commercial potential. Little research has occurred off Washington, although kelp beds are known to provide critical habitat for sea otters. *Macrocystis pyrifera* communities off California have been widely studied but these results are not transferable to *N. luetkeana*, *M. integrifolia*, and other kelp species and associated communities that occur in the Pacific Northwest. We recommend aircraft or satellite photos be used to map the distribution and extent of nearshore rocky reefs and kelp bed habitats off Washington and Oregon. SCUBA surveys will be needed to verify results of aerial inventories and to provide distribution information for various understory kelps (e.g., *Laminaria* spp.).

(2) *Survey benthic and pelagic communities at representative sites to describe community composition and assess food availability for sea otters and fish assemblages.*

Food resources in rocky reef-kelp bed habitats need to be assessed to evaluate their importance to existing and potential sea otter populations. These surveys will also be useful to evaluate their importance as food producing habitats for assemblages of juvenile and adult demersal fishes. We recommend benthic surveys in areas off Washington that are used by sea otters. Representative sites should also be selected off southern Oregon, since this region may experience oil and gas development and mineral mining and has also been identified by the U.S. Fish and Wildlife Service as a potential translocation site for sea otters (*see also* Task A-1.e.)

(3) *Conduct SCUBA surveys to describe population abundance, life history, and species composition of fishes using nearshore rocky reef-kelp bed habitats.*

We have already described the need for obtaining information on the distribution of juvenile rockfish and have suggested SCUBA surveys for shallow nearshore habitats to describe distribution, abundance, and food habits [*see* Activity A-1.c.(4)]. This research activity therefore applies to both a population and habitat objective.

Task A-2.d. Nearshore Soft Bottoms: **Describe composition, distribution, and abundance of fish and invertebrate assemblages associated with soft bottom habitats near shore and on the inner continental shelf (depths <100 m).**

The shallow-water, unconsolidated habitats of the inner continental shelf (<100 m) along the Washington and Oregon coast could experience the direct effects of commercial mining or of oil spills. Information is inadequate to describe critical habitats for commercial species to select low-risk sites for dredging placer minerals or sand and gravel. In particular, there is very little published information available about soft bottom habitats and communities within a few kilometers of shore. Along the central Oregon coast, nearshore habitats are important nursery areas for juvenile flatfish (Laroche and Holton 1979). Popular recreational dipnet fisheries are dependent on local populations of surf smelt (*Hypomesus pretiosus*) that concentrate to spawn on certain Washington (e.g., near Kalaloch) and Oregon (e.g., Yachats) beaches. Shallow subtidal razor clam (*Siliqua patula*) populations may provide important "seed stock" for the replenishment of intertidal populations on clamming beaches off Washington and Oregon. Surveys will be needed prior to development to insure that important nearshore and intertidal soft bottom habitats for fish and invertebrate production are adequately protected.

The following recommendations concern the southern Oregon coastal region (south of Cape Blanco) where there is considerable interest in the potential for mining placer minerals. Similar types of inventories would likely apply to other regions off Washington and Oregon if additional mining or drilling locations are identified.

(1) *Describe the distribution and composition of benthic invertebrate assemblages within the 100 m contour between Cape Blanco and the Rogue River, Oregon.*

Nearshore surveys of benthic invertebrate communities should be conducted concurrently with exploration surveys for placer minerals so that this information will be available when it is needed to review plans for offshore mining. An areawide prelease survey would also provide data needed to determine sample sizes and select control and experimental stations for quantitative baseline surveys [*see* Activity B-3.c.(1)].

(2) *Describe the distribution, composition, and feeding habitats of demersal fishes and the distribution, habitat use, and life history of Dungeness crab within the 100 m contour between Cape Blanco and the Rogue River. Test the hypothesis that demersal fishes are organized into assemblages that coincide with the distribution of benthic invertebrates and preferred feeding habitats.*

The importance of nearshore demersal habitats as nurseries and feeding areas for commercial groundfish species should be evaluated. Trawl surveys should be designed to provide information on the abundance and nearshore habitat use of juvenile and adult groundfish as well as Dungeness crab and other large, mobile invertebrates. Composition of stomach contents of fishes should be compared with the distribution of benthic invertebrates [Activity A-2.d.(1) above) to identify important feeding habitats. Sensitive habitats and periods of migration and reproduction for key demersal fish and invertebrate species should be identified.

Task A-2.e. Nearshore Pelagic Zone: **Describe composition, distribution, and abundance of pelagic fish assemblages in nearshore and neritic habitats on the inner continental shelf.**

Similar to demersal habitats (Task A-2.d), the neritic and nearshore pelagic zone within a few kilometers of shore has not been widely studied in the Pacific Northwest. These areas could be sensitive to nearshore disturbances caused by dredging for placer minerals, oil spills, spoil disposal, coastal pollution, etc. The shallow depth of these habitats, their importance as a migration corridor, their proximity to productive estuaries used by many marine and anadromous fishes, and their possible role as nurseries for larval and juvenile fishes suggest there is a need to survey nearshore pelagic habitats. As a first step, we recommend the following research:

(1) *Describe abundance, distribution, and feeding habitats of pelagic fishes within the 100 m contour between Cape Blanco and the Rogue River. Describe the abundance and movements of juvenile salmonids as they leave small coastal estuaries and migrate through the narrow coastal corridor.*

The importance of nearshore pelagic habitats to commercial fish species and assemblages should be studied along the southern Oregon coast. General patterns of abundance and the composition and distribution of pelagic fish assemblages should be described. Habitats used for reproduction, feeding, or juvenile rearing should be identified. Recommendations should be made to insure the timing or location of future dredging activities will avoid critical areas and periods of migration and reproduction for key pelagic species.

An important concern of this research is a detailed description of migration routes and preferred coastal habitats of juvenile salmonids from the time they leave many small estuaries on the southern Oregon coast (e.g., Rogue River, Sixes River, Elk River). Year-class success of coho salmon is established within a few weeks after smolts leave freshwater (Fisher and Pearcy 1988) and could be related to food supply, predation, or other environmental factors in nearshore habitats. Research is needed to avoid any additional environmental stress caused by development activities that might reduce survival during the first critical days or weeks that salmon smolts occupy the narrow coastal corridor. Any further reduction of wild stocks of coho salmon or many southern Oregon stocks of chinook salmon are a special concern because their numbers have declined substantially in recent years, and commercial harvest is already severely restricted to protect escapement of wild fish.

Surveys similar to this activity may become important in other coastal regions off Washington or Oregon if mineral or sand and gravel mining are proposed. Information provided by this research will also apply to the study of natural processes that influence the survival of juvenile salmon [*see* Activity C-3.b.(1)]. Specific effects of noise and disturbance on salmon behavior and migrations are considered in Activity B-1.a.(2). A study to monitor the effects of commercial mining on the distribution of pelagic fishes is described in Activity B-3.d.(1).

Task A-2.f. Offshore Rocky Reefs:

Describe composition, abundance, and distribution of fish and invertebrate assemblages associated with offshore rocky reef habitats.

The importance of offshore reefs to adult groundfish is inferred from abundances in commercial trawl catches on or near the reefs. However, large portions of these rocky banks are very steep and inaccessible to trawl gear and have never been adequately surveyed. Preliminary submersible surveys in 1987 suggest that offshore rocky reefs may be important nursery areas for juvenile rockfish and a major source of recruits to fishable populations surrounding the banks (unpublished cruise report, 2 September 1987 by William Pearcy, Oregon State University, School of Oceanography, Corvallis). Task A-1.c has already discussed the need for research on groundfish species off Washington and Oregon, and, in particular the lack of data to describe juvenile abundance or habitat requirements.

Biological surveys in rocky reef habitats may be a particularly important area of future research. Benthic invertebrate and fish communities associated with some rocky reef areas may be long-lived compared with soft-bottom communities and, therefore, may be slow to recover following a physical disturbance. In the 1960s, exploratory drilling for oil and gas was conducted near rocky banks off the central Oregon coast. Small volumes of oil and gas were found in the vicinity of Heceta and Perpetua Banks. Sediment thicknesses suggest that rocky reefs off Oregon may be areas of continued interest for oil and gas exploration. The importance of offshore reefs to production of commercial groundfish species needs to be studied before the environmental risks of oil and gas development can be evaluated.

Sensitive rocky bottom habitats have been the focus of considerable research in relation to oil and gas development on the Southeast Atlantic and Gulf coasts (Rezak et al. 1985). Descriptive studies on 30 or more fishing banks and reefs in the Gulf of Mexico led to a classification of the banks' communities that was translated directly into lease stipulations (letter dated December 17, 1986 from Thomas J. Bright, Texas A&M Sea Grant College Program, College Station, Texas). We recommend the following research activities for the rocky reef areas off the Washington and Oregon coast:

(1) *Classify and map physical habitat types represented among rocky reefs off Washington and Oregon (e.g., Heceta, Stonewall, Perpetua, and Coquille banks, Oregon; Cape Flattery Spit, Washington).*

Submersible surveys off Heceta Banks have shown considerable habitat diversity within offshore rocky reefs that is reflected in the structure of invertebrate and fish communities (unpublished cruise report, 2 September 1987 by William Pearcy, Oregon State University, School of Oceanography, Corvallis). Remotely operated vehicles (ROV) or towed underwater camera systems should be used to conduct a broad survey of the major offshore reefs off Washington and Oregon. These surveys should be designed to identify and classify the diversity of habitat types and to select appropriate areas for detailed biological surveys.

(2) *Test the hypotheses that* (1) *offshore rocky reefs are a major source of recruits to commercial fisheries surrounding these areas and* (2) *fish and invertebrate groups are organized into recognizable species assemblages that are associated with major classes of physical habitat represented among offshore rocky reefs.*

Previous research has shown that manned submersibles can be used to obtain quantitative data on benthic fishes and macroinvertebrates (unpublished cruise report, 2 September 1987 by William Pearcy, Oregon State University, School of Oceanography, Corvallis). The habitat survey [Activity A-2.f.(1) above] will help to select appropriate study sites so that biological results from the submersible can be applied to similar classes of habitat over a broader region of the continental shelf. Observations should be made to determine the composition and abundances of fish and macroinvertebrates and to evaluate the influence of habitat type on community structure. We recommend that Heceta Banks be among the sites chosen for detailed biological assessment to complement previous fish surveys conducted in this region.

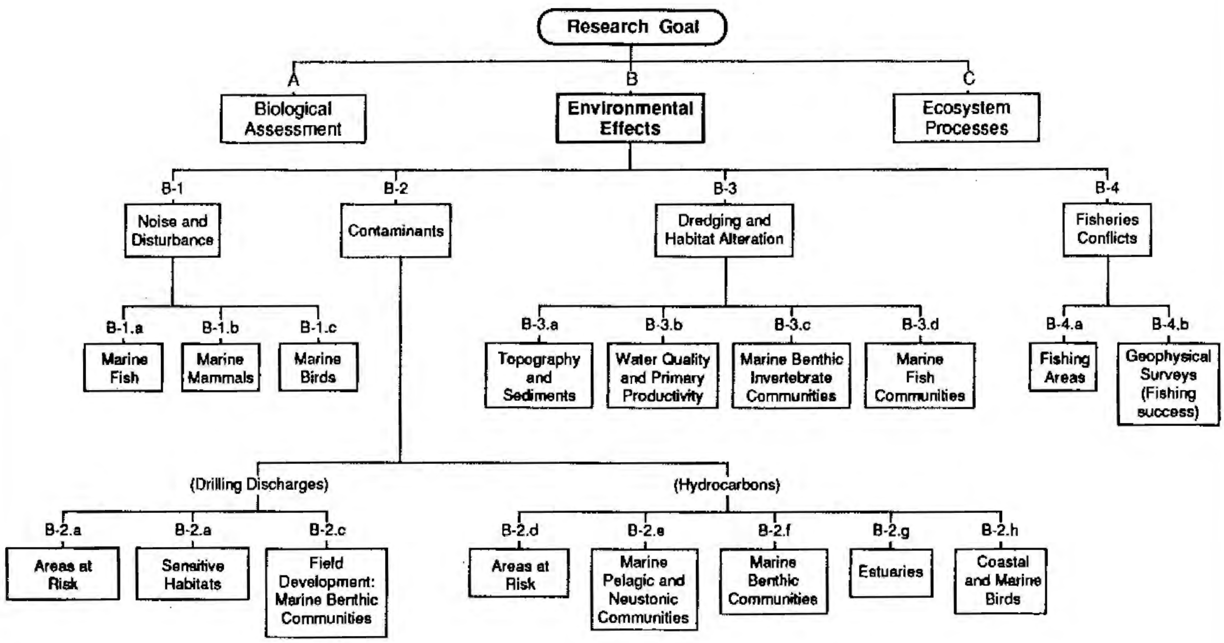


Figure 5. Research objectives and tasks in the Environmental Effects Program Element.

Program Element B. Environmental Effects:

Evaluate the effects of offshore development activities on important biological populations and communities in order to (1) establish or modify operating procedures that will minimize environmental risks or consequences, or (2) mitigate for losses that are incurred as a result of these activities.

The effects of oil, gas and minerals exploration and development may be expressed at one or many levels of biological systems: subcellular, organism, population, community, and ecosystem. Research will be necessary to evaluate the sensitivities of these levels of hierarchy to specific development activities or contaminants. Research on environmental effects may be needed to design lease stipulations, modify ongoing operating procedures, or mitigate for adverse effects that occur during development. These studies could encompass a large variety of research approaches in order to better evaluate or measure the effects of exploration and production activities.

Without knowing the specific development that will occur or the management criteria that will be applied to this region, the research needs we have defined in this program element (Figure 5) are necessarily general. We have recommended experimental studies to determine biological sensitivities and to develop operating standards that will minimize environmental risks. These include research on environmental effects that have not been widely studied or cannot be applied directly to the Washington and Oregon region. We also have recommended predevelopment baseline and postdevelopment monitoring studies that may be needed if certain types of development activities are permitted in the future. These studies will be important to evaluate the success of the management program, to alter operations if necessary, or to mitigate for a significant adverse outcome. We have suggested baseline and monitoring programs where the environmental effects of development will be very uncertain (with or without the benefit of experimental studies) or the biological risk is high.

Objective B-1. Noise and Disturbance: **Assess the effects of noise and disturbance from oil and gas and minerals development activities on marine organisms, populations, and communities.**

Sound produced or perceived by marine organisms influence a variety of biological activities important to growth and survival. Among these are social and reproductive behavior, predatory or avoidance behavior, migration, and communication. Activities associated with offshore exploration and development may alter the quality of the sound environment in ways that could mask the reception of biologically important signals, cause avoidance reactions and disrupt normal feeding or reproductive behaviors, or cause direct injury or death (Myrberg 1978; Schwartz 1985; Pearson et al. 1987).

Intense sound impulses are emitted underwater by geophysical survey devices (e.g., air guns, water guns, and electric sparker systems) used to explore for oil and gas or minerals. The risk of direct lethal effects to adult marine vertebrates and shellfish is probably minimal except for individuals located very near the sound source (e.g., Falk and Lawrence 1973; Pearson et al. 1987). However, potential effects on established patterns of behavior, distribution, and migration or the resulting implications for reproduction and survival of marine organisms are poorly understood. Sensitive larval and juvenile stages of marine invertebrates and fish may experience lethal as well as sublethal effects, but these have not been widely studied. Because there is considerable variation in the transmission and distortion of sound in different environments and in the hearing abilities and sensitivities of different species (Myrberg 1978; Schwartz 1985), it is difficult to apply the results of studies from one region to the conditions and species in another. We include in this objective, research tasks to evaluate the effects of geophysical acoustic surveys on selected fish and invertebrate species off Washington and Oregon.

Among other potential sources of noise and disturbance to marine organisms are the vessels and aircraft that service offshore facilities and the diesel engines, drilling rigs, dredges, or other equipment that operate at a development site. The effects of individual or cumulative sources of noise on animal behavior have not been adequately studied to understand the potential for disturbance of fish, mammal, and bird populations off Washington and Oregon. Information on the distribution, abundance, and reproductive behavior of many of these populations is inadequate to assess risks or to serve as a baseline for monitoring cumulative effects of increased noise and activity from offshore development. The sizes of buffer zones necessary to minimize disturbance of marine populations off Washington and Oregon are uncertain. Among the research activities listed below are studies of the effects of noise and disturbance from vessels, aircraft, or industrial sources on marine fishes, mammals, and birds.

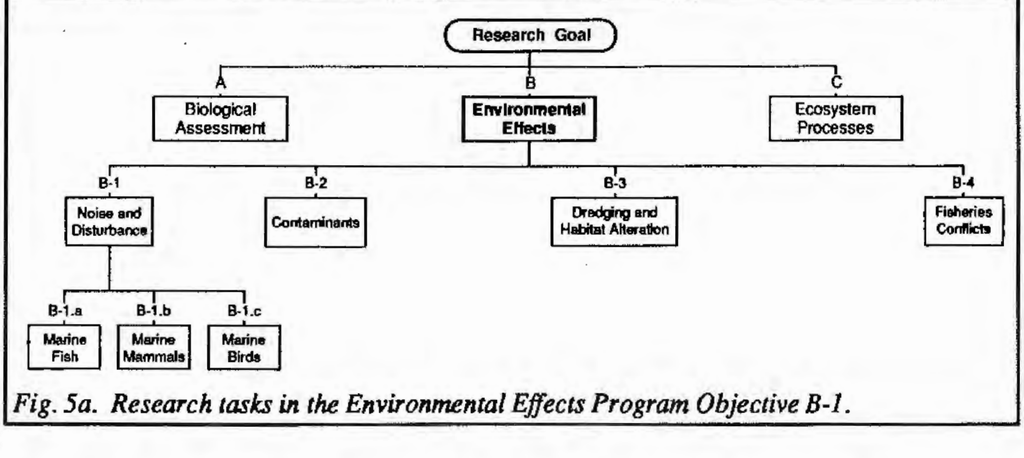


Fig. 5a. Research tasks in the Environmental Effects Program Objective B-1.

Task B-1.a. Marine Fishes: **Evaluate the effects of noise from oil and gas and minerals development activities on the behavior, growth, and survival of marine fishes.**

(1) *Describe the ambient sound environment in selected underwater habitats off the Washington and Oregon coast and evaluate the behavioral response of key fish species to background sound.*

The effects of ambient sound on the movements, choice of feeding or spawning areas, or other behavior of key fish species are poorly understood. Little research has been conducted to describe the sound environment throughout the range of depths and habitats a species normally encounters (Schwartz 1985). Baseline information for the ambient sound environment is needed to better understand the effects artificial sounds might have when superimposed on existing conditions. Behavioral responses of animals to ambient sound (or recordings of ambient sound) in selected habitats should be described for key pelagic and groundfish species. Such results will be useful to evaluate changes in behavior when artificial sound is added to ambient levels in a particular habitat or region [Activity B-1.a.(2) below].

(2) *Assess the effects of artificial sound from geophysical acoustic devices, oil drilling ships and platforms, and hopper dredges on behavior and migrations of juvenile and adult coho and chinook salmon.*

Fish species vary greatly in their sensitivities and behavioral responses to different frequencies of sound. Most studies of fish behavior have evaluated simple synthesized sounds or noise from vessels and fishing gear. There is little information about the effects of noise from specific offshore development activities on the migration behavior of juvenile or adult coho or chinook salmon. Research is needed to evaluate potential avoidance reactions, thresholds for detection, and buffer distances necessary around critical habitats or migration routes to protect populations from a source of noise and disturbance. Initial studies should consider the response of juvenile and adult salmon to recorded or synthesized sounds of seismic gear, oil drilling equipment, and hopper dredges. Recommendations should be made regarding location and timing of offshore activities or operational procedures needed to minimize potential conflicts with preferred habitats and migration routes. This research also applies to the effects of geophysical surveys on fishing success described in Task B-4.b. Activity A-2.e.(1) discusses related research on the nearshore habitats and migration routes for juvenile salmon off the southern Oregon coast.

(3) *Assess the effects of geophysical acoustic surveys on growth and development of fish and invertebrate larvae.*

Little published information is available on the effects of geophysical surveys on fish and invertebrate larvae. Research on northern anchovy (*Engraulis mordax*) larvae has been completed by the American Petroleum Institute, but results were unavailable to us at the time this plan was prepared. Among the research topics that may become important for the Washington and Oregon region are the effects of acoustic surveys on growth and development of larval and juvenile rockfishes and Dungeness crab. MMS and the California Department of Fish and Game have funded a study of Dungeness crab larvae which may influence the need or design for similar research in Washington and Oregon.

Task B-1-b. Marine Mammals: **Evaluate the effects of noise and disturbance from oil and gas and minerals development activities on the abundance, distribution, and behavior of marine mammals.**

Marine mammals use sound as a means of communication and perception in the marine environment. The consequences of intense underwater sounds generated by seismic survey equipment and other loud industrial noises may influence the distance over which mammals can communicate, cause behavioral changes, or injure hearing organs. Research in Alaska, for example, has documented changes in the distribution and migration of bowhead whales (*Balaena mysticetus*) away from areas that experience intense noise and activity (Ljungblad et al. 1985).

The research activities listed in this task concern the effects of cumulative sources of disturbance during offshore development. As exploration plans are better understood, the effects of seismic survey devices on marine mammal species may warrant specific research consideration. For example, industry may become interested in studying effects on northern sea lion populations off southern Oregon. Administrative rules have been adopted that would restrict geophysical surveys for oil and gas within 2 miles (3.2 km) of a zone surrounding Orford and Rogue Reefs (southern Oregon coast) if northern sea lions are sighted in this region. These restrictions are a precaution to protect the reproductive population of northern sea lions off Oregon [*see also* Activity A-1.f.(2)]. Language in the rules will allow the ban on testing in this region to be lifted if research indicates acoustic surveys have no significant impact on the sea lions.

(1) Describe predevelopment movements of migratory gray whales by shore-based census and offshore aerial transect. Describe distribution and feeding habitats for "resident" gray whales before and during industrial activities.

A number of studies show that industrial noises may affect whale populations. For example, research has documented changes in gray whale respiration rate, direction of travel, and migratory movement in response to underwater noises from drill ships (Malme et al. 1983). The data show that gray whales respond differently to various sources of noise which may reflect different behaviors or geographic areas. Therefore, it is questionable whether these and other results necessarily apply to gray whales off Washington and Oregon.

Gray whales move through Washington and Oregon coastal waters during fall-winter and winter-spring migrations, and a small population is resident throughout the year. Better information is needed on gray whale movements and feeding habitats prior to significant increases in noise and activity off the Washington and Oregon coast, so that critical areas can be defined and potential changes in behavior can be monitored. Benthic sampling should be conducted in potential feeding areas to improve our understanding of preferred feeding habitats. At the time this plan was drafted, a 3-year study of California gray whales was in progress to examine the effects of offshore development on migratory patterns. The need for additional experimental studies on disturbance effects and appropriate buffer zones around preferred habitats or migration routes should be reassessed following the results of the California research.

(2) Monitor abundance, use of rookeries, pup production, and survival of northern sea lions to insure the effects of cumulative sources of industrial noise and activity do not threaten the reproductive population in Oregon. Recommend guidelines to minimize disturbance of sea lions by vessels and aircraft.

The importance of the Oregon breeding population of northern sea lions is cause for concern about the cumulative effects of increased traffic from vessels and aircraft as well as potential habitat alterations during placer mineral and oil and gas exploration and development along the southern Oregon coast. Concurrent with surveys of feeding areas [*see* Task A-1.f.(2)], baseline information should be collected on the predevelopment population status, reproductive rates, and pup survival at Rogue and Orford reefs. An ongoing monitoring program to assess the health and status of the Oregon population should be established.

In addition to this baseline information, the effects of disturbance on haul-out behavior should be specifically evaluated. Observations of mammal behavior in relation to disturbance events could be monitored or the effects of specific types of disturbance could be tested experimentally. The latter approach would allow greater control to establish causal relationships and quantify safe distances for vessels or other sources of disturbance.

Task B-1.c. Coastal and Marine Birds:

Evaluate the effects of noise and disturbance from oil and gas and minerals development activities on coastal and marine birds.

Little is known about the potential effects of disturbance from offshore development activities on nearshore colonies of marine birds. Research in Alaska has shown that migratory waterfowl are disturbed by helicopter traffic associated with exploration activity on the continental shelf (Ward et al. 1987). In this instance, results caused concern that disturbance might reduce foraging efficiency and feeding times for black brant, for example. We recommend the following research for the Washington-Oregon region:

(1) *Evaluate the effects of disturbance events by vessels and aircraft on roosting and nesting birds, and, as needed, establish appropriate resrtictions or buffer zones to minimize disturbance.*

The risks of disturbance to colonies of marine birds off Washington and Oregon are not understood. Concerns include abandonment of preferred feeding and resting habitats or disturbance from nests for sufficient periods of time to leave eggs vulnerable to predators. We recommend research be conducted to determine the effects of vessels and aircraft on roosting and nesting birds. As discussed for mammals, an observational or experimental approach could be chosen. However, only an experimental approach would allow control over the types and distances of disturbance that are studied.

Objective B-2. Contaminants:

Assess the effects of contaminant discharges on organisms, populations, and communities.

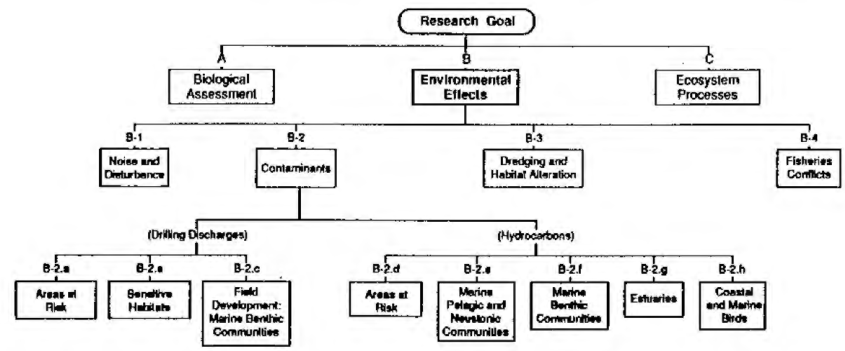


Fig. 5b. Research tasks in the Environmental Effects Program Objective B-2.

A tremendous volume of literature is devoted to the pollution effects of both drilling discharges and hydrocarbons associated with oil and gas exploration and development. Much of the early research focused on acute toxicity bioassays for various contaminants on numerous taxa of marine organisms. These data have been most useful to screen relative toxicities of contaminants and sensitivities of certain taxa or life history stages of organisms. Considerably less is known about the sublethal responses of marine organisms to these pollutants, and still less is known about the effects of these responses on populations, communities, and ecosystems.

Additional research on acute toxicities of drilling discharges or hydrocarbons is unlikely to provide much new insight about managing contaminants in the ocean off Washington and Oregon. (An exception to this rule may be the screening of new chemicals such as additives to drilling discharges or oil dispersants that have not been previously tested.) A major conclusion of a National Research Council (1983) review of the effects of drilling discharges probably applies equally well to research on many other contaminants in the marine environment:

> Our understanding of this narrow problem may be advanced most rapidly by conducting research on the broader topics of the accumulation and transfer of materials in the marine environment.

Research in this region should emphasize the processes that control dispersion of contaminants and determine the specific habitats or regions at risk from discharge at a particular location and time of year. For the habitats or ecosystems at risk, research will be needed to understand the uptake and transfer of contaminants through food chains and the potential for biomagnification effects. Baseline and monitoring programs may be warranted for selected habitats and communities where the potential long-term effects of drilling discharges or hydrocarbons are poorly understood.

Drilling Discharges

Additives to drilling fluids such as diesel fuel or certain biocides can be toxic to marine organisms. The effects of drilling discharges in the marine environment are thought to be confined to the benthos. However, since little is known about their transfer through food chains, the effects on demersal fish species that feed on benthic invertebrates, for example, is not clear. At most depths of continental shelves, fluids and cuttings disposed at a drill site are initially deposited within 1,000 m of the point of discharge (National Research Council 1983). However, the fate of drilling discharges following dispersion from the site of initial accumulation is uncertain. In high-energy environments, materials are rapidly dispersed and have minimal affect on benthic communities. Effects increase in poorly flushed environments where materials can accumulate. The toxic effects of drilling discharges and the physical effects of burial or sediment change on benthic invertebrate communities are difficult to distinguish in lab or field studies.

The pollution risk from drilling fluids and cuttings discharged into the marine environment is probably minimal if operations avoid sensitive habitats. The areas most sensitive to drilling discharges off Washington and Oregon are likely to be (1) estuaries or other shallow, protected areas, and (2) hard substrate communities (such as nearshore or offshore rocky reefs) where sediments do not normally accumulate and recovery rates may be slow. Future research in Washington and Oregon on the subject of drilling discharges should focus on sensitive areas, production drilling operations (which have not been adequately studied), and the toxic effects of proposed additives that have not been previously evaluated. The following research is needed:

Task B-2.a. Areas at Risk: **Identify geographic areas and habitats at risk from drilling discharges during oil and gas exploration or field development.**

(1) Evaluate potential location and extent of the plume and zone of deposition for drilling discharges from proposed oil and gas drilling operations.

Information about near-bottom currents and sediment transport processes near proposed development sites will be needed to evaluate the potential location and extent of deposition and resuspension of drilling discharges during oil and gas exploration or field development. Pre-drilling investigations should assure the potential distribution and accumulation of wastes will not threaten sensitive or important biological communities or habitats.

Task B-2.b. Sensitive Habitats: **Evaluate effects of burial or contamination of hard substrate communities from drilling discharges during oil and gas exploration.**

Rocky reefs and other hard bottom habitats support productive biological communities that may be vulnerable to burial or contamination from drilling discharges. Benthic communities in hard substrate areas may be relatively long-lived and slow to recover from disturbance. The state of Oregon has recommended that certain rocky reef areas be deferred from leasing for oil and gas. Surveys to inventory nearshore kelp bed and offshore rocky reef communities are discussed in Tasks A-2.c and A-2.f, respectively. If proposals for exploration drilling involve sites near these or other hard substrate communities, we recommend the following research:

(1) Evaluate potential sensitivity of hard substrate communities to drilling activities.

Rocky habitats near proposed exploration areas should be inventoried to assure drilling sites are chosen that will avoid important or sensitive invertebrate or fish communities. Surveys should describe composition and abundance of benthic invertebrate and associated fish communities. Factors to consider are toxicity of drilling wastes to local invertebrate taxa and potential periods of recovery following disturbance. Rates of dispersion at the sediment-water interface should be estimated at and near areas of proposed drilling to predict whether drilling discharges are likely to accumulate within rocky habitats.

(2) *Evaluate the effects of drilling discharges on benthic invertebrate communities. Describe successional changes in the community and rates of recovery associated with deposition of wastes or assimilation of toxins.*

If drilling for oil and gas occurs in or near hard substrate communities, a baseline study and long-term monitoring program at treatment and control stations should be established. Effects to consider in a long-term evaluation might include:

- the accumulation of material and toxic wastes at various distances from the drill site,
- rates of dispersion of material following initial deposition,
- effects of discharge on community structure,
- uptake of toxic wastes and sublethal responses among selected taxa, and
- recovery of the community after drilling is suspended.

Task B-2.c. Field Development:

Assess the long-term effects of drilling discharges during oil and gas field development on benthic invertebrate and demersal fish communities.

Most studies of the effects of drilling discharges have evaluated exploratory drilling operations. During development of an oil and gas field for commercial production, larger volumes of material are discharged from multiple wells drilled from a single platform. Little is known about the long-term effects of production drilling operations on benthic invertebrate and demersal fish communities. If production drilling occurs in the Pacific Northwest, we recommend the following research:

(1) *Conduct laboratory studies of bioaccumulation and the physiological effects of contaminants on selected indicator species of invertebrates found at the proposed drill site. Establish a baseline and monitoring program at the site to describe chemical accumulation and long-term changes in the structure of benthic invertebrate communities* (see also *Task B-2.e.).*

Combined laboratory and field methods have been used successfully to evaluate an exploratory drilling operation in California that could be adapted to study effects of production drilling (interview January 24, 1987 with Dr. Kenneth Jenkins, Molecular Ecology Institute, University of California, Long Beach). In the California research, physiological processes that control sublethal effects of drilling discharges were studied for selected invertebrate species (e.g, Jenkins and Brown, 1985). Laboratory results were then compared with information collected at the drill site on the chemical composition of accumulated wastes and changes in invertebrate community structure. Advantages of this method are the ability to interpret the causes of observed changes in the natural community and to apply results to similar benthic communities in other localities. Among other topics for which we have little information and that may be appropriate for evaluation of production drilling activities are:

- distribution and potential uptake of discharged materials following dispersion from the site of initial accumulation,
- recovery rates of the benthos after drilling is suspended, and
- uptake of contaminants and potential biomagnification effects on demersal fishes that feed on benthic invertebrates.

Hydrocarbons

The acute and sublethal effects of hydrocarbons on marine taxa have been widely studied. Laboratory research has shown that a very broad range of biological processes can be negatively affected by very low levels of hydrocarbon contamination (National Research Council 1985). Sensitivity and response to contamination vary widely by species and life history stage and the chemistry of specific hydrocarbons. Adequate information exists on the lethal toxicities of hydrocarbons to the key commercial species that occur off Washington and Oregon (Malins and Collier 1981). Applying laboratory results to the natural ecosystem is the most difficult problem that will limit the understanding of pollution effects. Studies of the natural processes that control biological variability are needed to apply existing knowledge about oil pollution effects to the Washington and Oregon region (*see* Program Element C). Other research needs include:

Task B-2.d. Areas at Risk: **Identify geographic regions and habitats at risk from acute and chronic oil spills.**

A high priority should be given to the prediction of oil spill movements off the Washington and Oregon coast and in estuaries to define areas or habitats at risk. The movement of spills into nearshore feeding areas, onshore, and within estuaries is a particular concern. Spill trajectories should be evaluated from representative locations on the continental shelf or slope, potential onshore receiving or transfer sites, and transport lanes to and from these locations. As a precursor to improved evaluation of the nearshore transport of oil, we recommend the following research:

(1) Review the adequacy of existing nearshore circulation data and oil spill trajectory models to assess the risk of oil spills to coastal habitats. Recommend research as needed to improve future risk assessment.

Most data on winds, waves, and currents for this region have been collected offshore on the middle or outer continental shelf and slope. Little information exists about nearshore circulation processes that would influence the movement of oil spills onto shore and into estuaries. A technical review committee should be established among physical oceanographers familiar with the Washington and Oregon region to identify data needed to predict nearshore movement of oil. The committee should also review the assumptions of the Minerals Management Service oil spill model that will be used for environmental assessments in this region and recommend research that will be needed to make reasonable predictions of spill trajectories and risk to coastal habitats.

(2) Review adequacy of existing data to predict the movements of contaminants within Washington and Oregon estuaries. Recommend research needed to improve future risk assessment.

Physical data for estuaries should be reviewed to identify research needed to describe the potential movement, upstream extent, and flushing rates for contaminants. Larger estuaries such as Gray's Harbor, Columbia River Estuary, Yaquina Bay, and Coos Bay, where pipelines may be constructed or oil may be transferred, should be a priority of this review. However, other smaller estuaries also may be important to consider, especially if spill trajectories indicate a high risk of contamination along adjacent areas of coastline.

(3) Review the adequacy of existing oil spill contingency plans for coastal habitats and estuaries in Washington and Oregon. Update existing plans and prepare additional plans as needed.

Oil spill contingency plans have been prepared for only a few of the larger estuaries in the Pacific Northwest. Recent oil spills off Grays Harbor, Washington (1988) and in Prince William Sound, Alaska (1989) provide useful case studies to consider the adequacy of existing oil spill contingency plans and the need for additional plans for coastal and estuarine areas off Washington and Oregon. Analysis of oil spill trajectories and maps of estuarine habitat distribution [*see* Activity A-2.a.(1)] may be useful to identify in the plans specific actions needed to protect high risk or sensitive habitats.

Task B-2.e. Marine Pelagic and Neustonic Communities: **Assess the effects of oil pollution in pelagic and neustonic environments and, in particular, effects on commercial stocks of fish and shellfish.**

Effects of hydrocarbons in pelagic marine environments are thought to be relatively short term due to rapid dispersion, evaporation, and degradation at the surface and in the water column. However, the effects of oil pollution on pelagic organisms have not been widely studied so that the risks of chronic spills in open water are difficult to evaluate. Low water temperatures tend to slow degradation processes (National Research Council 1985) and may increase the duration of acute or chronic contamination in the cold-water environment off Washington and Oregon. At the same time, hydrocarbon metabolism and clearance rates in fish may be reduced at low temperature and thereby increase the biological risks of exposure to oil (National Research Council 1985). For these reasons, it may be important to evaluate the risks of chronic oil pollution in pelagic environments where development activity is focused. We recommend the following research:

(1) Evaluate sublethal effects of petroleum hydrocarbons on key zooplankton and larval or juvenile fish species.

The sensitivity of juvenile and larval stages of many taxa to a low level of hydrocarbon exposure causes particular concern about pollution effects on important stocks of fish and shellfish. Effects on larval behavior and feeding activity are often a first sign of contamination in many test organisms. Little is known about the potential effects of low level contamination on species and assemblages of zooplankton and larval fish and the subsequent recruitment of commercially important species (National Research Council 1985). Toxic or sublethal effects of hydrocarbon contamination on the larvae of important groundfish and invertebrate species may be an important research topic for the Washington and Oregon region. Ultimately, a better understanding will be needed of the environmental factors that control zooplankton and larval fish production in order to interpret pollution effects in the field (*see* Task C-3.b).

(2) Evaluate effects of petroleum hydrocarbons on the production and structure of marine neustonic communities.

Among the most vulnerable organisms to oil spills are those that occupy the uppermost surface layers of the water column. Neustonic communities are directly affected by oil slicks that spread in a thin surface film over the water. Dungeness crab megalopae are a major component of neustonic communities off Oregon (Shenker 1988). This and other invertebrates and larval fish that occur in the neuston are frequent prey items of juvenile salmonids (Brodeur et al. 1987). Little is known about the importance of neustonic communities to larval and juvenile fish production (*see* Task C-3.b). We recommend experimental studies be conducted to evaluate potential effects of oil contamination on production and structure of the neustonic community. The use of field enclosures (mesocosms) may provide a useful method for studying natural communities. Effects of petroleum contamination on key larval or juvenile fishes that prey on neustonic organisms should also be investigated.

Task B-2.f. Marine Benthic Communities:

Assess the effects of chronic oil pollution in benthic communities and habitats near offshore oil and gas production platforms.

Offshore production areas may experience hydrocarbon contamination from small spills or leaks from the wellhead, pipelines, or platform; discharges with ship ballast water; or releases of diesel fuel added to certain drilling fluids. The effects of chronic, low-level discharge of hydrocarbons in marine environments have received less attention than acute effects. We recommend the following research:

(1) Establish a baseline and monitoring program to describe potential petroleum contamination, and evaluate long-term changes in the structure of benthic invertebrate and demersal fish communities near offshore oil and gas production platforms.

Baseline and monitoring programs should be conducted at offshore production sites to measure hydrocarbon concentrations in sediments and the water column and to investigate long-term responses by benthic communities. Such studies may also reflect the combined effects of other toxic wastes and the burial of benthic organisms that result from the discharge of drilling fluids and cuttings (*see also* Task B-2.c). Demersal fishes in the vicinity of offshore development sites may be highly sensitive to oil pollution because they are closely associated with sediments that can become traps for spilled hydrocarbons. Experimental laboratory studies may be important to understand sublethal effects among key invertebrate and fish species and to interpret results of field surveys.

Task B-2.g. Estuaries: **Evaluate chronic hydrocarbon contamination and synergistic pollution effects in estuarine ecosystems.**

Nearshore and shoreline areas may receive disproportionately high concentrations of oil from acute or chronic spills. Because residence time for pollutants in protected inshore waters may be long, embayments and estuaries are among the most vulnerable coastal areas to a variety of domestic and industrial pollutants. The single or synergistic effects of pollutants on estuarine communities and ecosystems are poorly understood. We recommend the following research:

(1) Evaluate the potential effects of chronic oil pollution on epibenthic invertebrate communities and associated estuarine food chains.

Small spills from vessels, oil pipelines, storm sewers, and various support facilities on shore could increase the risk of frequent, low-level oil contamination in some estuaries. Chronic effects of oil contamination on epibenthic invertebrate communities and associated food chains have not been widely investigated. Eelgrass, saltmarsh, and tidal flat habitats are very sensitive to oil spills. The production of epibenthic crustaceans (particularly harpacticoid copepods and amphipods) within these habitats is critical to a large variety of fishes in the Pacific Northwest such as juvenile salmon and flatfish. Field enclosures (mesocosms) may be useful for experimental studies of low level oil contamination on natural invertebrate assemblages.

(2) Monitor chemical contaminants in selected estuarine boat basins and evaluate potential synergistic effects of chronic pollution on invertebrate communities.

Little is known about the cumulative or synergistic effects of oil with other industrial and domestic contaminants that occur in estuaries. Boat basins may afford an opportunity to examine potential cumulative effects between chronic low level hydrocarbon pollution and other contaminants. Poorly flushed boat basins within Washington and Oregon estuaries experience chronic contamination from a variety of pollutants such as diesel oil, tributyl tin, and domestic wastes (Slotta and Noble 1977). Some basins may serve as an early warning of system-wide pollution effects that could occur as contaminant levels gradually increase in less restricted areas of an estuary. Studies of selected boat basins should evaluate contaminant levels in water and sediments, assimilation of contaminants by key benthic organisms, and potential effects on community structure. Preliminary surveys of basins should be conducted to identify appropriate indicator species. Experimental laboratory or field enclosure studies may be necessary to directly test effects of low levels of individual and multiple contaminants commonly found in boat basins.

Task B-2.h. Coastal and Marine Birds: **Monitor coastal bird populations as indicators of oil contamination in the marine environment off Washington and Oregon.**

(1) Maintain a long-term monitoring program along beaches and among local breeding colonies to estimate bird mortalities and detect offshore spills.

Marine birds are highly susceptible to oil. Beach surveys have been conducted for several years along a few sections of the Oregon coast to monitor bird mortality related to contamination, environmental conditions, or other factors. A long-term beach monitoring program should be established to estimate bird mortality along representative sections of the

Washington and Oregon coast. These data would provide a low-cost method for monitoring the occurrence of offshore spills and the relative magnitude of impact on bird populations. Cooperative surveys could be organized between federal or state wildlife agencies and The National Audubon Society or other private organizations.

As an addition to the beach sampling effort, local breeding populations of nearshore feeding birds (e.g., shorebirds, snowy plover *Charadrius alexandrinus*, marbled murrelet *Brachyramphus marmoratus*, pigeon guillemot *Cepphus columba*, common murre *Uria aalge*, black oystercatcher *Haematopus bachmani*) should also be monitored for potential pollution effects. These species will be among the first to indicate any severe problems associated with the loss of food resources or habitat due to oil contamination or other effects.

(2) *Analyze gut samples of seabirds as a potential monitoring tool for petroleum pollution off Washington and Oregon.*

Some seabirds may provide an indirect method for monitoring levels of hydrocarbon contamination in the marine waters off Washington and Oregon. Certain seabird taxa (Procellariiformes) ingest sublethal doses of oil that can be measured in gut samples collected from live birds (Boersma 1986). Chemical analysis of gut contents may provide useful indicators of chronic, low level oil pollution at the surface of the ocean where the birds feed. Analysis of gut contents from different geographic regions could provide a valuable index of relative pollution levels for selected areas off the Washington and Oregon coast.

Objective B-3. Dredging and Habitat Alteration:

Assess the biological effects of sediment disturbance, removal, or disposal caused by dredging, placement of structures, or other activities associated with oil and gas or minerals development.

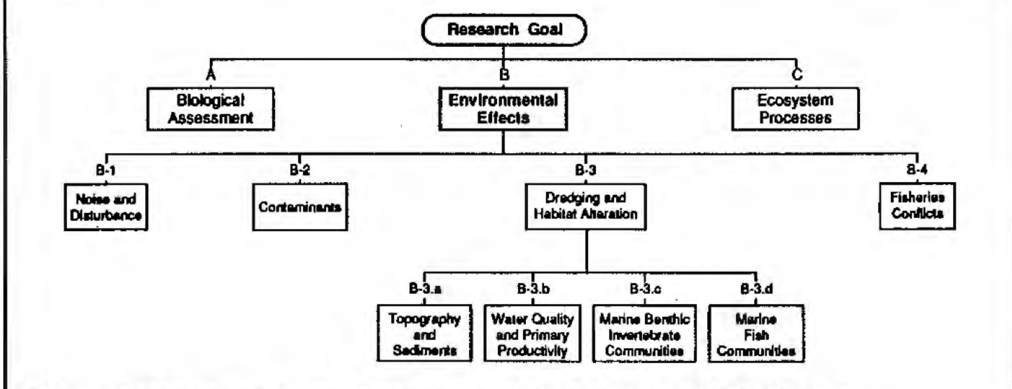


Fig. 5c. Research tasks in the Environmental Effects Program Objective B-3.

Oil and gas or mineral development will disturb the ocean floor and directly remove or alter associated biological communities. For example, oil and gas operations may disturb sediments during placement of platforms, anchors, pipelines, or other structures; create new habitat provided by these structures; and alter sediment characteristics by depositing drilling fluids and cuttings near the drill site (*see also* Task B-2.a, B-2.b, and B-2.c). Biological surveys necessary to select appropriate pipeline corridors, to locate development platforms, or to monitor recovery of the benthos following disturbance may vary for each development proposal. These research activities could be added to this objective as specific development plans for oil and gas are identified.

Offshore dredging for placer minerals will also remove benthic habitat and organisms and alter sediment characteristics and bottom topography. Sediments will be screened during mining operations, and waste material will be discharged at sea. The discharge of fine particles will create a plume of suspended material and a downcurrent zone of sediment redeposition. Changes in suspended sediment loads and water quality, bottom topography, and sediment characteristics will directly alter benthic and pelagic habitats and associated plant and animal communities. The significance of these effects will be determined in large part by the scale of the mining operation and the specific environmental conditions and biological communities at or near the mining site.

There is considerable published information on the environmental effects of short-term dredging operations, particularly channel maintenance dredging in harbors and estuarine waters. However, the test of a continuous, marine dredging operation at a fixed location has not been conducted in the United States (OTA 1987), and the specific environmental effects off Washington and Oregon are to a large degree uncertain. In this objective we have listed a sequential series of research activities to assist with decisions before and during mining operations. These activities include: (1) Prelease investigations to evaluate a mining proposal, assist with siting decisions, and, establish operating standards; (2) Baseline studies to quantify environmental and biological conditions prior to dredging at a chosen site, and (3) Post-lease studies to measure the effects of dredging (relative to baseline conditions) and monitor the effectiveness of lease stipulations. Effects on sediments and topography, water quality and primary productivity, and fish and invertebrate communities are considered in this objective. Biological studies specific to the effects of noise and disturbance during offshore mining are included in Objective B-1.

Task B-3.a. Topography and Sediments: **Assess geographic areas and habitats at risk and the potential effects of mineral dredging on topography, sediment characteristics, and sediment transport.**

(1) *Evaluate potential distribution of the sediment plume and the zone of redeposition of sediments during proposed placer mining operations. Describe potential changes in local sediment characteristics and identify habitats at risk from dredging.*

The selection of dredging sites for marine minerals will require information about the specific geographic area and habitats that will be at risk. A sediment transport model should be developed to predict the direction of movement and the location and extent of the sediment plume and zone of redeposition. This will require, for example, site-specific information on current directions and velocities and the amounts and physical characteristics of sediments (e.g, particle size, settling velocities) that will be disturbed and discharged by the dredge. Habitats and communities within the predicted path of dredging and zone of redeposition should be identified. Potential effects on sediment characteristics of these habitats and the implications for biological recovery after dredging should be described.

(2) *Investigate potential effects of placer mining operations on bottom topography, longshore sediment transport, and shoreline accretion or erosion.*

Mining activities in shallow waters may cause significant topographic changes near shore. Large dredge holes may render areas inaccessible to trawl gear used by commercial fishermen or create conditions unsuitable for the reestablishment of healthy benthic communties. Topographic changes may also alter wave patterns and sediment transport processes which may cause erosion of beaches and damage to property. The potential for coastal erosion or changes in shoreline configuration that may result from mineral mining should be assessed before mining permits are issued. Sources of sediment to local beaches should be identified and the effects of altered topography on longshore transport should be modelled prior to dredging.

(3) *Determine the effects of dredging and resedimentation on sediment characteristics, bottom topography, and shoreline accretion or erosion.*

When a mineral lease is granted, physical changes in nearshore habitat and shoreline conditions should be measured to evaluate the accuracy of prelease predictions [Activities B-3.a.(1) and B-3.a.(2)] and to insure lease stipulations are sufficient to avoid undesirable effects. Measurements may include the location and extent of sediment redeposition, the rate of redeposition in dredged areas, changes in sediment characteristics and bottom profile, and effects on beach replenishment.

Task B-3.b. Water Quality and Primary Productivity: **Evaluate the effects of sediment disturbance and discharge during mineral mining on water quality and phytoplankton productivity.**

(1) Describe sediment chemistry at the proposed mining site and evaluate the potential for release of nutrients, heavy metals, or toxins into the water column.

Most studies of heavy metals and toxins released into the water column during dredging have examined polluted harbors and estuaries. During mineral mining in a high-energy coastal environment, the potential for contaminated sediments releasing substantial quantities of toxins into the water column will likely be minimal. However, the structure and productivity of marine plankton communties are highly sensitive to very small concentrations of dissolved metals, for example (e.g., iron, manganese, copper, zinc, cadmium) (OTA 1987). Concurrent with other on-site, prelease investigations [Activities B-3.a.(1) and B-3.a.(2) above], changes in water chemistry from a continuous dredging operation should be evaluated. Laboratory bioassays of the effects of predicted chemical change on plankton community structure and productivity may be warranted, if sediment analyses suggest measureable quantities of nutrients, metals, or toxins would be released [*see* Activity B-3.b.(3) below].

(2) Measure effects of mineral mining on turbidity and water chemistry.

When a minerals lease is granted, a sampling program should be established to evaluate effects of dredging on water quality. Baseline surveys will be required to determine background water quality levels prior to dredging. During dredging, a sampling program should measure the seasonal location and extent of the plume relative to prelease predictions [see Activity B-3.a.(1)]. Water quality conditions should be compared with baseline levels at sites within and outside the dredging plume. Results of prelease investigations of sediment chemistry [Activity B-3.b.(1) above] may affect selection of appropriate indicators of water quality effects. These may include, for example, turbidity, nutrient, and heavy metal concentrations.

(3) Evaluate effects of mineral mining on chlorophyll concentration and primary production in the water column.

Rapid dispersion in open coastal waters should minimize turbidities at an offshore dredge and disposal site. However, the biological effects of a chronic turbidity plume that is continuously renewed during a commercial mining operation have not been evaluated and are poorly understood. Effects could be significant to local food chains, for example, if plankton production is suppressed after the spring transition period when coastal upwelling is strong and larval and juvenile fish are abundant. In conjunction with water quality studies [Activity B-3.b.(2) above], research may be warranted to evaluate effects of reduced light levels or changes in water chemistry on phytoplankton standing crop (chlorophyll concentration) and productivity. The need for this research should be evaluated according to prelease predictions of turbidity [*see* Activity B-3.a.(1)] and water quality effects [Activity B-3.b.(1) above] or limited tests of an offshore dredging operation.

Task B-3.c. Marine Benthic Invertebrate Communities: **Evaluate the effects of placer mining operations on benthic invertebrate communities.**

(1) *Measure the effects of mineral mining on invertebrate community structure and describe successional changes and rates of recovery for the community at dredged and disposal sites.*

Effects of dredging on benthic community structure and rates of recovery will be determined in part by the magnitude of change in sediment characteristics. Communities are more likely to approach predredging conditions following a recovery period if sediment characteristics are not dramatically altered by mining. However, even when sediments remain similar, the structure of invertebrate communities may differ substantially between pre- and postmining periods. If a minerals lease is granted, baseline and postdevelopment surveys will be needed to evaluate the long-term effects of offshore mining on benthic habitats and communities.

Preliminary surveys to describe invertebrate assemblages (*see* Task A-1.e) and to identify sensitive nearshore habitats (*see* Task A-2.d) may provide preliminary data needed to design quantitative baseline studies. Experimental sampling stations should be selected at the proposed dredge site and along a gradient downcurrent from the site to describe effects of sediment redeposition on benthic invertebrate communities. Control stations should be established outside the zone of impact for pre- and postdredging evaluations. Locations for control and experimental sites may be determined in part by prelease predictions [*see* Activity B-3.a.(1)] of the area of redeposition near the proposed mining site. An adequate baseline to detect quantitative changes in invertebrate communities may require at lease two years of predredging data for both experimental and control stations (OTA 1987).

Task B-3.d. Marine Fish Communities: **Evaluate the effects of marine dredging activities on pelagic and demersal fish communities.**

A large-scale and long-term dredging operation near shore could represent a consistent source of disturbance and turbidity that could interfere with behavior, migration, feeding, and assimilation by marine organisms. Together with changes in benthic food sources, these results could have a negative effect on nearshore fish production. Experimental studies to understand the effects of noise and disturbance on fish, mammals, and birds are described in Objective B-1. We recommend the following research to evaluate the effects of a commercial mining operation on fish distribution, food habits, and production.

(1) *Evaluate the combined effects of habitat removal and disturbance and increased turbidity on the distribution, food habits, and growth of pelagic and demersal fishes.*

The secondary effects of habitat loss or changes in food availability on fish production are among the most difficult environmental impacts to anticipate or to measure. The effects of mineral mining on demersal or pelagic fish communities may be impossible to assess quantitatively. Nonetheless, we recommend a survey of fishes be conducted coincident with benthic invertebrate surveys [*see* Activity B-3.c.(1)] to monitor any major change in migration, spawning activity, food habits, or growth. Inventories to describe nearshore pelagic and demersal fish communities (*see* Task A-2.d and A-2.e) should provide information needed to design more intensive surveys at the mining site. Experimental and control stations should be sampled before, during, and after dredging to evaluate changes in (1) composition of demersal and pelagic fish communities; and (2) distribution, habitat use, and food habits of key species representative of demersal and pelagic food chains.

Effects of turbidity on behavior or feeding efficiency of key species may require concurrent study in the laboratory to interpret field results. If dredging occurs during migration periods [*see* Activity A-2.e.(1)], research also may be needed to evaluate effects of mineral mining on the nearshore movement and feeding activity of juvenile salmonids.

Objective B-4. Fisheries Conflicts: **Identify potential conflicts between offshore development activities and the successful conduct of commercial fisheries. Collect information necessary to avoid interference.**

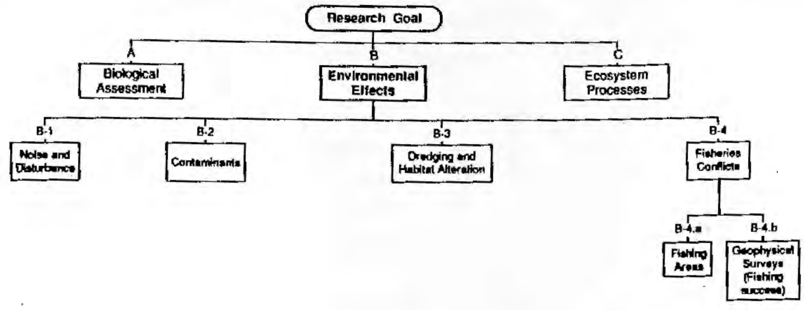


Fig. 5d. Research tasks in the Environmental Effects Program Objective B-4.

Marine mining and oil and gas development will involve many activities and environmental effects that could interfere with commercial fishing operations. Potential conflicts include loss of available area for fishing; entanglement of fishing gear with seismic survey equipment, anchor lines, offshore pipelines, or other obstructions; fouling of gear with oil from chronic or acute spills; navigational hazards near offshore structures or from increased vessel traffic; reduced fishing success from the effects of seismic survey operations or dredging activities on fish behavior; loss of harvest potential if fish are tainted during an oil spill; loss of fish producing habitat. Many of these problems can be avoided or the risk minimized by prohibiting development activity within favored fishing grounds, restricting certain operations during peak periods of fish migration or fishing activity, and developing agreements and methods of communication between fishing and oil or mineral industries. We recommend the following research:

Task B-4.a. Fishing Areas: **Describe the distribution of commercial fishing effort, harvest, and economic value off Washington and Oregon, and make recommendations to minimize the risk that offshore development activities will interfere with Washington and Oregon fisheries.**

(1) Analyze commercial logbook data for shrimp and groundfish species to describe distribution of effort, catch, and economic value to fisheries.

We have already described analyses of existing commercial logbook information to identify distribution and abundance patterns for shrimp and groundfish species off Washington and Oregon [*see* Activities A-1.c.(1) and A-1.d(1)]. Computer programs developed by the ODFW will allow harvest and effort data from shrimp and groundfish fisheries to be plotted in 5 by 5 mile (8.1 by 8.1 km)blocks. These data also can be used to describe favored fishing areas and productive habitats where interference with these fisheries should be avoided. Dollar values should be applied to average pounds landed in each fishing block as an indicator of economic importance. This information will be useful to evaluate the economic consequences of lost fishing opportunity related to oil and gas or minerals development proposals. Maps of economic, harvest, and effort data can be compared with proposed 3 by 3 mile (4.8 by 4.8 km) oil and gas leasing tracts to identify areas of potential conflict and to suggest measures that will minimize potential conflict with commercial fisheries.

(2) Survey commercial Dungeness crab fisheries to describe distribution of effort, catch, and economic value.

There are no logbook data to analyze distribution of catch and effort by the commercial crab fishery. We have proposed trawl surveys to describe distribution, abundance, and life history of Dungeness crab [*see* Activity A-1.d.(2)]. These would also provide information about the habitats that support the crab population and commercial fishery. However, because the fishery is dependent on large adult male crab, a more direct survey method also may be needed to identify the specific areas where crabbing effort and harvest tend to be concentrated. One approach could involve aerial surveys to describe coastwide distribution and effort of the fishery and on-board observers to estimate harvest by location.

(3) Survey troll fisheries to describe distribution of effort, catch, and economic value of Pacific salmon. Evaluate potential effects of offshore development proposals on the fishery allocation system in the Pacific Northwest.

The risk of conflict between offshore development activities and troll fisheries for salmon is a particular concern in the Pacific Northwest. Salmon fisheries in the region are very intensively managed to prevent overharvest of wild stocks and to allocate fish among tribal, commercial, and sport fisheries in Washington and Oregon. Offshore development activities could have serious social and economic consequences for troll fisheries and local communities if they affect fishing success or access to established fishing areas. There is a particular concern among the 25 treaty Indian tribes of Washington and Oregon which have been granted a property right to 50 percent of the harvestable anadromous fish within their normal and accustomed fishing areas. Displacement from these areas could have a severe impact on tribal fishermen and on a very complex fisheries allocation structure in the Pacific Northwest.

Research is needed to describe the distribution of catch and effort among commercial and tribal troll fisheries to minimize the risk of displacement by offshore development activities. Study methods described in Activity A-1.b.(1) to predict the distribution of adult salmon will also produce information about the distribution of catch and effort required in this research activity. In addition, as development plans for the continental shelf unfold, potential effects on the fisheries allocation structure in the Pacific Northwest should be evaluated. The social, legal, and economic implications of these effects should be assessed.

Task B-4.b. Geophysical Surveys (fishing success):

Evaluate the effects of geophysical acoustic surveys on the "catchability" of commercial fishes (*see also* Objective B-1.).

In California, commercial fishermen have reported that sounds generated by geophysical survey equipment disperse rockfish aggregations and reduce fishing success. MMS sponsored research to test the effects of a single air gun on rockfish behavior and catch per unit effort for hook and line fisheries (Pearson et al. 1987). Results of experimental trials showed a 50% decline in setline catch per unit effort for rockfish species in response to the air gun. Exposure time in these trials was longer than for a typical geophysical survey. In addition, these studies did not evaluate duration or distance of impact or the effects that might occur when a large array of air guns is used. Research is continuing to address these questions. However, different sound transmission properties may limit application of California studies to the specific geographic and environmental conditions off Washington and Oregon. The need for additional evaluation of effects on groundfish species for this region should be reevaluated following results of ongoing studies. We also recommend the following research:

(1) Evaluate the effects of acoustic surveys on the catch rate of commercial salmon trollers.

Results of studies on rockfish catch and behavior raise additional questions about the potential effects of geophysical surveys on troll fisheries for salmon. As discussed above [Activity B-4.A.(3)], displacement of migrating salmon or reduced fishing success could have severe consequences for tribal and commercial fisheries in the Pacific Northwest. Effects of geophysical surveys on salmon behavior and migrations are discussed in Activity B-1.a.(2). We also recommend research to test the effects of air guns on catch per unit effort by commercial trollers if geophysical surveys will overlap in time and space with salmon fisheries off Washington and Oregon.

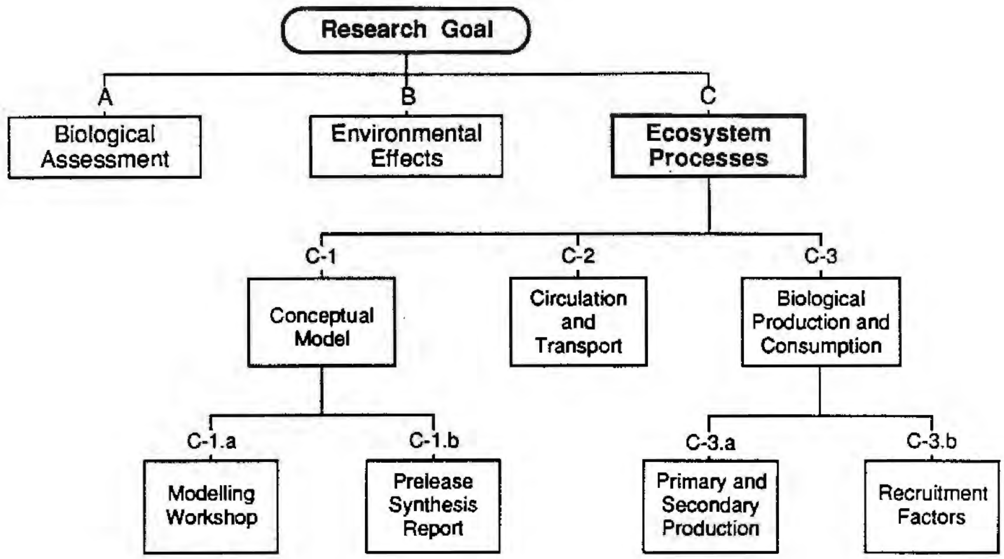


Figure 6. Research objectives and tasks in the Ecosystem Processes Program Element.

Program Element C. Ecosystem Processes:

Describe the physical and biological processes that control the transfer and transport of energy and materials in order to understand possible responses of the marine ecosystem to individual or cumulative effects of offshore development.

In Program Element B, we described categories of information needed to assess whether a pollutant or other disturbance is likely to cause serious injury to organisms or communities that are directly exposed. However, experimental studies of the sensitivity of an organism, population, or community to environmental disturbance are not necessarily a measure of the changes that will occur in an ecosystem. Materials and energy are transported or cycled so that subtle changes at one level of the ecosystem can have more significant repercussions at others. An environmental studies program must strike a reasonable balance between issue-oriented studies needed to describe sensitivities to specific environmental effects and process-oriented studies needed to interpret the possible outcome of these effects (*Figure* 2).

The National Research Council (1985) concluded that the understanding of natural variations in marine populations and ecosystems and the inability to apply laboratory studies to the field are among the factors that most seriously limit assessment of oil pollution effects. Lack of data for representative areas and time periods to describe, for example, variations in primary production, nearshore circulation, or abundance and recruitment of key commercial species will similarly limit understanding of environmental risks for the Washington and Oregon region. The very high cost of ocean research and the difficulties in sampling a very large and highly variable environment require careful planning to design meaningful ecosystem studies. We recommend the following research (*Figure 6*):

Objective C-1. Conceptual Model: **Develop a conceptual model to (1) synthesize existing knowledge about oceanographic processes off Washington and Oregon, and (2) identify research needed to understand the principal factors that control natural variation in selected populations or communities and the ecosystem.**

A conceptual model should be developed for the Washington-Oregon region as a tool to define research needs. The purpose of the model is not to make quantitative predictions but to identify the components and processes of the ecosystem that may be most sensitive to environmental change or disturbance. The development and testing of a model should highlight deficiencies in our existing information that most severely restrict understanding of the causes of natural variability in the ocean off Washington and Oregon. The model should also provide a useful organizational structure to integrate separate elements of this research plan into an ecosystem context. The absence of such a framework during the early stages of planning has limited the capacity of other marine research programs to later synthesize results. Synthesis is more feasible if the framework for integration is in place when the research is planned.

Task C-1.a. Modelling Workshop: **Conduct a workshop of physical and biological oceanographers and fisheries scientists to develop and refine an ecosystem model for coastal and marine waters off Washington and Oregon.**

A workshop of scientists should be convened to develop a model of the coastal and marine ecosystem. Walters et al. (1978) used a similar workshop approach to develop a similation model of juvenile salmon production off British Columbia. Their results helped to identify uncertainties about the factors that control marine production of juvenile salmon. Among these, for example, were the rate of renewal of zooplankton in surface waters where salmon feed and the relationship between body size and mortality rate of juvenile salmon.

Figure 7 and the following activities describe the process we recommend to develop a conceptual model for the Washington-Oregon coastal and marine ecosystem. Participants in the workshop should include individuals who have conducted research and are most familiar with physical and biological oceanography of the Northeast Pacific region. Individuals could be selected among the technical advisors to this research plan (*Table 2*).

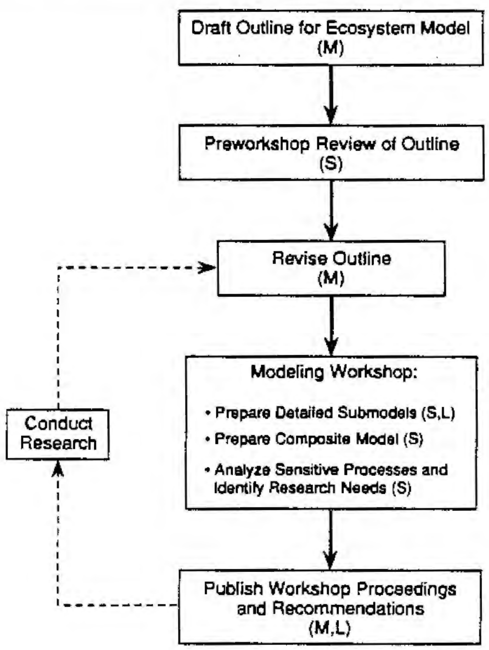


Figure 7. Procedure for preparing a conceptual model of the coastal and marine ecosystem off Washington and Oregon. Individuals responsible for each step in the process are as follows: M = Project Manager, S = Participating Scientists, L = Leaders of working groups responsible for preparing submodels (see text).

(1) *Prepare a draft hierarchical classification of the major physical and biological subsystems that compose the coastal and marine ecosystem off Washington and Oregon.*

A proposed outline ("straw man") for a model should be prepared by a project manager and sent for review by participating scientists before the workshop is convened (Figure 7). The draft outline should describe the major component submodels that would be used to characterize physical and biological processes, but not the details of processes within the submodels. From comments on the draft, a revised outline should be prepared to provide an organizational structure for the modelling workshop.

The scales of processes that control biological variability in the ocean are often poorly understood. Physical processes that occur over a large range of spatial and temporal scales may interact to determine biological distributions and production in marine ecosystems (Lasker 1978; Smith 1978; Walsh 1978; Mysak 1986). We propose that a hierarchical organization be devised for a conceptual model to describe both large and small scales of variability that may control populations and communities off Washington and Oregon.

Figure 8 illustrates a hierarchical classification that could serve as a preliminary organization for an ecosystem model. Appendix A defines the categories we have chosen for this classification. Spatial scales range from the entire subarctic Pacific region to the California Current system, domains within this system, subsystems within domains, and habitats within subsystems. In this example, physical and biological processes would be described for epipelagic (upper 200 m), mesopelagic (200m-1000m), and benthic habitats within and between each major geographic subsystem of the Coastal Domain. Appropriate populations, assemblages, or communties would be designated as indicators of biological processes in pelagic and benthic habitats.

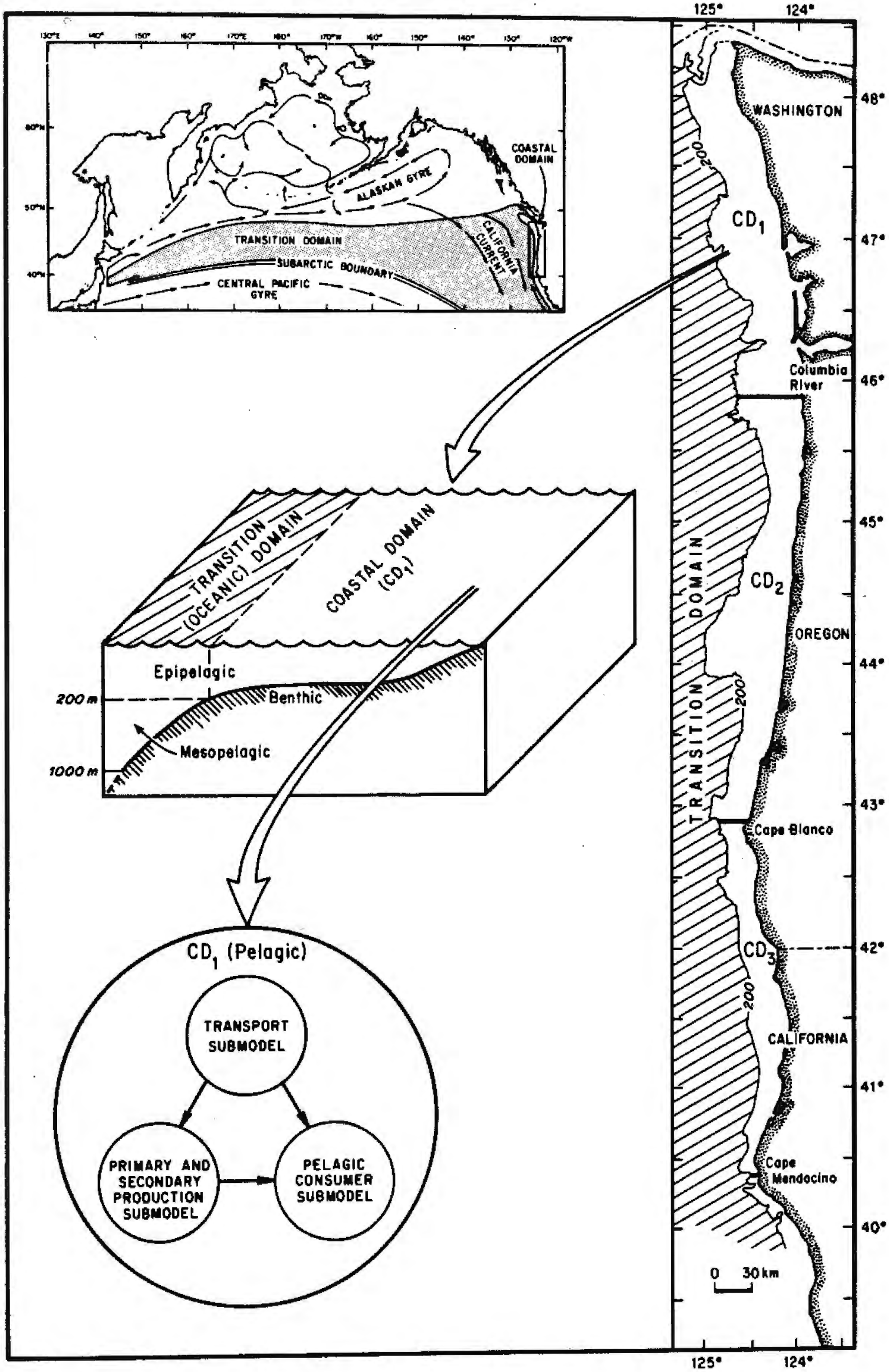
The principal time scales that control biological processes at each level of the system hierarchy also should be described in the model. For example, interannual variation in the strength of the California Current, could be a determinant of biological potential along the Washington and Oregon coast (Chelton et al. 1982; McLain and Thomas 1983; Fulton and LeBrasseur 1985). On the other hand, short-term (days to months) variability in the onset, duration, and intensity of upwelling may be critical to understand productivity within each subsystem of the Coastal Domain (Small and Menzies 1981).

Because decisions that govern offshore development will tend to focus on specific areas of impact, a geographical organization for a conceptual model would be useful for resource management as well as research. The presumption of a geographical classification is that it has some functional relationship to the organization of biological systems. It will be necessary to reorganize many sets of single species data collected off Washington and Oregon to understand community and ecosystem levels of biological organization. A number of tasks in the Biological Processes Program Element of this research plan were chosen to reformat population data to describe the composition and distribution of species assemblages. The results of these analyses would be beneficial to determine whether the geographic categories selected for a conceptual model are reflected in the composition and distribution of marine assemblages.

(2) *Describe the principal processes that control biological variability within and among the component submodels.*

The details of processes within and among the various compartments of the model would be the task of a workshop of oceanography and fisheries professionals. In our example (Figure 8), we have suggested that separate submodels be developed to describe transport, primary and secondary production, and consumption processes within and between each subsystem of the model. The appropriate types of consumer submodels leading from primary and secondary producers should be established before or soon after the workshop is convened. For example, a trophic model approach could be used to describe food webs among assemblages of

Figure 8. Example of a generalized outline for an ecosystem model. Spatial scales range from the entire subarctic Pacific to domains and subsystems within the northern California Current region (Vancouver Island, British Columbia to Cape Mendocino, California). The region is subdivided into Coastal and Transition (Oceanic) domains (modified from Favorite et al. 1976) and illustrated in the insert map of the subarctic Pacific. The Coastal Domain is further subdivided into subsystems (CD_1, CD_2, CD_3) as defined in Appendix A.



pelagic and demersal consumers. As an alternative, population models might be chosen to review factors that influence the recruitment of key indicator populations from demersal and pelagic habitats. If the latter method is chosen, salmon and groundfish population models might be logical choices for these submodels. Of particular concern should be a description of the physical factors that influence recruitment and survival of early life history stages since these are likely to be most sensitive to environmental disturbance (*see* Task C-3.b).

During the workshop, participants would be divided into separate work groups to diagram and discuss the details of processes within the component submodels (Figure 7). These groups would be reconvened periodically to discuss results and interrelationships among the submodels. When the details of the submodels have been agreed upon, the work groups would present their findings to the entire workshop and a composite model would be prepared. The most sensitive ecosystem processes within and among the compartments would be discussed, and priorities for research identified. If data are sufficient, computer simulation would be a useful tool to evaluate the most sensitive features of the model and to identify critical gaps in our understanding of processes. Results and research recommendations would be summarized in a final workshop proceedings prepared by the project manager and the leaders of each working group.

Task C-1.b. Prelease Synthesis Report:

Prior to leasing for oil and gas and minerals, prepare a written report to (1) integrate and summarize prelease information about biological production processes, distribution of species assemblages, and location of critical habitats; and (2) provide recommendations for managing living marine resources of the Washington and Oregon continental margin.

Integration and analysis of the prelease studies recommended in this plan with other information scattered throughout the published and unpublished literature will be necessary if the information is to be useful for ocean management. We recommend a synthesis report for Washington and Oregon be prepared as an oceanographic atlas that is structured in the same ecosystem or geographic hierarchy (e.g., system, subsystems, habitats, etc.) that is developed during the ecosystem modelling workshop. Such an organization would reformat existing information in a geographic context that is needed to make management decisions for specific areas of the continental margin. A computerized geographic information system for the Washington-Oregon continental margin [*see* Activities A-1.c.(1) and A-1.d.(1)] would be helpful to integrate research results from a variety of information sources.

A hierarchical organization for a synthesis report would highlight small and large scales of variability in the ecosystem that will tend to influence the outcome of management decisisons. The component submodel diagrams and other results of the modelling workshop (see Task C-1.a) should be presented for each of the subsystems discussed in the report. Important processes that may influence biological production and recruitment in each subsystem should be described. The report would summarize the distribution of species assemblages [defined in Activities A-1.a.(1), A-1.c.(2), A-1.e.(1)] and identify areas of high productivity and species diversity. The potential sensitivities of subsystems and habitats to disturbance should be described or classified in the synthesis atlas.

Objective C-2. Circulation and Transport Processes:

Describe circulation and transport processes that influence or control biological production and the movement and distribution of materials and energy in estuarine and marine environments.

The processes that transport materials in the water column and at the sediment-water interface will determine the distribution of contaminants in the ocean. The areas at risk from an oil spill or discharge of drilling fluids will depend on the velocity and direction of currents at the time and location of discharge. Research activities to evaluate areas at risk from offshore development of oil and gas or minerals are listed in the Environmental Effects Program Element [*see* Tasks B-2.(a), B-2.d, B-3.(a)].

Winds, currents, and upwelling also affect biological production processes. The state of the production system as determined by physical processes will influence the outcome of environmental disturbances that occur at a particular time and location. Additional research is needed to better understand the physical mechanisms that control biological variability. Most oceanographic studies off Washington and Oregon have described currents on the mid- or outer shelf or slope. There is very little information about nearshore circulation processes. It is also difficult to compare data sets and interpret results coastwide from studies that have been collected in different locations and for different periods of time. In the future, satellite imagery may be very useful to develop a synoptic view of nearshore currents and circulation processes needed to interpret the physical causes of biological variation.

The proposed ecosystem modelling workshop (*see* Task C-1.a) would provide a forum to integrate existing knowledge and to identify the studies of physical processes that are most needed to understand biological variability. Submodels prepared during the workshop should consider the factors that control nutrient regeneration and transport and influence primary and secondary production. As discussed above, the model will need to define appropriate spatial and temporal scales that characterize physical processes and, in turn, control biological production. Scales of physical processes that may be critical to biological production off Washington and Oregon include the scale of frontal systems (hours to days, meters to tens of kilometers); the scale of upwelling and relaxation events (days to weeks, tens of kilometers); and the scale of seasonal and interannual phenomena such as El Niño (months to years, hundreds to thousands of kilometers).

Objective C-3. Biological Production and Consumption Processes:

Describe biological production, consumption, and recruitment processes and their relationship to physical factors in estuarine and marine ecosystems.

Task C-3.a. Primary and Secondary Production:

Compare primary and secondary production rates and processes within subsystems of the Washington-Oregon region during years of high and low upwelling conditions.

The coastal upwelling system and associated biological production processes in Oregon have been studied extensively (e.g., Peterson et al. 1979; Small and Menzies 1981; Huyer 1983; Smith 1983). However, most of this research was conducted in the 1960s and early 1970s during a time of relatively strong upwelling and high productivity. Average spring-summer upwelling conditions off Oregon have been weak, and ocean temperatures have been above normal since the mid-1970s. The response of the marine ecosystem to decreased levels of coastal upwelling and, particularly, the effects on primary and secondary production and zooplankton distribution and abundance should be studied. Such studies become particularly important in light of recent predictions of global warming related to increases in atmospheric carbon dioxide. Satellite data may provide an opportunity to relate detailed research at a few sites with coastwide information on surface currents, chlorophyll, and temperature.

Most research on primary and secondary production has focused on the central Oregon coast where typical upwelling and Ekman transport processes have been described. Stronger upwelling and much greater volumes of transport have been estimated in coastal "jets" off the southern Oregon and northern California coast (Interview June 23, 1986 with Ted Strub, College of Oceanography, Oregon State Unversity, Corvallis; Abbott and Zion 1987). The biological implications of these findings are uncertain. Large differences in the volume or timing of offshore transport south of Cape Blanco could dictate very different rates of primary and/or secondary production or distribution and survival for larval fish or crab and other planktonic organisms. Marked differences in the migration patterns for Oregon stocks of chinook salmon from coastal rivers north and south of Cape Blanco (Nicholas and Hankin 1988) may be one example of an adaptation to distinct production systems off Oregon. The lack of biological information and the potential interest in development along the northern California and southern Oregon coast suggest that the region south of Cape Blanco should be a target for future research. The relative lack of information for the coastal and marine region off Washington indicates this also may be an important area for future study of primary and secondary production processes.

Task C-3.b. Recruitment Factors: **Evaluate seasonal and interannual factors that influence larval recruitment and year-class strength of commercially important populations of fish and shellfish.**

The importance of interannual variations in the ocean environment are not clearly understood but likely play a significant role in year-class strength for commercial fish stocks in Washington and Oregon (e.g., Nickelson and Lichatowich 1984; Bottom et al. 1986). The marine environment in this region is a physical and biological transition zone between dissimilar water masses (Fager and McGowan 1963; McGowan 1971; Favorite et al. 1976). It is influenced by a mixture of cold, nutrient-rich water transported southward in the California Current and warmer water transported northward in the Davidson Current (California Undercurrent). Species composition and zooplankton biomass and production may be affected by year-to-year fluctuations in the strengths of currents from the north and south (Chelton et al. 1982; Fulton and LeBrasseur 1985). The most obvious biological effects have occurred during unusually strong El Nino events in the Eastern Tropical Pacific. During El Nino conditions, biologists have reported range extensions for tropical plankton and other species, changes in the migration routes of salmon returning to the Fraser River in British Columbia (Wickett 1967; McLain and Thomas 1983) and reduced size and fecundity of adult coho salmon off Oregon (Johnson 1984). The interrelationships between these large-scale processes and local upwelling events on annual recruitment of commercial fish and shellfish species off Washington and Oregon are unclear.

There is a need to better understand biological responses to climatic changes that affect the ocean environment in this region. The effects of hydrocarbons or other pollutants may vary substantially with the condition of the marine ecosystem at the time of contamination. We recommend the following research to evaluate recruitment factors for salmonids and pelagic larval fishes:

(1) *Evaluate physical and biological factors that affect growth and survival of juvenile coho and chinook salmon in estuarine and nearshore marine environments.*

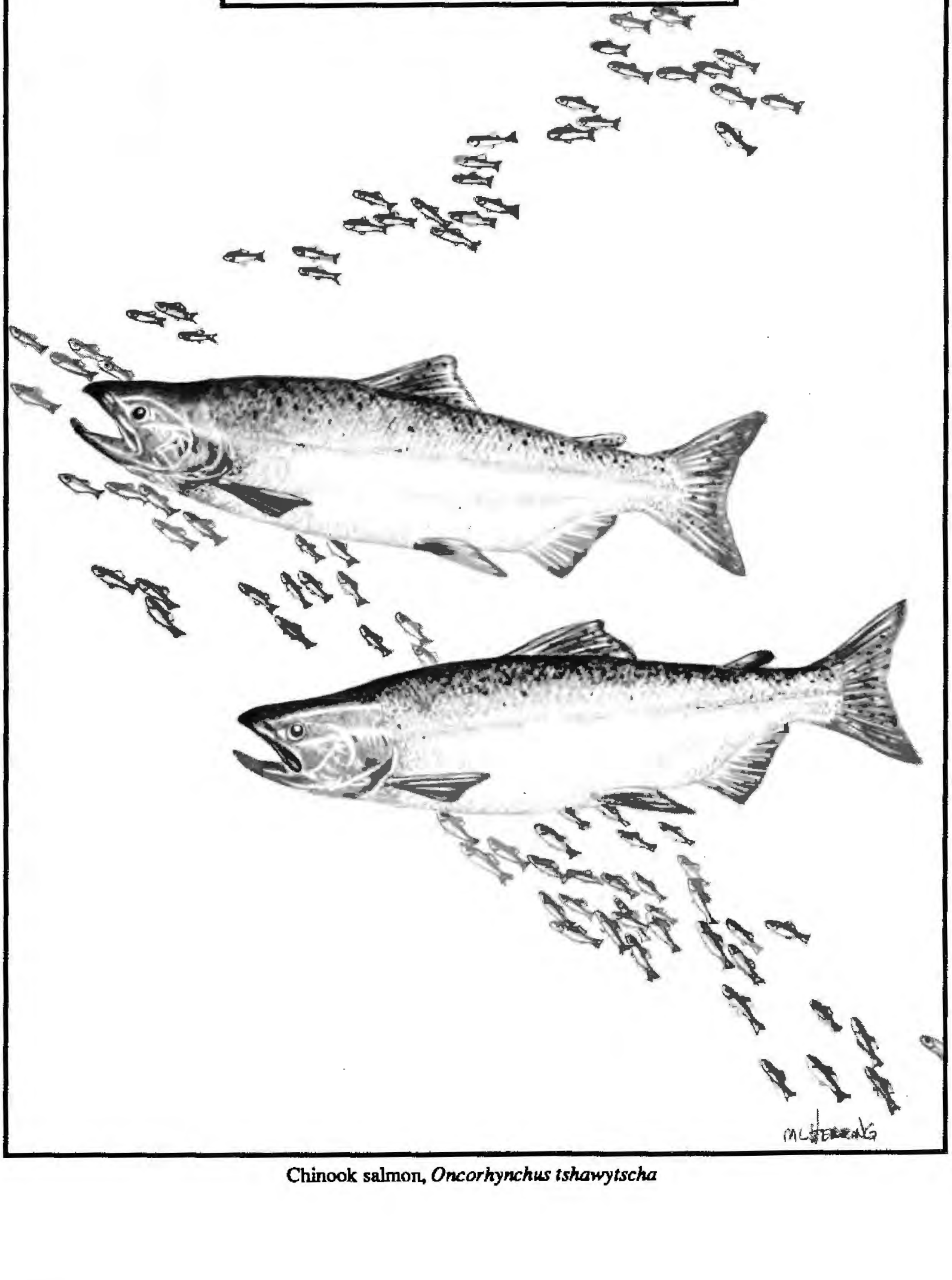
Research is needed to understand factors that affect estuarine and early marine survival of hatchery and wild stocks of juvenile salmonids. The success of an entire year-class of coho salmon is somehow affected by conditions encountered in the ocean during the first few weeks after the smolts leave fresh water (Fisher and Pearcy 1988). Although production of Oregon coho has been correlated with temperature and upwelling conditions (Nickelson 1986), the specific factors that govern survival in the estuary or nearshore ocean remain uncertain [*see also* Activities A-2.e.(1) and B-3.d.(1)].

Although estuaries are considered important rearing habitat for many stocks of chinook salmon (Reimers 1973; Healey 1982; Simenstad et al 1982; Nicholas and Hankin 1988), the factors that control survival in estuarine or nearshore marine environments or their influence, if any, on the abundance of returning adults are not understood. We recommend research be conducted to compare the relative growth and survival of north and south migrating stocks of chinook salmon with the distribution of ocean temperature, cholorophyll, or other environmental parameters.

(2) *Evaluate factors that influence recruitment of pelagic larval fishes off Washington and Oregon. Test the hypothesis that annual larval abundance and seasonal distribution are controlled by differences in ocean currents and upwelling processes within dissimilar oceanographic regimes along the Washington, Oregon, and northern California coast.*

Little is known about the factors that control recruitment of pelagic fish larvae off Washington and Oregon. Surveys to date have primarily described distribution patterns. As we have noted above [Task C-3.(a)], there has been little research off southern Oregon relative to other areas of the coast. In particular, research should investigate the effects of strong offshore transport processes in this region on the recruitment, distribution, and abundance of groundfish larvae. Comparisons should be made among subsystems of the Oregon-Washington region (Appendix A) to test the hypothesis that annual larval recruitment and seasonal distribution are controlled by differences in ocean currents and upwelling processes within different oceanographic regimes.

Priorities and Implementation



Chinook salmon, *Oncorhynchus tshawytscha*

Plan Review

Potential development of petroleum and mineral resources on the continental margin raises many more environmental questions than agency budgets can afford to answer. Designation of priorities among the large number of possible research activities is an important next step to formulate state agency budget requests and to encourage research activities by appropriate federal funding sources. The modelling workshop proposed in this plan (Task C-1.a) will help to identify priorities for studies of Ecosystem Processes (Program Element C). However, a workshop cannot address priorities among many of the Biological Assessment (Program Element A) and Environmental Effects (Program Element B) research activities which also have important management implications for Washington and Oregon. A review process is needed to select among the long list of topics we have identified and to encourage research that is deemed most important.

While this plan was prepared, a number of other planning and resource assessment activities began in response to potential petroleum and mineral development off Washington and Oregon. These activities may list additional research needs that will require review before priorities for environmental studies are established. Among these planning activities are the following:

1. MMS funds environmental studies to provide information related to oil and gas leasing and development. Annual environmental studies plans are prepared by MMS to identify proposed research activities for the Pacific Outer Continental Shelf (OCS) region (MMS 1988a). Research needs for Washington, Oregon, and California are suggested by state representatives to a Regional Technical Working Group, an advisory body to MMS. In 1988, MMS also sponsored a conference to identify environmental studies specific to the Washington-Oregon region (MMS 1988b)

2. A joint Washington-Oregon OCS Technical Advisory Group was formed to review proposed MMS environmental studies and to recommend research related to offshore oil and gas development. The group includes representatives from numerous state and federal agencies, the Northwest Indian Fisheries Commission, environmental groups, private consultants, and research institutions in Washington and Oregon. Research recommendations suggested by members of the Technical Advisory Group were incorporated in the final draft of this plan.

3. In 1987, the Washington State Legislature provided funds to the University of Washington Sea Grant Program (Substitute Senate Bill No. 5533, Ocean Resources Assessment Project) to summarize existing knowledge about the state's ocean resources and to identify appropriate study topics for the MMS environmental studies program. The bill mandates that the director of the Washington Sea Grant Program submit results of the Ocean Resources Assessment Project to the 1989 legislature. Among the reports that will be available from this assessment are a study of state and local influence over offshore oil decisions (Hershman et al. 1988); an evaluation of hydrocarbon potential of the Washington outer continental shelf; a review of coastal oceanography of Washington and Oregon (Landry and Hickey, 1989); results of a 3-day workshop to develop a conceptual framework for considering future OCS research (Kasperson et al. 1989); and an outer continental shelf studies plan.

4. In 1987, the Oregon Legislature passed a bill (Senate Bill 630) that established a 17-member Ocean Resources Management Task Force to prepare a management plan for ocean resources and activities off the coast of Oregon. The plan is intended to coordinate existing state agency programs and other interests in the ocean and to expand the Oregon Coastal Zone Management Program to include ocean resources. The plan will consider not only oil and gas development but the full range of ocean management issues off Oregon. Elements of the plan will include: an analysis of state and federal laws, progams, and regulations that affect ocean resources; a study of present and future resource uses off Oregon and the management programs for them; maps and other technical information to provide information for plan decisions; and research needs and other recommendations to improve state management programs for ocean resources. An interim plan was presented to the Joint Legislative Committee on Land Use in July 1988 (Oregon Ocean Resources Management Task Force 1988). The final plan will be submitted in June 1990.

Table 3. Steps to review research priorities and implement a long-term environmental studies program for living marine resources of the Washington-Oregon continental margin.

Step	• Activity or parties responsible
I. Identify research needs	• Oregon Department of Fish and Wildflife (this plan) • Ecosystem modelling workshop (Task C-1.a) • Washington Ocean Resource Assessment Project • MMS Environmental Studies Symposium (MMS 1988b)
II. Review research needs	• Washington-Oregon OCS Technical Advisory Group • Oregon Ocean Resources Management Task Force
III. Recommend regional research priorities (oil and gas issues)	• Washington-Oregon OCS Technical Advisory Group
IV. Review regional recommendations and adopt state research priorities (all ocean management issues)	• Oregon Ocean Resources Management Task Force • Washington State resource agencies
V. Encourage priority research by potential funding agencies and research institutions	• State agencies and legislators • Sea Grant institutions • Federal agencies • State representatives to Pacific OCS Regional Technical Working Group
VI. Synthesize results of prelease research, recommend management structure, and re-evaluate research priorities	•Task C-1.b of this plan

Table 3 proposes a review process to identify regional and state priorities for environmental studies. First, the results of this plan and the recommendations of other planning groups (listed above) should be reviewed to identify areas of agreement and disagreement and to develop a consensus about research priorities. Reviewers should include the Washington-Oregon OCS Technical Advisory Group and the Oregon Ocean Resources Management Task Force. We suggest that the Technical Advisory Group recommend a list of regional priorities specific to oil and gas development among the objectives, tasks, and activities listed in this plan; the results of the MMS (1988b) environmental studies symposium; and the findings of the Washington Ocean Resources Assessment Program. The advisory group should develop criteria they will use to assign priorities among the large number of potential study topics. The influence of development schedules and management decisions on future research priorities are discussed below. Second, the recommendations of the Washington-Oregon OCS Technical Advisory Group should be reviewed by state agencies that will use environmental studies to manage ocean resources. In Oregon, the Ocean Resources Management Taskforce is an appropriate group for review of research priorities.

Development Schedules and Timing of Environmental Studies

The timetable for research will be controlled in part by development schedules for oil and gas and marine minerals. Offshore development can be divided into exploration, prelease, and postlease phases. Research needs within each period will differ with the types of management decisions that are made. Accordingly, priorities for research may be ranked separately within pre- and postlease periods.

Oil and Gas

Many of the studies we have proposed apply to decisions that will be made during prelease planning for oil and gas leasing. Among these are decisions regarding where development will and will not be allowed (*Table 4*, Category I). Studies intended to identify critical habitats and potential lease deferral areas must be completed prior to the March 1991 Draft Environmental Impact Statement (EIS) and preferably, by June 1990, when the areas included for study in the EIS are selected (*Figure 9*). Although all the studies listed in category I (*Table 4*) may not be completed during the prelease period, some may be a prerequisite to more detailed research that will be needed during the postlease phase.

In addition to the Biological Assessment projects in Program Element A, a number of objectives and tasks from other elements of the research plan apply to prelease decisions (*Table 4; Figure 9*). Coastal circulation studies are needed during the prelease period to define areas at risk from chronic or catastrophic oil spills (*see* Task B-2.d). Studies of recruitment factors for commercial fishes (*see* Task C-3.b) would be beneficial to evaluate environmental risks before a decision is made whether to allow development in certain regions of the continental margin. Finally, studies of the effects of disturbance events on sea lion haul-out behavior [*see* Activity B-1.b.(2)] and on nearshore breeding colonies of marine birds [*see* Activity B-1.c.(1)] would be helpful during the prelease period. The lack of previous studies on these effects makes it difficult to estimate an appropriate size for buffer zones to protect important wildlife colonies. This information will be needed first to define deferral areas and later to develop postlease stipulations that will minimize disturbance from air and vessel traffic.

Most studies in the Environmental Effects Program Element apply to decisions that will be made during the postlease phase of oil and gas development (*Table 4; Figure 9*). However, baseline surveys must begin several years before the start of development activity to describe natural variations and provide a statistically valid design to test for postdevelopment effects. For example, proposed studies to evaluate chronic pollutant effects [*see* Activity B-2.f.(1)] require that control and treatment sites be identified and sampled several years before drilling for oil. It may be necessary to delay certain development activities for sufficient periods to establish a valid pretreatment baseline.

If oil and gas leasing off Washington and Oregon occurs as scheduled (*Figure 9*), only a limited number of the studies we have suggested for the prelease phase can be completed in time to provide information for the Draft Environmental Impact Statement. We recommend all studies in Category IA (*Table 4*) be among the highest priorities for prelease research. These activities will provide areawide information that can be generated quickly from existing data at a minimal cost. A portion of the logbook analyses for Oregon shrimp and groundfish [*see* Activities A-1.c.(1), A-1.d.(1); B-4.a.(1)] has been completed (Starr and Saelens 1987). Additional analyses will be needed before the draft EIS is prepared to compile other years of catch data and to examine relationships between physical factors and observed patterns of fish distribution.

We also recommend that coastal circulation studies receive a high priority during the prelease period (*see* Task B-2.d and Objective C-2). These are necessary to predict the movement of oil spills, to assess risks to critical nearshore and estuarine habitats, and to better understand physical factors that affect biological distributions and productivity. We reemphasize that a technical committee of physical oceanographers should review the specific circulation studies that are required, particularly for the nearshore region off Washington and Oregon [*see* Activity B-2.d.(1)]. Finally, oil spill contingency planning [*see* Activity B-2.d.(3)] is also an immediate need whether or not offshore development proceeds, since tankers regularly transport oil off the Washington and Oregon coast.

Little time is available for prelease environmental studies (*Figure 9*). We recommend that the states specify a minimum prelease research program required before the decision is made whether to proceed with a Washington-

Table 4. Classification of proposed research into categories of information needed to make pre- and postleasing decisions during oil and gas development. Many of the Biological Assessment surveys (Program Element A) may also apply to decisions about mineral mining activities. Research needs specific to mineral mining are listed in Table 5.

Decision category	Research tasks, activities
I. Prelease Planning	
A. Analysis of existing data	A-1.a.(1) Larval fish (NMFS data)
	A-1.c.(1) Groundfish (logbook data)
	A-1.c.(2) Groundfish (NMFS data)
	A-1.d.(1) Shrimp (logbook data)
	A-1.e.(1) Benthic invertebrates (published surveys)
	A-2.a.(2) Estuarine fish communities (survey data)
	B-4.a.(1) Shrimp/groundfish fisheries (logbook data)
	C-1.a Ecosystem modelling workshop
B. New field studies	A-1.b.(1) Adult salmon
	A-1.c.(3) Adult groundfish
	A-1.c.(4) Juvenile rockfish
	A-1.d.(2) Crab
	A-1.f. Marine mammals[a]
	A-1.g. Coastal & marine birds[a]
	A-2.a.(1) Estuarine habitats
	A-2.b.(1) Rocky intertidal habitats
	A-2.c. Hard bottoms-kelp beds[a]
	A-2.f. Offshore rocky reefs[a]
	B-1.b.(2) Disturbance: sea lions (haul-out behavior)
	B-1.c.(1) Disturbance: coastal & marine birds
	B-2.a.(1) Drilling discharges: areas at risk
	B-2.d. Hydrocarbons: areas at risk[a]
	B-4.a.(2) Crab fisheries
	B-4.a.(3) Salmon fisheries
	C-2. Circulation and transport
	C-3.a Primary & secondary production
	C-3.b Recruitment factors[a]
C. Program synthesis	C-1.b Prelease synthesis report
II. Geophysical Exploration	B-1.a.(2) Disturbance: salmon migrations
	B-1.a.(3) Seismic effects: fish & invertebrate larvae
	B-4.b.(1) Seismic effects: salmon fisheries
III. Postlease Management	
A. Predevelopment baseline surveys	B-1.a.(1) Disturbance: fish
	B-1.b.(1) Disturbance: gray whales
	B-1.b.(2) Disturbance: sea lions (production, survival)
	B-2.b. Drilling discharges: hard substrate communities[a]
	B-2.c.(1) Field development: benthos (community survey)
	B-2.f.(1) Hydrocarbons: benthos
	B-2.h. Hydrocarbons: coastal & marine birds[a]
B. Postdevelopment surveys	Same as above
C. Experimental studies	B-1.a.(2) Disturbance: salmon
	B-1.b.(2) Disturbance: sea lions (haul-out behavior)
	B-1.c.(1) Disturbance: coastal & marine birds
	B-2.c.(1) Field development: benthos: (bioaccumulation)
	B-2.e Hydrocarbons: pelagic & neustonic communties[a]
	B-2.g Hydrocarbons: estuaries[a]
D. Ecosystem processes	C-1.a Ecosystem Modelling workshop
	C-2 Circulation and transport
	C-3.a Primary & secondary production
	C-3.b Recruitment factors[a]

[a] *Includes all research activities listed in the plan under this task.*

Oregon oil and gas lease sale. The Washington-Oregon Technical Advisory Group should evaluate priorities among all of the research activities listed for prelease decisions (*Table 4*, Categories IA, IB, II, and IIID) or research for postlease management that must be started prior to the lease sale (*Table 4*, Category IIIA). Research activities that are not included among studies for the minimum program level but are a prerequisite to more detailed postlease research should also be identified. These recommendations should be reviewed by the Oregon Ocean Resources Management Task Force. Joint Washington and Oregon recommendations for a minimum prelease program should be presented to MMS through state representatives to the Pacific OCS Regional Technical Working Group.

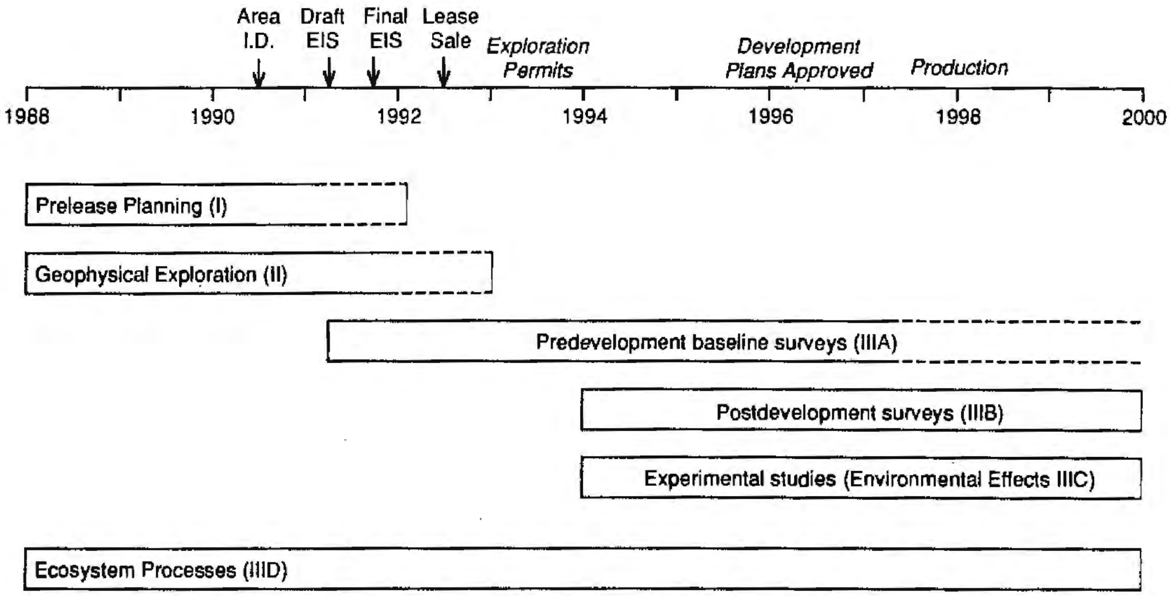


Figure 9. The timing of research needs in relation to the schedule of pre- and postleasing activities for the Washington-Oregon oil and gas lease sale. The schedule of development activities at the top of the figure assumes exploratory drilling might begin within a year and production activities within 5 or 6 years of the 1992 lease sale. Roman numerals (and letters) in each box below the timeline correspond to the decision categories and associated research activities listed in Table 4. Dashed lines on boxes indicate that the specific period for which a category of research will be needed to support pre- or postleasing decisions is indefinite.

Marine Minerals

Many of the coastwide surveys we have recommended prior to oil and gas leasing off Washington and Oregon (*Table 4*, Category I) would also provide useful information to evaluate proposed mineral dredging operations. Distribution of commercial groundfish catch and effort, for example [*see* Activity A-1.c.(1)], may be important to select mining locations that will minimize the risk of interference with established fisheries. In addition to numerous surveys in Program Element A that apply generally to ocean management, some research activities we have listed are specific to the effects of commercial mineral mining. *Table 5* lists research that pertains to exploration, prelease, and postlease phases of mineral development. We recommend this series of studies as a protocol for evaluating environmental risks of placer mining off the southern Oregon coast. Although some individual information requirements may differ, a similar sequence of research activities would apply to other Washington and Oregon coastal areas if sand and gravel or placer mining is proposed.

Table 5. Classification of proposed research into categories of information needed to make pre- and postleasing decisions for marine mineral mining operations. The list of research activities is suggested as a protocol for site evaluation and measurement of biological effects for the southern Oregon coast.

Decision category	Research tasks, activities
I. Mineral Exploration	
	A-1.f.(2) Northern sea lions
	A-1.f.(3) Nearshore marine mammals
	A-2.c Nearshore hard bottoms-kelp beds[a]
	A-2.d Nearshore soft bottoms[a]
	A-2.e.(1) Nearshore pelagic fishes
II. Prelease Planning	
	B-3.a.(1) Sediment plume
	B-3.a.(2) Topography and shoreline
	B-3.b.(1) Sediment chemistry
III. Postlease Management	
A. Predevelopment baseline-postdevelopment monitoring	
	B-1.b.(1) Disturbance: gray whales
	B-1.b.(2) Disturbance: sea lions (production, survival)
	B-3.a.(3) Topography and shoreline
	B-3.b.(3) Chlorophyll and primary production
	B-3.c.(1) Benthic invertebrate communities
	B-3.d.(1) Fish communities
B. Experimental studies	
	B-1.a.(2) Disturbance: salmon
	B-1.b.(2) Disturbance: sea lions (haul-out behavior)
	B-1.c.(1) Disturbance: coastal and marine birds

[a] Includes all research activities listed in the plan under this task.

The first stage of environmental studies will require surveys to describe species composition and abundance and to identify critical marine habitats within the general region of potential mining interest (*Table 5*, Category I). These surveys should be conducted concurrently with geological studies of mineral distribution and concentration to insure that biological information keeps pace with development proposals. A series of more detailed environmental studies will be needed when specific areas of development interest are selected but before development leases are granted. We have recommended studies to evaluate distribution of the sediment plume, determine whether toxic chemicals will be released during mining, and assess potential effects of dredging on nearshore sediment transport processes (*Table 5*, Category II).

During this prelease period, detailed biological surveys will be needed to choose specific sites for mining that avoid important habitats and to develop a baseline for later monitoring biological effects (*Table 5*, Category IIIA). Several years of predredging information may be necessary to provide a statistical baseline for a site. These surveys should be repeated during and after mining activity to describe changes and to monitor rates of biological recovery. Studies of the effects of noise and disturbance during mining operations (*Table 5*, Categories IIIA and IIIB) may also become necessary if dredging operations are located near important bird, mammal, or salmon populations.

Synthesis of Prelease Information

Washington and Oregon will need to quickly review, reformat, and interpret available oceanographic information to prepare for decisions that will be made prior to a federal oil and gas lease sale. Analysis of this information is also needed to develop and implement a permanent ocean management structure off Oregon as required by the Oregon Ocean Resources Management Act (SB 630). The Oregon management program is not limited to oil and gas issues but must consider all potential resource uses and activities of the continental margin. We recommend that an interpretive report in the format described in Task C-1.b be prepared to synthesize results of all prelease environmental information and to evaluate its implications for managing living resources of the continental margin. The prelease synthesis report should review sensitivity of offshore subsystems and habitats to disturbance and recommend sites for lease deferral prior to the Area Identification phase of the oil and gas leasing program (*Figure 9*).

Environmental Risk and Uncertainty

Resource decisions that affect complex marine ecosystems will always be made with imperfect information. The principal challenge to resource managers is to minimize the risk of long-term or irreversible adverse effects. To avoid these effects, "environmental safety factors" (Bella 1979) should be applied to decisions about offshore resource use. The magnitude of the safety factor should be proportional to the magnitude of risk. The greater the ignorance about biological resources or the environmental effects of a development activity, the greater the safety factor that will be necessary for a management decision (Bella and Overton 1972; Holt and Talbot 1978; Bella 1979).

The manner in which uncertainty about environmental risks is managed and the specific safety factors that are applied to ocean resource decisions will substantially influence priorities for the research listed in this plan. There are three management options that could be applied to a development activity: prohibit the activity, delay a decision, or permit the activity (*Figure 10*). A decision to prohibit development in certain areas may minimize or avoid resource conflicts. Deferral of high risk areas during prelease planning for oil and gas development, for example, could eliminate the need to evaluate certain environmental effects following the lease sale. A delay in a decision to allow development until specific data are available would immediately direct research toward priority geographic or subject areas. Similarly, the stipulations that are placed on an approved offshore operation will also influence priorities for research. A "no discharge" requirement for specific contaminants, for example, would eliminate the need to predict or measure their effects, unless industry is interested in

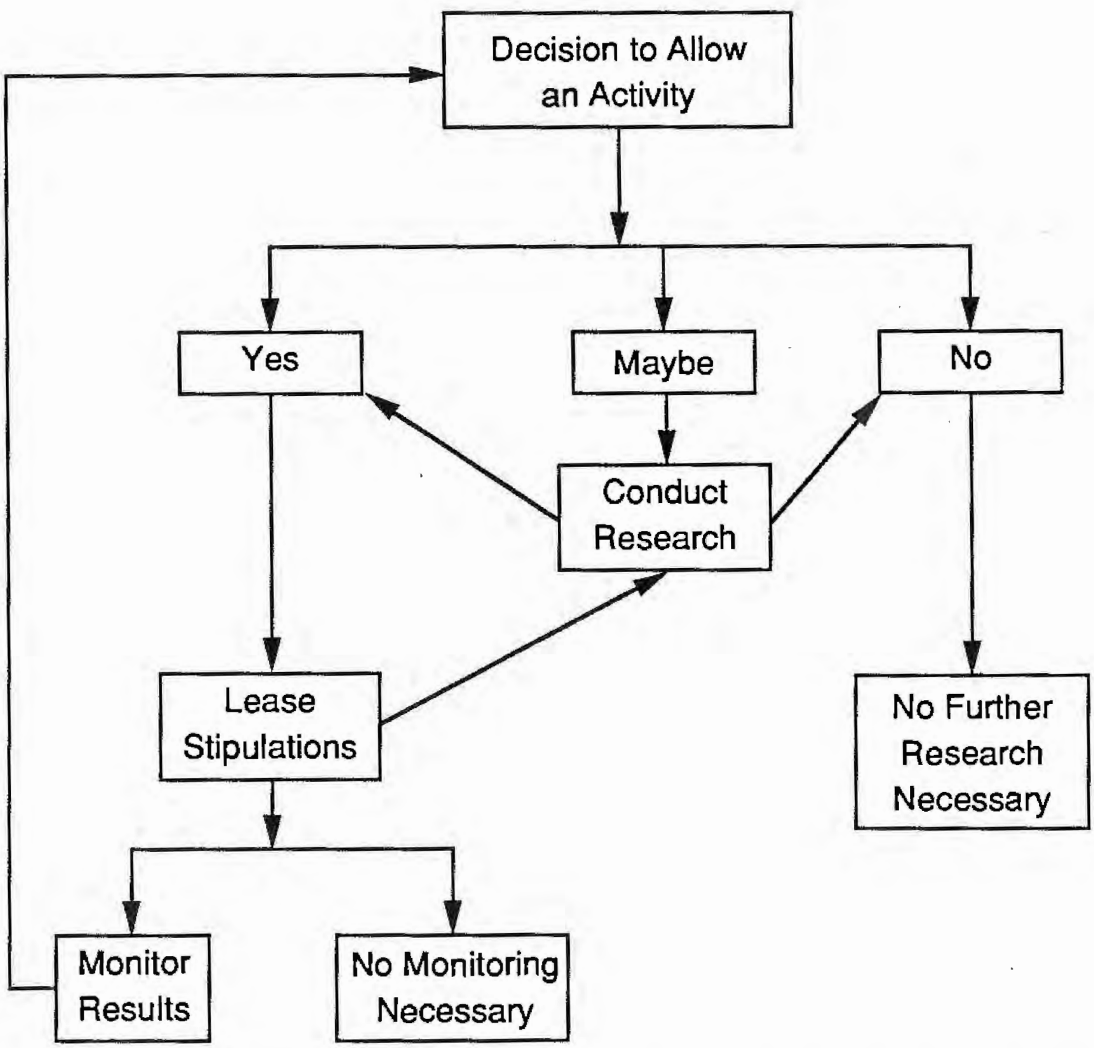


Figure 10. The need and priorities for research will be influenced by the decisions that regulate offshore development.

gathering evidence necessary to remove such restrictions. On the other hand, careful evaluation of offshore operations may be necessary if development approval is granted despite a lack of information about environmental effects. Detailed baseline and postdevelopment surveys may be required to measure these effects or, if the risk is considered minimal, then simple monitoring programs to review compliance with lease stipulations may be sufficient.

Management criteria for development activities and pollutant discharges are applied differently in different marine environments and regions of the United States. We recommend that Washington and Oregon conduct a thorough review of the federal lease stipulations and discharge criteria that have been applied to oil and gas and minerals development throughout the country. This review should identify the methods used to minimize environmental risks in other regions and indicate management options potentially available to Washington and Oregon. Such a review would help to anticipate research needs and to recommend stipulations that are most appropriate for the particular species and environments in the Pacific Northwest.

State legislation requires that the Oregon Ocean Resources Management Task Force provide recommendations for a management program for ocean resources within 200 miles of the Oregon coast. A system of management zones with specific performance standards for each zone might be useful to incorporate environmental safety factors into an ocean resources management program for Oregon.

Management zones have been used successfully as a method to protect the diversity of resource values among and within Oregon estuaries (e.g., Bella and Klingeman 1973). Habitats were mapped (Bottom et al. 1979) to help coastal planners designate development, conservation, and natural management zones within Oregon estuaries. Management zones also have been designated on the Belgium continental shelf to regulate sand and gravel mining (OTA 1987). These include zones where mining is prohibited and areas that permit mining but require various levels of environmental monitoring. Canada may adopt similar designations to regulate offshore mining (OTA 1987).

A combination of management zones and performance standards may be the best alternative for Washington and Oregon to maintain biological diversity and the health and productivity of the marine environment. Management zones and standards could be assigned to appropriate biophysical subunits of the continental margin (e.g., subsystems and habitats described in Activity C-1.a) as a means to protect critical habitats, to maintain ecological diversity, and to spatially segregate activities that may not be compatible in the same location. An appropriate degree of restriction could be specified for various types of development activity (e.g., exploration drilling, mineral mining, seismic surveys, etc.) within each biophysical unit and management zone. The following are a few examples of management zones that could be considered:

(1) High Risk Zone: The environmental risk is considered too high to justify disturbance. Specific categories of development (or all types of development) are prohibited year-round or seasonally because biological resources are considered highly valuable, vulnerable to disturbance, or slow to recover. Areas in this management category might include critical spawning or rearing habitats, regions of very high biological productivity, and important fishing areas. Representative examples of the principal habitat types in the region could be designated for protection under this category in an effort to maintain ecological diversity. Geologically unstable areas could also be given a high risk classification due to the threat to oil platforms, pipelines, or other structures. Other areas may be appropriate for this designation if contaminants discharged from these sites are likely to threaten sensitive resources in other locations.

(2) Navigation Zone: Certain activities or the placement of permanent structures might be prohibited within, for example, shipping lanes, naval training areas, and offshore dump sites to minimize navigation hazards. Other exclusive management zones (designated areas for fishing, dredge disposal, mineral mining, etc.) also may be appropiate to minimize potential resource conflicts and to reserve areas for priority uses.

(3) Conditional Zone: If uncertainty about environmental risks in an area is very high, some types of development may be prohibited until the results of research indicate that environmental risks can be maintained at an acceptable level. Examples of research requirements in a conditional zone might include: qualitative surveys to determine the distribution of habitats and species; experimental studies to evaluate environmental effects and determine the need for lease stipulations; studies of natural processes (e.g., circulation, food webs) to determine transport or transfer of pollutants; or pre- and postdevelopment sampling to quantify environmental effects of an operation. Appropriate indicator species or assemblages could be designated within conditional zones for experimental studies, monitoring programs, or ecological evaluations. Results of research in conditional zones should allow redesignation of these areas to permit (number 4 *below*) or prohibit (number 1 *above*) certain categories of development.

(4) Development Zone: The risk of adverse effects is considered low or can be minimized by lease stipulations. Minimum performance standards for leasing agreements may be specified for each development zone to provide an adequate margin of safety within a particular biophysical region (e.g., discharge of contaminants prohibited or restricted, operations seasonally restricted). Baseline studies or compliance monitoring also may be required in leasing agreements for some categories of development.

One advantage of this approach is that minimum standards for information are incorporated into the management system. The level of commitment to develop is determined by the magnitude of environmental risk and uncertainty. A direct tie between development commitments and information needed for decision-making will be particularly important as the federal oil and gas leasing program is implemented. The Washington-Oregon planning area is very large, and time and financial resources available for environmental studies before the scheduled lease sale are limited. An ocean management structure should define the level of environmental risk that each state is willing to assume given the status of knowledge that exists immediately prior to the lease sale. This structure should insure that the most important research keeps pace with development proposals so that environmental studies are not merely an *ad hoc* response to decisions that already have been made. Accordingly, as research provides a better understanding about risks, adjustments can be made in the environmental safety factors applied to future development activities.

Ecosystem Management

If, as we have suggested, a primary function of environmental management is to maintain the overall health of marine ecosystems (Lewis 1980), then planning should occur at the ecosystem level. Regional management is necessary to direct local resource uses in a manner that will minimize the risks of single or cumulative effects on an entire ecosystem. Species composition and oceanographic conditions indicate that the northern California Current region (Cape Mendocino, California to Vancouver Island, British Columbia) may be considered an ecological unit that is appropriate for regional planning and management.

Management activities within the northern California Current region presently are scattered among a large number of state and federal agencies whose jurisdictions divide the ecosystem along geographic and resource boundaries. Different agencies are responsible for managing marine birds, marine mammals, sport and commercial fisheries, pollutant discharges, dredging and disposal, and oil, gas, and mineral development. Preparation of an Oregon Ocean Resources Management Plan (Oregon Ocean Resources Management Task Force 1988) represents an important step toward integrated management. Ultimately, a regional structure or process will be necessary to coordinate management activities in Oregon with those in northern California and Washington.

Research activities in the Pacific Northwest are also segregated among many agencies and institutions. An integrated program of research is needed to assure that the sum of individual environmental studies yields the understanding that is required to manage the entire ecosystem. This plan addresses several scales of information to support ecosystem management in the northern California Current region. Areawide surveys are necessary to understand large-scale variability and to direct local development activities in a manner that will minimize risks to the ecosystem. Studies of single and local environmental effects are needed to develop lease stipulations, make siting decisions, and monitor performance. The high cost of oceanographic studies dictates that, wherever possible, individual research activities should also consider the broader regional goals that are a mutual concern of many research agencies and institutions. It is our hope this plan will encourage cooperation among the many research interests in the northern California Current region.

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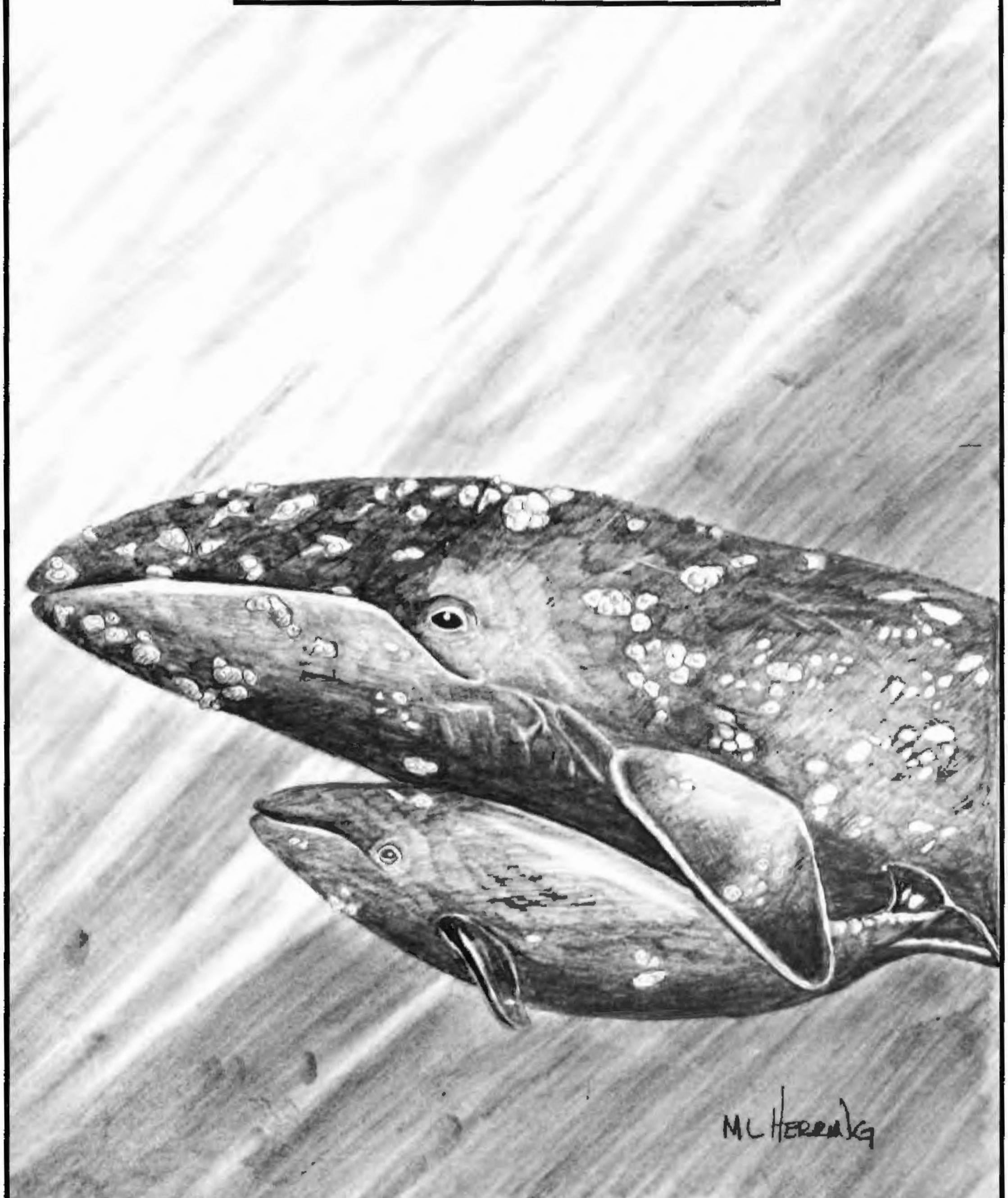

Gray whale, *Eschrichtius robustus*

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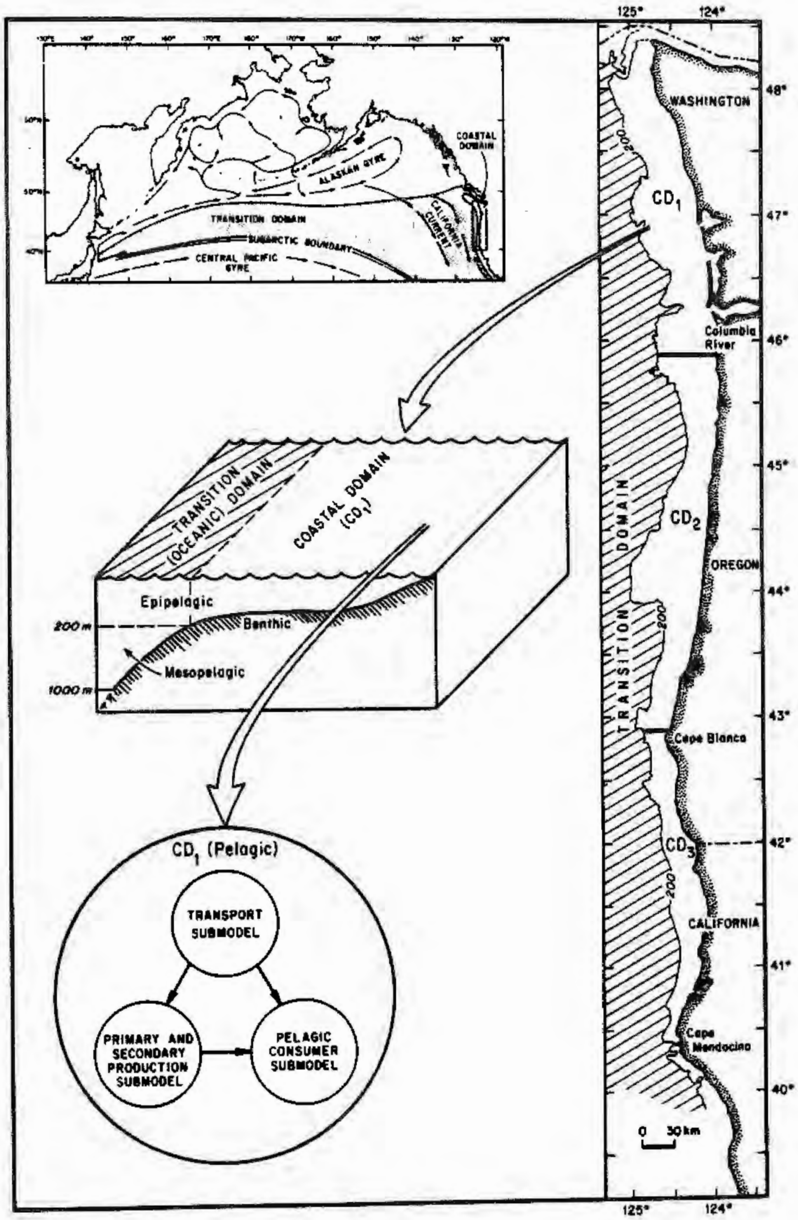
Appendix

Sanderling, *Calidris alba*

APPENDIX A.
CLASSIFICATION OF PHYSICAL AND BIOLOGICAL DOMAINS AND SUBSYSTEMS OFF WASHINGTON, OREGON, AND NORTHERN CALIFORNIA

A classification of oceanic domains for the subarctic Pacific region was described by Dodimead et al. (1963) and updated by Favorite et al. (1976). The domains are a representation of subregions with distinct physical properties. A similar classification applied on a finer scale to Washington and Oregon would provide a logical framework for a conceptual model (see Objective C-1). We recommend a hierarchical classification be devised to describe processes that influence the organization of the marine ecosystem over a variety of spatial scales, e.g., North Pacific region, California Current system, domains within this system, subsystems within domains, habitats within subsystems. An example of such a classification is given in Figure A-1. General criteria for defining domains and subsystems follow.



Appendix Figure A-1. Example of a generalized outline for an ecosystem model. Spatial scales range from the entire subarctic Pacific to domains and subsystems within the northern California Current region (Vancouver Island, British Columbia to Cape Mendocino, California). The region is subdivided into Coastal and Transition (Oceanic) domains (modified from Favorite et al. 1976) illustrated in the insert map of the subarctic Pacific. The Coastal Domain is further subdivided into subsystems (CD_1, CD_2, CD_3) as described in the text (see Activity C-1.a.1).

Domains

As a first order of classification, Estuarine, Coastal, and Oceanic domains can be defined to distinguish among brackish water, nearshore, and offshore oceanographic properties along the entire length of the Washington, Oregon, and northern California (to Cape Mendocino) coast (Appendix Figure A-1; Favorite et al. 1976). Separate demersal and pelagic divisions should be recognized within all three domains to distinguish processes that occur in the water column from those that occur at the sediment-water interface. A 200 m depth, roughly the edge of the continental shelf and slightly below the depth of the permanent pycnocline (100-150 m), is an appropriate coastal-oceanic break. The pelagic division of the oceanic domain may be further segregated into appropriate depth strata. For the purposes of the offshore limits of this research plan (upper continental slope), an epipelgic zone (0-200 m) and a mesopelagic zone (200-1000 m) may be sufficient.

Subsystems of the Coastal Domain

The coastal domain can be subdivided into a number of compartments (subsystems) that define geographic areas with similar geological features; similar patterns of variation in winds, currents, and upwelling; and, presumably, similar processes that control biological production. Strub et al. (1987) and Landry and Hickey (1989) provide information used to define the following subsystems:

(1) Washington Coastal Subsystem

Currents along the Washington continental shelf follow relatively uniform seasonal cycles. Alongshore currents are northward in fall and winter and southward in spring and summer. In the winter, the Columbia River plume turns northward along the Washington coast. Southerly winds and downwelling force cold, fresh, river water from the plume inshore the length of coastal Washington. In summer, northerly winds force the Columbia River plume southward off Oregon. During this period, upwelling and associated Ekman transport processes are a dominant feature the length of the relatively uniform Washington coastline. Maximum upwelling off Washington occurs in June, one or two months earlier than along the Oregon coast. Intensity of coastal upwelling off Washington is generally less than off Oregon.

(2) Northern Oregon Coastal Subsystem (Cape Blanco, Oregon to the Columbia River mouth)

This subsystem is a transition zone between the uniform seasonal current cyles to the north and larger short-term fluctuations that predominate to the south (Strub et al. 1987). Interaction between the Columbia River plume and coastal upwelling zone is a dominant feature in this region. In the summer, northerly winds cause the Columbia River plume to shift from the nearshore Washington coast to the Oregon offshore region. Sharp density and nutrient gradients occur at the surface where warm, low salinity Columbia River water lies seaward of cold, nutrient-rich, upwelled water. The offshore density gradient combined with southward winds cause strong southward surface flows in this region during the summer. In winter, southerly winds and resultant downwelling trap fresh water from coastal rivers near shore, but the effects are small compared with the influence of Columbia River water off Washington.

It may be useful to further subdivide the region between Cape Blanco and the Columbia River into units of similar bathymetry that may represent distinct production areas. For example, a series of rocky reefs occur on the middle and outer shelf between Florence and Cascade Head. These banks interrupt the relatively straight bathymetric contours that occur to the north and south and may influence local current patterns. Production of demersal fish near the banks is thought to be very high. By contrast, between Cascade Head and the Columbia River mouth, groundfish abundance is consistently low (Groundfish Management Team 1984). Small and Menzies (1981) also distinguished between subregions roughly north and south of Cascade Head on the basis of differences in bathymetry that were also reflected in patterns of chlorophyll distribution.

(3) Southern Oregon-Northern California Coastal Subsystem (Cape Blanco, OR to Cape Mendocino, CA)

The zone of upwelling and increased nutrients is wider in this region than along the central and northern Oregon coast, and influence of the Columbia River plume is less. Summer winds and upwelling are stronger and more variable than in regions to the north. Off northern California and southern Oregon, very strong offshore transport seems to occur at depths much greater than is explained by typical upwelling processes. These "jets" may represent meanders caused by the deflection of southward flowing currents around Cape Blanco and Cape Mendocino. Offshore transport in a single jet may be equivalent to the Ekman flow produced by coastal upwelling along 1,000 km of shoreline (Interview June 23, 1986 with Ted Strub, College of Oceanography, Oregon State Unversity, Corvallis). These transport processes could have an important role in the production and distribution of phytoplankton, zooplankton, and larval fish and invertebrates.