LONG-TERM ENVIRONMENTAL EFFECTS OF OFFSHORE OIL AND GAS DEVELOPMENT

Edited by
Donald F. Boesch
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PREFACE

With the expansion of exploration for oil and gas in offshore regions during the 1970s, there was much concern regarding the environmental effects of future development. In the United States legal and legislative actions have been taken to stop or slow development, in large part based on concerns that deleterious effects on the marine environment would result. Ambitious Federal programs of studies of the potentially affected environment were implemented to address these concerns and ensure environmental protection. Despite these efforts, controversies regarding the seriousness of potential effects still exist, particularly with regard to subtle, but long-term effects.

Despite several evaluations of existing knowledge of the effects of offshore oil and gas development, the concern over long-term effects was unfocused. What exactly are the effects which might occur and what is the relative seriousness of each? In response to the need to answer these questions and to develop a considered and carefully planned strategy to address the remaining concerns, a detailed assessment was undertaken by a group of experts, culminating in this book. These efforts were supported by the National Oceanic and Atmospheric Administration and the National Science Foundation.

The ultimate purpose of our efforts is to develop recommendations for the design of an environmental research and monitoring program to quantify and evaluate the significance of subtle and long-term effects of offshore oil and gas development activities. To accomplish this the participants decided that extensive background must be developed to support the conclusions and recommendations. Hence, detailed technical papers are included in addition to the overall assessment and research plan in Chapter 1.

A large number of individuals contributed diligently and significantly to the completion of the volume. In addition to the authors of the individual chapters, a Steering Committee consisting of Donald F.Boesch, James N.Butler, David A.Cacchione, Joseph R.Geraci, Jerry M.Neff, James P.Ray and John M.Teal defined the scope, selected the technical authors, reviewed their contributions and developed the consensus assessment and recommended research needs. Throughout their deliberations, William G.Conner and Douglas A.Wolfe of the National Oceanic and Atmospheric Administration and James Cimato of the Minerals Management Service participated as liaisons with their agencies. Glynis A.Duplantis, Veronica A.Lyons, Lisa M.Brunette, and Diane Zelasko performed the word-processing through the many revisions.

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CHAPTER 1

AN ASSESSMENT OF THE LONG-TERM ENVIRONMENTAL EFFECTS OF U.S. OFFSHORE OIL AND GAS DEVELOPMENT ACTIVITIES: FUTURE RESEARCH NEEDS

Donald F.Boesch, James N.Butler, David A.Cacchione, Joseph R.Geraci, Jerry M.Neff, James P.Ray and John M.Teal

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SUMMARY

Of the many issues raised regarding the potential effects of expanded development of offshore oil and gas resources, the potential for long-term and insidious effects on the marine environment has frustrated resolution. It is suspected that chronic effects are of greatest concern but, paradoxically, they are hard to detect and quantify.

This chapter presents a critical evaluation on the large body of information assembled and reviewed in succeeding chapters related to the long-term effects of offshore oil and gas development activities. We have attempted to focus on those marine environmental effects which are long-lasting (>two years) and significantly deleterious to human resources (such as fisheries) and ecosystem integrity. This evaluation is based on interpretation of relative risks based on the probability and severity of effects and on the potential that new scientific information or interpretation of existing information could contribute to resolution of an issue. We then provide recommendations for the studies required, their feasibility and the use of resulting information.

Because ecosystems are complex, open and dynamic, there are fundamental problems in identifying the nature and extent of environmental effects and in determining causality. Uncovering subtle effects in the coastal ocean requires long-term observation and difficult and imaginative experimentation to overcome the obstacles provided by natural variability, statistical limits of detection, the effects of other human activities, recognition of recovery, and unknown relationships within ecosystems and their role in supporting human resources.

The potential for long-term effects depends on the environment in which the development takes place or through which the oil and gas is transported and how the development is accomplished. In the United States, offshore oil and gas production has to date been limited to the northwestern Gulf of Mexico (the vast majority), southern California and Cook Inlet, Alaska. Although an ambitious program of exploration and development of previously undeveloped "frontier" areas was begun in the 1970s, no economically viable discoveries have yet been made outside of these historically producing regions. Based on indicators including proven reserves, current drilling activities, estimates of undiscovered

resources and industry interest, it is now clear that, although some exploratory activity and potential production may take place off the Atlantic coast, Florida, the northwestern states and in the Gulf of Alaska, U.S. offshore oil and gas development will be concentrated in the northwestern Gulf of Mexico, off southern California and in the Beaufort and Bering Seas of Alaska for the remainder of the century. Drilling in the deeper waters of the continental slope and under heavy sea ice conditions will present new challenges to the industry in terms of environmental engineering and safety.

Modes of transportation of oil and gas from offshore will vary depending on the product and amount of production, the distance to shore, the nature of the intervening environment, and the capabilities of onshore facilities. The extent and duration of effects of oil spills resulting from pipeline ruptures or loss from transshipment will vary depending on the nature of the coastal ecosystems affected and the presence of colonies of birds and mammals. Similarly, dredging for pipelines and required navigational access will pose different threats to disparate coastal environments. Knowledge of the comparative sensitivity of marine ecosystems often limits extrapolation of results from one area to another.

Based on detailed consideration of the probability and severity of effects and the potential for resolution of uncertainties, we have identified ten categories of potential long-term environmental effects of offshore oil and gas development activities for future investigation. Of high priority are 1) chronic biological effects resulting from the persistence of medium and high molecular weight aromatic hydrocarbons and heterocyclics and their degradation products in sediments and cold environments; 2) the residual damage from oil spills to biogenically structured communities, such as coastal wetlands, reefs and vegetation beds; and 3) effects of channelization for pipeline routing and navigation in coastal wetlands. Of intermediate priority are 1) effects of physical fouling by oil of aggregations of birds, mammals and turtles; 2) effects on benthos of drilling discharges accumulated through field development rather than from exploratory drilling; and 3) effects of produced water discharges into nearshore rather than open shelf environments. Of lower priority are 1) effects of noise and other physical disturbances on populations of birds, mammals and turtles; 2) the reduction of fishery stocks due to mortality of eggs and larvae as a result of oil spills; and 3) effects of artificial islands and causeways in the Arctic on benthos and anadromous fish species.

For each of these major categories of effects, sequential approaches are developed for quantification of long-term effects. Recommended research includes generic experimental approaches, for example, on the persistence of medium and high molecular weight hydrocarbons in sediments and their metabolic fate in organisms; observational studies, for example, following the recovery of oiled communities and monitoring of potentially affected colonies of birds and mammals; carefully designed measurements of environmental processes, for example, transport of contaminated sediments and hydrologic flow in altered wetlands; and regionally focused field assessments.

For each stage of the recommended study sequence, an appraisal of the feasibility of the study is given based on whether it can be satisfactorily accomplished within a 10-year time frame using available methods or requires development of new methods or innovative approaches. The preferred regional focus, where appropriate, is also indicated.

Given the great diversity of potential effects and regional differences in potential effects, we recommend implementation of and commitment to a U.S. interagency program plan which guides regional research and monitoring efforts together with generic research programs. Of critical importance to the success of such a program are centralized management within agencies and sufficient interagency overview to assure compliance, iterative review of objectives and progress, emphasis on innovation and application of state-of-the-art methods, and multiyear research funding.

INTRODUCTION

Concerns regarding the effects of offshore oil and gas development activities on the marine environment have focused most sharply on oil spills and the operational discharge of materials, such as drilling fluids, during exploratory drilling. Such effects are generally perceived as acute and ephemeral, although potentially catastrophic in the case of oil spills. The acute effects of oil spills and drilling discharges have become increasingly well understood (National Research Council, 1983, 1985), due in part to heavy investment of public and private support of research.

In recent years, insidious effects have been uncovered for agents and activities once presumed harmless, for example poly chlorinated biphenyls (PCBs) and carbon dioxide released into the atmosphere. As a consequence, environmental scientists and the general public turn their attention to the potential for less obvious and longer-lasting effects of human activities and byproducts. This leads, as Lewis (1982) pointed out, to "the apparent paradox that it is the unknown, the suspected but hard-to-detect chronic effects, that are the real cause for concern." It is against this background that the National Marine Pollution Program Plan (Interagency Committee on Ocean Pollution Research, Development, and Monitoring, 1981) concluded that the most significant unanswered questions for offshore oil and gas development are those regarding the effects on ecosystems of long-term, chronic, low-level exposures resulting from discharges, spills, leaks and disruptions caused by development activities.

True to this paradox, concerns about long-term and chronic effects are difficult to resolve, the issues contentious, and the angst high. In the summary of a British symposium on the long-term effects of oil pollution, Clark (1982) highlighted the considerably divergent views. Debates rage over appropriateness of methodologies, interpretation of results and the potential for undiscovered effects (e.g., Sanders and Jones, 1981).

An overall assessment of the potential environmental effects of existing and future offshore oil and gas development requires critical evaluation beyond that provided by the authors of the individual review chapters on which this synthesis is based. Specifically, we must determine whether the potential for an effect is realistic, of long duration, and significantly deleterious to human resources or ecosystem integrity. All of these characteristics are relative: how probable must the effect be, how long must it persist, and how pervasive must be its repercussions? All these evaluations call on our judgments.

The term "long-term effect" is almost always used without definition. Is it an effect that persists or one which results from a persistent activity? The latter includes the first, but an acute event may result in a persistent effect. As used here, long-term effects are those which either result from activities which extend over long time periods or persist as a result of brief activities. Because the recovery of marine communities from oil spills has been documented for periods ranging from two to ten years (Clark, 1982), long-term will be operationally considered to include time periods greater than two years.

Using this terminology, an oil spill resulting from a blowout or pipeline rupture may have long-term effects if the effects persist for more than two years. It is these residual effects which are the subject of our attention and the more immediate effects are of interest only insofar as they relate to an understanding of these residual effects. More pertinent to the offshore oil and gas development issue, however, are the cases of habitat disruptions or chronic petroleum contamination, either as a result of continuous or intermittent discharges (produced waters, drilling fluids containing oil, deck washings, etc.) or from repetitive, accidental spills (numerous small spills and a small number of major spills during the life of a field).

Setting some required level of significance of the effect (either to humans or the ecosystem) is more difficult, because it involves consideration of spatial extent, persistence and recover ability, as well as the value of the ecosystem components affected. In general, field assessments around point source discharges from oil and gas development structures have been able to document biological effects only well within 1 km of the source. Our present concern is focused primarily on effects which occur on much larger scales. It is unwise, however, to set an exact spatial threshold for concern because of the interaction of space, recovery time and resource value. For example, an effect which is elicited over 1 km^2 of a rare or exceptionally valuable habitat and persists for decades is certainly of greater concern than one which occurs over 2 km^2 of a more widespread habitat and lasts no more than two years.

Environmental resources of value to humans are the focus of our assessments of risks and severity of effects. These resources include those of direct economic value, such as fisheries, but also include those which may be of little or no economic value, but are of intrinsic value to human society. Examples of the latter include marine mammals, endangered species, and rare or aesthetically pleasing environments. In addition to direct effects on those resources, we have also to consider effects on the marine and coastal ecosystems which support these resources insofar as these effects place the resources of ultimate concern in jeopardy.

We include in this evaluation the environmental effects of oil and gas development activities in offshore environments, including the area which is legally defined in the United States as the Outer Continental Shelf (beyond state territorial waters and under Federal jurisdiction) as well as nearshore environments where ownership is vested in the states. Our considerations are limited to marine ensvironments of the continental shelf and slope and to aquatic environments of the coastal fringe which are affected by offshore activities. Effects on terrestrial environments and social and economic impacts are not reviewed.

We begin our assessment with a consideration of the problems inherent in detecting and evaluating long-term environmental effects. Secondly, we identify the coastal and offshore ecosystems most likely to be affected and their relative susceptibility. We then deduce, based on the detailed evaluations of the supporting technical reviews and the above criteria of duration and significance, the potential long-term effects of offshore oil and gas development on resources of intrinsic and economic value, and the ecosystem functions which support these resources. In this assessment, we provide an evaluation of the relative risks of such effects based on consideration of their prosbability and severity, although the limits of our understanding and the diversity of environments under consideration do not allow these evaluations to be absolute. We also discuss, for each issue identified, the potential that new scientific information or the interpretation of existing information could contribute to the satisfactory resolution of that issue. Finally, we provide some more detailed recommendations regarding the studies required, their feasibility and the use of resulting information in decision-making.

IDENTIFYING LONG-TERM ENVIRONMENTAL EFFECTS

Most ecosystems are complex, open and dynamic. This results in fundamental problems in identifying the nature and extent of environmental effects of contaminants or human activities and in determining causality. These problems plague all environmental sciences, but become particularly difficult in the case of long-term effects in the coastal ocean. There effects may be subtle, the requirements for observation long-term, and the difficulties in relevant experimentation great. It is helpful here to consider in a general sense these fundamental problems in order to properly evaluate the limitations to current understanding and the requirements for improved study design.

Variability

Variations inherent to biological systems result from both the natural variability of the physical environment and of the biological processes themselves. Natural variation in space and time has been one of the greatest problems encountered in assessments of effects in the field (Chapter 14). Natural variability often overshadows impact effects or confounds the resolution of such effects. Variations in space exist on a variety of scales and have to be understood, at least at scales above that of the sample size, in order to determine if differences observed in contaminant levels or biota are attributable to a human activity. Understanding temporal variability is also important in “before-and-after” comparisons of environmental variables or biological response to an impact-producing activity. Particularly when the frame of reference is "long-term," one must compare the magnitude of an environmental effect to the concurrent range of natural variability.

The appropriate length of study may be difficult to predict *a priori,* but the generation time of important species would usually be a reasonable starting point. For some responses it is necessary for interactions to occur that may be a product of the generation times of the interactants, e.g., predator control of ecosystem structure. Note that for long-lived animals, such as some sea birds, the appropriate time frame for studies may well be decades. Identification of the nature and causes of variation should be an objective of ecosystem studies. It is not appropriate simply to consider variations as part of measurement error. They must also be recognized as an integral part of biological systems.

Benthic communities, at least in temperate waters, are less variable spatially than planktonic ones. The benthos is also generally less variable temporally than the plankton because benthic organisms are more fixed in place and generally longer-lived. For these reasons, as well as the relatively greater susceptibility of organisms exposed to contaminants accumulated in sediments, the identification of long-term pollution effects in the benthos has been more successful than in other ecosystem components.

The problems caused by natural variations in time and space for the identification of effects induced by human activities have sometimes discouraged the use of baseline and monitoring approaches (Burroughs, 1981). As discussed below, this problem is most constructively viewed in terms of setting limits of change, within which effects are either acceptable or simply undetectable within the constraints of practical design. Furthermore, even effects which can be definitely ascribed to a certain activity must be evaluated in the context of natural temporal variability to determine if they are significant.

Limits of Detection

The success and efficiency with which effects can be identified depend on assumptions about the degree of change in variables one wishes to detect. This may seem simple and obvious, but it is surprising how frequently these assumptions are not made explicity (Chapter 14). Insensitive methods using sampling designs with poor power are able to detect only the grossest effects and thus have little to contribute to determination of long-term, potentially subtle effects. It is important that the sampling design be capable of detecting the degree of change which is considered unacceptable or which nature forces us to accept as feasible. Furthermore, the sensitivity of methods to detect such a change should be clearly stated.

It is also advisable that studies be designed to measure biological and environmental variables of ecological or economic importance or special usefulness as indicators. Effects not considered in the design of a study can rarely be found through an unfocused, general survey. This is especially true in the oceans because marine ecosystems are too poorly understood and too inaccessible to be able to detect unanticipated effects. By contrast, terrestrial environments are more accessible to direct observation, allowing more timely modification of the course of study when confronted by the unexpected.

Effects of Other Human Activities

Man uses the oceans for many purposes and it is necessary to consider the effects of a specific activity such as offshore oil and gas development in the context of the effects of other uses. This is instructive both in terms of evaluating the environmental "costs" of various uses in the same currency and the capacity of the ecosystem or resource to absorb the impacts. Practical difficulties with such comparisons include limited knowledge about the effects of the various uses and assignment of cause of observed alterations among the uses. Although it may be appealing simply to compare the relative contribution of contaminants from different sources, this may be misleading because of variations in exposure mode and concentration. Furthermore, biological response may be non-linear. That is to say, the additional 5% contribution of a contaminant, for example, may overwhelm the capacity of an ecosystem to accommodate it.

Interrelationships in Ecosystems

The more that is learned, the more ecologists are surprised by how thoroughly and complexly the components of ecosystems are connected. Variations or alterations in one biotic component may have subtle repercussions in other seemingly unrelated components. This feature contributes to a lingering uncertainty about whether the effects of a contaminant or activity are understood well enough to be predictive. In addition, ecosystems may be highly connected to other ecosystems, particularly in the coastal ocean. Continental shelf ecosystems interact with coastal systems by environmental forces (e.g., runoff, storms, etc.) and movement of biota between them. Similarly, the continental shelf is influenced by the dynamics of the adjacent oceanic regime through boundary current variations, upwelling and similar phenomena (Chapter 3).

Recovery

There is remarkable ignorance about the processes and rates of recovery of living resources and ecosystems in coastal environments after perturbations caused either by natural events or human activities. Even defining recovery is difficult and covers a range of possibilities. If an economic resource is the prime consideration, then return of that resource to its previous productivity might be a suitable definition. In the extreme, complete recovery may require the restoration of the ecosystem to its pre-impact state, including the relative age distributions of its populations, occurrence of all species previously present, etc. In any practical sense, however, the definition of recovery must include some consideration of the normal variations in ecosystems; a system can seldom be expected to return to the identical state from which it started. It would be more appropriate to consider recovery complete when the system is again varying within the bounds exhibited by similar but undisturbed (control) systems. The time required for a system to recover, however defined, can be used as a measure of the significance of an effect. If this time is short, the action is less significant than another action resulting in a much longer recovery period.

Relationship of Ecosystems to Human Resources

Concern about environmental effects is ultimately based on resources of value to society, whether economic, inherent or aesthetic. The case of an activity deleteriously affecting a commercial or recreational fishery, for example, is relatively clear-cut. The value of the resources affected can be determined and weighed against the societal benefits of the activity. Although the simplicity of this process is greatly overstated, social valuation of effects on the ecosystems which support these resources is much more difficult than for effects on the resources themselves. The relationships of ecosystem components to the resources is poorly understood, and, consequently, evaluations of the resulting effects on the resources are usually conjectural. One approach is to focus on those factors which appear to be critical to the success of resource populations and on those other living components known to be important in supporting the resources, for example, prey populations. Even then, there are considerable uncertainties regarding overlooked or obscure population controls, on one hand, and the capacity of the resource species to accommodate ecosystem change (for example, by switching to alternate prey) on the other.

SUSCEPTIBILITY OF COASTAL AND OFFSHORE ECOSYSTEMS

Many concerns about environmental risks of offshore oil and gas development are raised from a regional perspective. Public officials, managers, and the general public, when confronted with the potential for oil and gas exploration and potential development off their coast, perceive a set of environmental issues of local relevance. A broader perspective must consider the large differences in development potential, proximity to shore, and transportation modes in various regions of the United States as well as in other parts of the world. Furthermore, the great diversity in the marine and coastal ecosystems which may be affected by such development must also be considered in this assessment of potential long-term effects.

Several questions must be addressed. Where is development most likely? How will it be accomplished? What is the relative susceptibility of the coastal and offshore resources and ecosystems involved? To what degree can experience or understanding about effects in one region be applied in assessing the potential for long-term effects in another?

Location of Development

Offshore oil and gas production in the United States is presently limited to the northwestern Gulf of Mexico, southern California, and Cook Inlet, Alaska. The vast majority of the past and present production is from the Gulf of Mexico.