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Donald F. Boesch

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BIOLOGICAL EVALUATION
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EVALUATING IMPACTS ON CONTINENTAL SHELF ENVIRONMENTS CONCEPTS AND PROSPECTS[1/]

Donald F. Boesch
Virginia Institute of Marine Science

INTRODUCTION

New and expanding activities on the continental shelf including disposal of wastes and dredged material, deepwater ports, floating nuclear power plants, mining, and oil and gas exploitation, have spawned increased interest in the ecology of continental shelf ecosystems and the environmental effects of these activities. Changing patterns of historical uses of the shelf environment, i.e., fishing and transportation, and as yet hypothetical new uses, such as tapping energy from the ocean's currents and gradients, will undoubtedly further increase our concern for the coastal oceans.

In response to the increasing demand for use of the continental shelf and driven by increased awareness of environmental problems, many government agencies (most of them federal) and private corporations have greatly expanded environmental impact research on the continental shelves of United States. The adequacy, aims and approaches of these investigations often differ substantially from each other. This has been a cause of criticism by the scientific community, government officials and the public. In this paper I outline the nature and extent of activities potentially impacting continental shelf ecosystems, review past experiences and ongoing programs concerning impact evaluation, point out features of continental shelf ecosystems which should influence how we study them, and attempt to develop a conceptual framework for future investigations related to environmental impacts.

CONTINENTAL SHELF ACTIVITIES

Many of the new and expanding activities can be considered offshore extensions of typically land-based activities (such as waste disposal) for the purpose of reducing environmental risks to the coastal zone.

Ocean dumping is practiced for the disposal of chemicals, dredged materials, sewage sludge and other refuse. Ocean disposal is regulated by the Environmental Protection Agency (EPA) under authority of the Marine Protection, Research and Sanctuaries Act of 1972 (P.L. 92-532 as amended by P.L. 93-254). Permits are issued by EPA, or by the Corps of Engineers in the case of dredged material, for ocean disposal at specified dump sites (Fig. 1). Environmental criteria for permitting ocean dumping (EPA 1973) rely heavily on chemical analyses of the waste or bioassays, although field monitoring is sometimes required. Generally speaking, however, ocean dumping of wastes on the continental shelf is disfavored by EPA in favor of alternate disposal methods (e.g. land-based disposal, disposal farther offshore and incineration) or recycling. However, pressures continue to mount for increased shelf disposal of dredged material since disposal in and around coastal waters has become increasingly restricted.

Ocean outfalls for the discharge of sewage and sewage sludge loom attractive to localities under pressure to reduce inputs to bays and estuaries. Large population centers in Southern California and South Florida already rely on direct disposal of sewage into continental shelf waters. Many smaller coastal cities and towns are finding ocean outfalls an attractive alternative to current disposal practices.

Another waste product for which ocean disposal is proposed is heat from electric generating plants. Nuclear power plants are in operation or under construction on the ocean shore in California and plans have been developed for the construction and operation of floating nuclear power plants. Although the tremendous heat capacity of the ocean practically eliminates any threat of thermal pollution by offshore power plants, entrainment effects are potentially significant with regard to species with localized distributions and planktonic larvae.

Economic and environmental considerations argue for the location of some traditionally land-based activities offshore. Offshore oil ports allow the use of the more economical, very large crude oil carriers and reduce the hazards to the coastal zone. Two large volume offshore ports, one off Louisiana and another off Texas, are being planned and others

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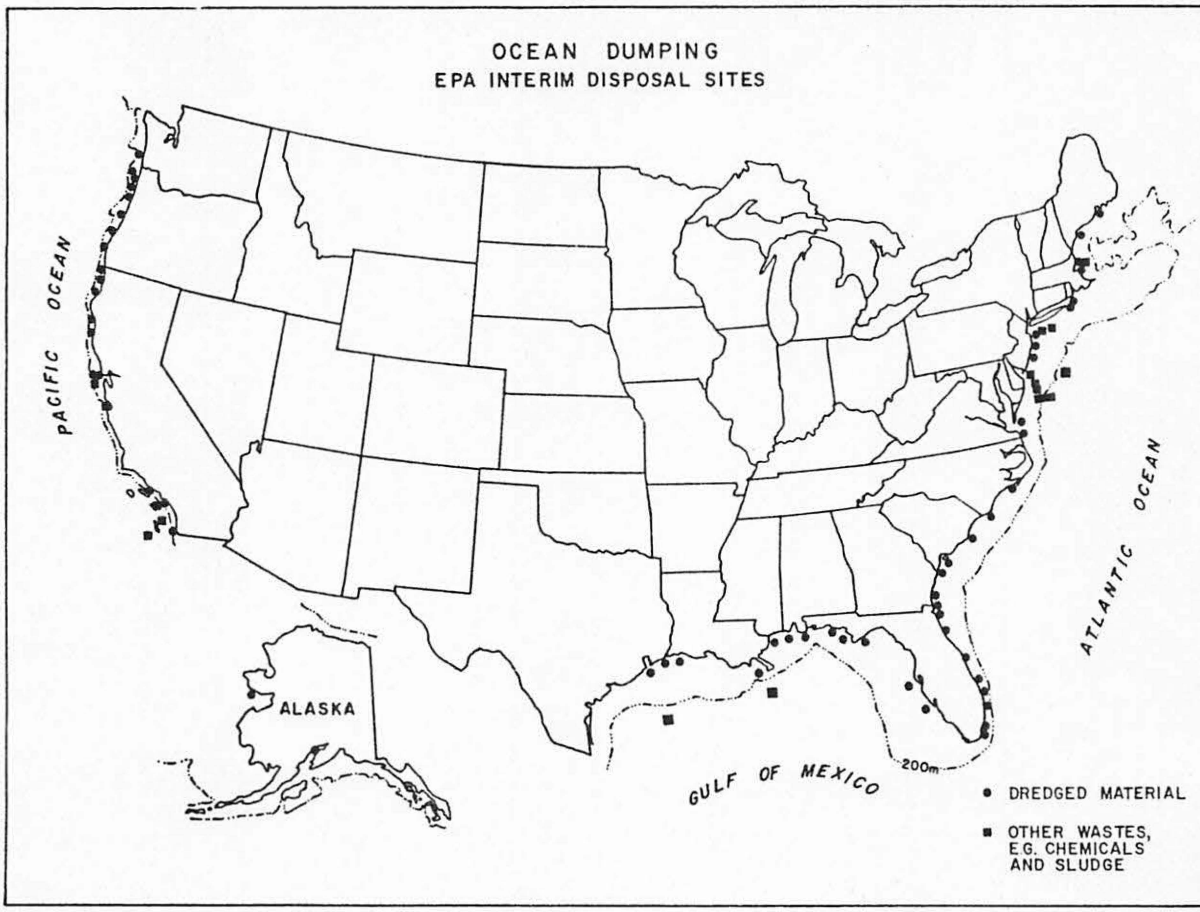

Figure 1. Interim ocean disposal sites on or near the continental shelf of the United States.

have been suggested for off Middle Atlantic and South Atlantic states. Offshore islands, possibly constructed from waste dredged material, have also been suggested to accommodate industry which may be incompatible with conservation of the coastal zone.

Mineral resource extraction is now becoming a widespread activity on the world's continental shelves. This includes extraction of surface minerals, chiefly sand and gravel for building materials, as well as subsurface resources, including oil, gas and sulfur. The continental shelf activity presently drawing by far the most attention is oil and gas development. This is due to the expansion of activities, heretofore concentrated mainly off Louisiana and Texas and parts of Southern California, to Atlantic and Pacific coasts and vast areas of the Alaskan continental shelf. The leasing and development of these outer continental shelf (OCS) tracts is under control of the Department of the Interior, specifically the Bureau of Land Management (BLM) which leases OCS lands thereby effectively permitting the right to exploit oil and gas resources, and the U.S. Geological Survey (USGS), which regulates development.

In additon to widespread concern regarding the onshore impacts of extensive development of frontier OCS areas, questions have been raised about the environmental impacts of offshore petroleum development on continental shelf ecosystems. In particular there are threats of acute and chronic contamination of the ecosystem by petroleum hydrocarbons, the introduction of trace metals, sedimentation by drill cuttings and drilling muds, and effects resulting from the installation of pipelines. These concerns have prompted the extensive environmental studies of frontier areas sponsored by BLM, which will be addressed in more detail below.

The environmental ramifications of living resource extraction on the continental shelf will undoubtedly receive increased attention in the near future. A large portion of the national fishery is already based on the continental shelf, but with the 200-mile fishery jurisdiction virtually new resources have become available to segments of the U.S. fishing industry. The unprecedented prospects for managing these resources will hopefully be realized by management schemes which take into account the environmental effects of alternate fishing methodologies.

In the case of many of the continental shelf activities mentioned above, it is important to point out that key issues regarding severity of impact revolve around scientific questions which have scarcely been addressed. There is much legitimate scientific controversy -- for example about the effects of chronic low-level contamination by petroleum hydrocarbons -- at the heart of the environmental impact assessments on which decisions regarding these activities are based. Thus at times decisions are made involving massive commitment of resources and potentially long-term environmental effects on frightfully little firm evidence. From this point of view, one can argue that the high costs of pertinent environmental research on the shelf are clearly cost justifiable if they affect decision-making.

PREVIOUS STUDIES

Few intensive impact evaluations have been conducted on continental shelf environments. Perhaps the most intensively studied activity has been ocean dumping in the New York Bight apex, where large quantities of sewage sludge, dredged material, construction debris and acid-iron wastes have been discharged in a rather confined area off northern New Jersey. The impacts of these activities have been studied by or for the Corps of Engineers, the National Oceanic and Atmospheric Administration (NOAA) and EPA, and are the focus of the ongoing Marine Ecosystems Analysis (MESA) program of NOAA. Early results emphasizing the effects of sludge disposal were summarized by Pararas-Carayannis (1973) and the National Marine Fisheries Service. Reports on the effects of acid-iron disposal were published by Vacaro et al. (1972) and Wiebe et al. (1973). An overview of these studies is presented in these proceedings by O'Connor, and more detailed findings have been published in proceedings of a symposium held on this subject in November 1975 (Gross 1976).

The New York Bight experience is a case study in the difficulties of conclusively demonstrating impacts in the real world, where natural and anthropogenic factors other than ocean dumping of wastes may exert overwhelming influence on ecosystems. For example, dump sites are located at the head of the Hudson Shelf Valley which forms a unique and discrete habitat for which no suitable unaffected control habitats exist. Also, for many pollutants, direct input by dumping pales by comparison to the inputs from the Hudson River and New York Harbor. As a result, although contamination of the environment and impacts to some segments of the biota have been demonstrated, the composite evidence has failed to unequivocally demonstrate serious effects on the marine resources of the region.

In much more limited studies of the impact of ocean dumping Lear et al. (1977) conclude that dumping of Philadelphia sewage sludge has resulted in trace metals contamination of bottom sediments and localized impacts on benthic organisms.

The environmental impact of waste discharges by ocean outfalls into the Southern California Bight have received substantial recent investigation, chiefly by the Southern California Coastal Water Research Project (SCCWRP). Each year approximately 1.4×10^9 m^3 (1,000 mgd) of municipal wastewater and 0.25×10^9 m^3 (180 mgd) of discrete industrial wastes are discharged into the Bight (SCCWRP, 1973). Municipal wastes include treated sewage effluent and sludge discharged via ocean outfalls at depths of 6-100 m. Significant contamination of shelf and basin environments by trace metals and chlorinated hydrocarbons was demonstrated by the SCCWRP studies. Localized effects on the benthos and fishes near outfalls were also found. Nonetheless, the conclusion was reached that "there is no evidence to document that present wastewater disposal practices have had any substantial adverse or irreversible effects on the general ecological characterics or environmental quality of the Bight" (SCCWRP 1973).

The impacts of oil and gas development on continental shelf ecosystems have received much less attention than the New York Bight or Southern California Bight situations. The effects of large oil spills from offshore platforms in the Santa Barbara Channel in 1969 and east of the Mississippi River Delta in 1970 (Chevron spill) received some investigation.

Studies of the Santa Barbara blowout were concentrated on the intertidal biota, marine mammals and birds (Allan Hancock Foundation 1971). Much less attention was directed at assessing effects on offshore communities even though it was known that substantial quantities of oil did reach the seabed. Continental shelf benthos was resampled at several "baseline" stations sampled a decade earlier and changes in the biota were noted. However, it was surmised that these changes could have been due to heavy rainfall around the time of the spill, the effects of drilling and spills in the channel, the increasing pressure of land-derived pollutants, or even natural fluctuations in population levels.

Environmental contamination by petroleum hydrocarbons and effects on benthos and nekton were investigated following the 1970 Chevron spill. Results were summarized by McAuliffe, et al. (1975) although the particulars are as yet unreported, and thus have not been subject to scientific scrutiny. These studies showed that petroleum hydrocarbons did contaminate sediments within a 5-10 mile radius of the platform, but the authors were unable to demonstrate any biological effects.

Finally, only one extensive environmental study of offshore oil fields has been conducted -- this a study off Timbalier Bay, Louisiana, by the Gulf University Research Consortium, sponsored by a group of offshore operations companies. Results are as yet unpublished, but overview summaries suggest a lack of significant effects on the offshore environment. Unfortunately, many of the unpublished reports reveal incomplete data, a lack of suitable controls or poor sampling design, as well as often being inconclusive.

The purpose of the foregoing review is to demonstrate that even the most extensive and intensive impact assessments on the continental shelf environment have been inconclusive or have produced equivocal or debatable conclusions. There seem to be several general explanations for this failure to come to grips with the problem: (1) large, open, dynamic shelf ecosystems are more difficult to study than smaller freshwater and coastal systems; (2) research was often of insufficient quality or completeness, principally because of inadequate support; (3) the natural causes of spatial and temporal variation were unknown; (4) baselines and controls were not, or could not be, effectively used; and (5) impacts on specific biotic components have been difficult to relate to resource values or to total ecosystem "health."

CURRENT STUDIES

A host of government agencies have interests concerning environmental impacts on the continental shelf and several are sponsoring or conducting monitoring studies, baseline studies or basic research on shelf ecosystems in order to enhance our ability to detect, understand, or predict environmental impacts. MESA studies of the New York Bight and SCCWRP studies of the Southern California Bight are examples of continuing programs.

The EPA mandate concerning environmental impacts is understandably broad and encompasses many activities but the agency has special responsibilities concerning ocean dumping. The EPA is conducting baseline and impact assessment research at some dump sites, for example off Delaware Bay. The Agency also has a major responsibility for experimental work on the lethal and sublethal effects of contaminants on shelf organisms and communities. NOAA is, of course, responsible for MESA investigations and for impact assessments related to fishery resources. This agency is also heavily involved in managing and conducting some of the BLM environmental studies of frontier oil and gas areas described below.

The Army Corps of Engineers, principally through its Dredged Material Research Program (DMRP), is concerned with ocean dumping of dredged material (Boyd et at. 1972). The DMRP has conducted field studies involving the closely monitored dumping of dredged material at several sites around the nation. Two of these sites were located on the shallow continental shelf off Galveston, Texas, and off the mouth of the Columbia River. The DMRP has also sponsored experimental research on such topics as the bioavailability of toxic contaminants of dredged material and the effects of burial on benthic communities.

The Department of Energy is sponsoring rather basic research on continental shelf processes. Studies on the Atlantic coast are directed toward processes which may relate to environmental impacts associated with coastal nuclear power plants. The Coast Guard has responsibility for regulating offshore ports and is supervising baseline sampling at Gulf of Mexico deepwater ports sites. The National Science Foundation funds basic research on continental shelf ecosystems not necessarily related to impact assessments, but which may indirectly contribute to a better understanding of impacts of man's activities. The NSF has also through its International Decade of Ocean Exploration sponsored research on the fate and effects of trace pollutants in the ocean environment.

The Outer Continental Shelf Environmental Studies Program of the Bureau of Land Management has attracted considerable attention because of the size of the program (over $44 million in FY 1978) the geographical scope and particular emphases of the studies, its role in decision-making concerning oil and gas development and the new entry of BLM into environmental research. BLM OCS baseline studies were conducted on the eastern Gulf of Mexico shelf (MAFLA region), the South Texas shelf, the Southern California Bight, the Middle Atlantic shelf (Baltimore Canyon Trough), the Southeast Georgia Embayment, Georges Bank, and extensive portions of the vast continental shelf of Alaska. Other environmental assessments of drilling and production activities have begun or are planned.

The BLM Environmental Studies Program has expanded explosively since 1974 and the study design had to be quickly developed and implemented. The scope of studies as recently perceived by BLM is outlined in Table 1. Basically, studies are classed as Reconnaissance Studies, Benchmark Studies and Fate and Effects Studies. The greatest emphasis in terms of biological studies is on the so-called benchmark studies which are broad, multi-year survey programs intended to provide a statistically sound characterization of key environmental aspects (National Research Council 1977). The objective is to establish the range of variation of critical parameters that may reflect the impact of oil and gas exploration and development activity. Thus, the studies are fundamentally descriptive "baseline" studies which are of limited predictive value in assessment of anticipated impacts.

A recent National Research Council (1977) review of the BLM Environmental Studies Program concluded that because of the emphasis on descriptive studies, it does not effectively contribute to oil and gas leasing decisions. Furthermore, the NRC review found the program scientifically deficient because of the lack of explicit hypotheses or statements of the scientific purpose for which the gathered data were intended. At the end of 1977 the decision was made to suspend most of the benchmark studies pending redesign of the program.

Although the studies conducted under the BLM program will provide a wealth of scientific information on the continental shelf environment, it (as with many other recent large studies) has suffered from unrealistic expectations of the utility of descriptive data, an excessively narrow scope of study emphasis, restrictive methological stipulations and overly rigid contractual procurement.

Relatively little attention has been placed on understanding why various parameters are distributed the way they are, other than to perform correlation with coincidentally measured parameters. While the premise that changes witnessed after oil and gas development which can be attributed to development activities may be reasonable for petroleum hydrocarbons, for example, it is assuredly tenuous for many other parameters, especially biotic ones. For these, change following development can only be interpreted with knowledge of the natural factors and processes responsible for observed spatial and temporal variations. Furthermore, decision-makers need predictive information. Descriptions and correlative understanding of environmental parameters are of little predictive value. To meet these needs, more emphasis is clearly needed on experimental "fate and effects" studies.

Environmental research activities on the continental shelf have experienced a quantum increase in the last few years. As noted, many federal agencies are involved. Unfortunately there is too little formal coordination of federal research activities on the continental shelf at national, or even regional, levels. Since there are substantial overlaps in the information needs of the various agencies, it is obvious that both the agencies and the research community would benefit from the cooperative development of research objectives for continental shelf ecosystems.

THE CONTINENTAL SHELF ENVIRONMENT

The preceding parts of this paper are mainly prologue, for my objective is to contribute to a conceptual framework for impact evaluation on the continental shelf. At this point it is necessary to briefly discuss some important features of continental shelf ecosystems which should influence how we study them. I will approach this by initially making two very simple observations: (1) the continental shelf is different from both coastal and estuarine waters and the open ocean; and (2) the environmental characteristics of continental shelves vary widely.

Most marine biological knowledge is based on coastal and estuarine or open ocean organisms. The green waters of the continental shelf have historically been beyond the reach of brown water (coastal) oceanographers and something to travel through for blue water oceanographers. The continental shelf environment is in some respects inter-

Table 1. Summarization of Bureau of Land Management's Environmental Studies Program (National Research Council, 1977).

RECONNAISSANCE STUDIES

- Identification of unique biological assemblage, resources or physical environments which may be perturbed by OCS petroleum development activities

- Identification and quantification of natural hazards or conditions which jeopardize OCS exploratory or production activities

BENCHMARK STUDIES

Chemical Indices

High Molecular Weight Hydrocarbons in:

Benthic organisms
Sediments
Pelagic organisms
Dissolved in seawater
Particulate matter in seawater
Zooplanton

Low Molecular Weight Hydrocarbons in Water

Trace Metals in:

Benthic organisms
Sediments
Pelagic organisms
Particulate matter in seawater
Zooplankton

Biological Indices

Benthos (taxonomy and biomass)

Macroepifauna
Macroinfauna
Meiofauna
ATP - biomass
Demersal fishes
Microfauna (especially Foraminifera)

Water Column

Zooplankton
Neuston
Ichthyoplankton
Pelagic fishes
Bacteria
Phytoplankton

Histopathology

FATE AND EFFECTS STUDIES

Physical Processes

Lagrangian drift
Transport mechanisms
Physical alteration of petroleum (e.g. evaporation, dissolution, emulsification, photooxidation, etc.)
Surface and subsurface current patterns
Weather and wave observations
Hydrography

Biological Effects

Biological alteration of contaminants
Acute toxicity data
Chronic toxicity data
Sublethal physiologial effects
Potential bacteriological indicators of contamination
Biological accumulation and deposition of contaminants

Geological Processes

Suspended sediment (transmissometry, mineralogy, etc.)
Sediment-organism relationships

Chemical Processes

Biogenic sources vs. petroleum-derived hydrocarbons
Chemical characterization of petroleum
Speciation of trace metals

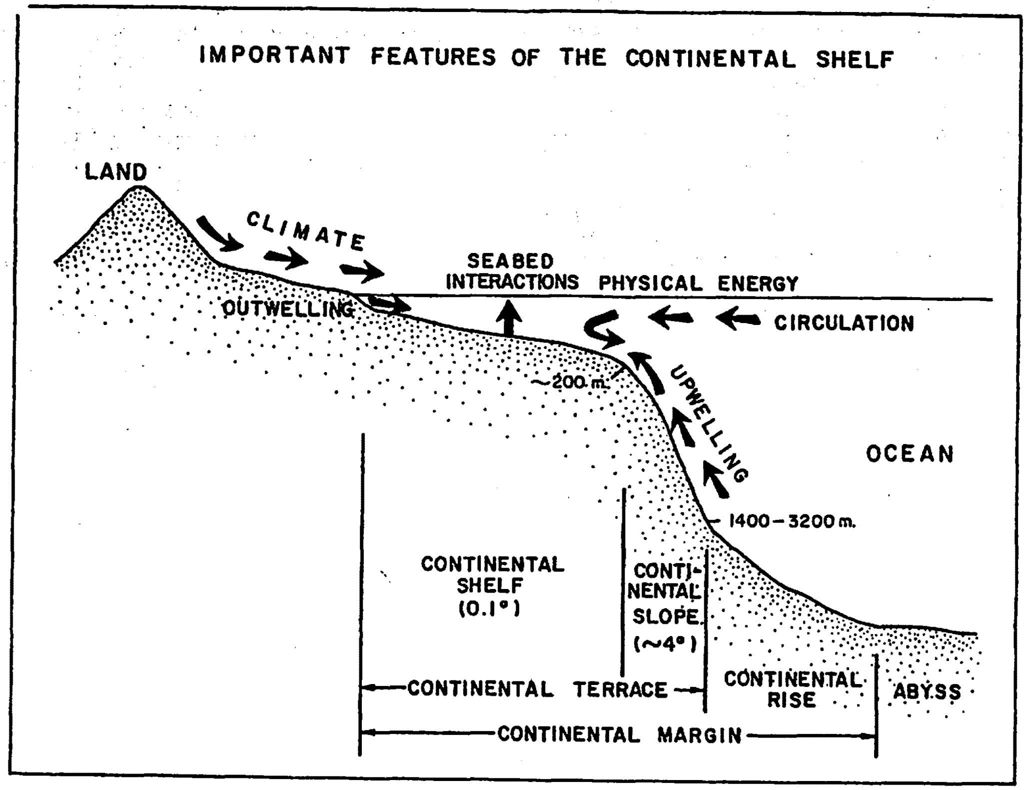

Figure 2. Important features of the continental shelf environment which distinguish it from coastal waters and the open ocean.

mediate between coastal and oceanic environments (Fig. 2). Like the coastal zone, the shelf may be considerably influenced by the climate and the material contributions (outwelling) of the land. On the other hand continental shelves are strongly influenced by oceanic circulation patterns and even by the deep ocean (upwelling or onwelling).

A feature distinguishing the coastal sea from the open ocean is the functional importance of the sea bed on the shelf. On the shelf the seabed supports a much greater portion of total productivity and is more important in the cycling of materials, including nutrients, than the open sea. Furthermore, there is much greater interaction between benthic and pelagic organisms on the shelf, with many benthic species having a pelagic phase of their life cycle and some pelagic species having a benthic phase. The continental shelf environment is further characterized by the dissipation of great amounts of physical energy from geostrophic and tidal currents and, especially, from waves.

These characteristics suggest we should approach the study of continental shelf ecology somewhat like estuarine ecologists, emphasizing interactions of components of the ecosystem (i.e., benthos-nekton-plankton), small scale phenomena and the importance of allochthonus inputs, but without the luxury of working with a discrete and relatively closed system such as an estuary. On the other hand, oceanographic approaches, emphasizing large scale processes and internal regulation, have also to be applied.

The diversity of the continental shelves of the United States should be obvious from even the simplified bathymetry indicated in Fig. 1. The shelves are physiographically different, ranging from the narrow, almost nonexistent shelf off California to the very broad shelves of the Atlantic and Gulf coasts, which have been produced by the Holocene transgression of the shoreline across a coastal plain. Physiography affects the relative ocean influence, the degree of recycling of materials and the sedimentology of the shelf. Narrow shelves are more greatly influenced by large scale oceanic conditions whereas broad shelves are more internally regulated. Temperature on the Atlantic shelf is greatly influenced by the continental climate while temperature on the Pacific Coast is governed by ocean water mass conditions. Outwelling from land is a major influence on some shelves and is insignificant on others. For example, the Mississippi River is a dominating influence on parts of the Louisiana shelf but the riverine inputs in the Middle Atlantic Coast are mostly trapped in large coastal plain estuaries.

The design of ecological studies and impact evaluations should take into account the important features of the particular environment under study. Standardized study designs and methods should be sufficiently flexible to allow such accommodation.

AN INTEGRATED APPROACH TO BIOLOGICAL IMPACT EVALUATION

As discussed earlier, previous attempts at biological impact evaluation on the continental shelf have suffered several shortcomings. The first two listed -- the inherent difficulty of studying large, open systems and the adequacy of support -- are to a large degree beyond the control of scientists. The last three -- unknown causes of natural variation, inefficient use of baselines and controls, and inability to cast impacts in a frame of reference of resources or ecosystem function -- are potentially solvable with appropriate scientific design. Overcoming these three stumbling blocks should be a paramount consideration in the design of baseline, monitoring and experimental effects studies.

I would like to propose here an integrated approach to biological impact evaluation which starts with baseline studies and incorporates predictive studies with appropriate monitoring. It emphasizes the necessity to dynamically describe and understand the causes of community structure and assess the role or importance of biotic components to ecosystem function and resources. The proposed scheme is iterative, under which impact evaluation programs would dynamically evolve as directed by feedback, rather than be planned in detail from the start. I will not attempt to prescribe subject-specific guidelines for the design and conduct of environmental assessments on the continental shelf. There have been many other attempts to produce such a compendium, notably an unpublished report by the NOAA Scientific and Technical Committee on Marine Environmental Assessment, and the reports of regional workshops convened for this purpose by BLM. Rather, I will focus attention on how the various phases of impact evaluation -- initial impact assessment, baseline studies, prediction studies, monitoring studies and final impact evaluation -- should interact as suggested in Figure 3.

Preliminary impact assessment, of the before-the-fact type characteristic of Environmental Impact Statements begin with estimations of the nature and fate of associated pollutants or habitat modifications and then address the effects of the planned activity on the environment. This requires identification of biotic components which are most susceptible and some preliminary definition of the nature of susceptibility. Potential effects are then hypothetically cast in the large context of impacts on resources or ecosystem properties. These are the conclusions (i.e., regarding biotic susceptibility and its implications) which one seeks to refine by conducting environmental impact evaluations, for it is hoped that these conclusions will affect decisions concerning the conduct of human activities in the environment.

Preliminary impact assessments should of course affect the design of baseline, predictive and monitoring studies. The results of these studies in turn serve to refine the impact assessments. This feedback process should be regularly iterative throughout the course of the studies. That is to say, products of the studies should be continuously used to redefine susceptibility and the redefinition should effect a redirection of studies. While the wisdom of such an approach seems obvious, in practice such regular feedback is often difficult because specifically written contracts or work statements bind the researcher to a set course.

"BASELINE STUDIES"

I will here use the term "baseline studies" broadly to include all those environmental studies which serve to describe, quantify or promote understanding of an ecosystem or its components as it exists before the planned activity. The first phase of baseline studies should involve both broad reconnaissance of the environment in question and collection of data which, with existing knowledge, can serve to provide a basic description of the environment. Such studies would include measurements and descriptions of a wide array of biotic and abiotic components. Broad brush, short-term descriptive studies are an especially valuable first step for the study of poorly known

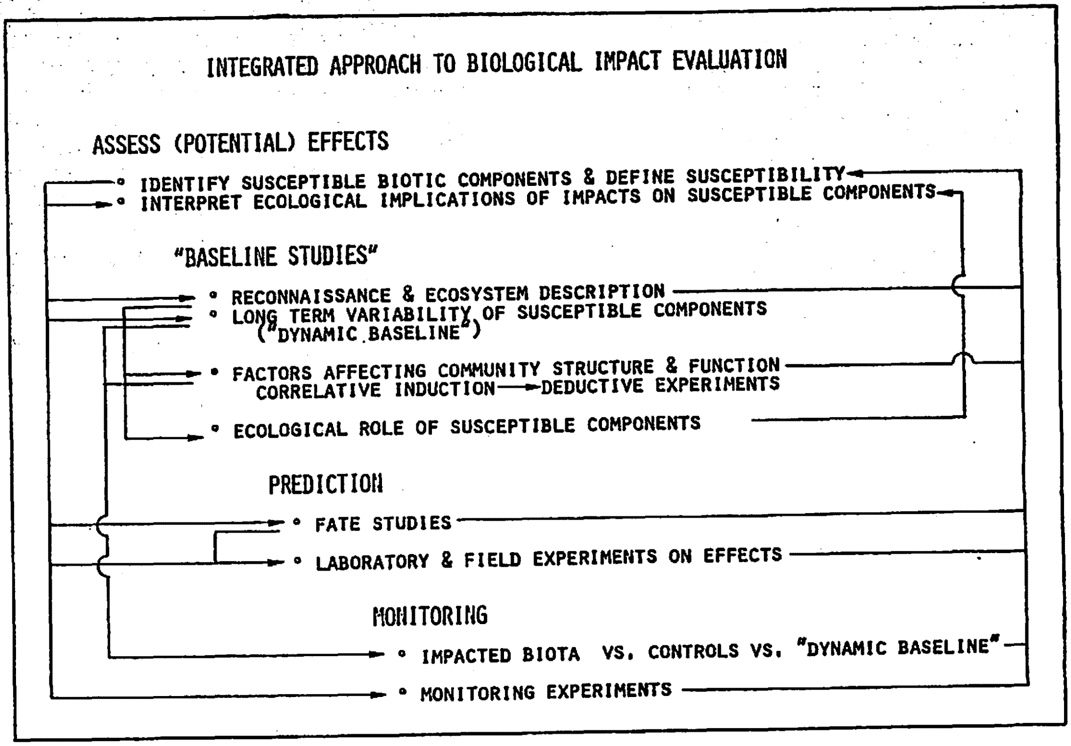

Figure 3. Schematic depiction of interactions suggested in an integrated biological impact evaluation program.

ecosystems such as most continental shelves. The results of preliminary reconnaissance should quickly be applied to redefining susceptibility, pointing out which biotic and abiotic components should be more intensively studied over longer periods.

Study of the long-term variability and dynamics of susceptible components should then begin. Design of these studies should be influenced by reconnaissance and descriptive studies, since it is presumptuous to assume that an efficacious sampling strategy can be blindly designed without a reasonably accurate environmental description. Long-term, intensive studies should be rigorously quantitative and the limits of variation should be described, resulting in a "dynamic baseline" against which changes during or after the impacting activity can be measured. However, the dilemma of the baseline is that no matter how confidently one can demonstrate change in populations, it is impossible, strictly by comparing before and after statistics, to prove cause. Furthermore, organisms being what they are, it would often not be surprising to find the population level of a given species to fall outside the limits witnessed over a long baseline sampling period. This points to the necessity of including in baseline studies, research on factors affecting populations and community structure and function in addition to direct statistical descriptions of biological parameters. To be in a position to unequivocally demonstrate impacts one needs to know the causes as well as the extent of natural variation.

Ecological factors can be partially understood through induction from convincing sets of correlations between environmental variables. To demonstrate causality one needs to experimentally test the hypotheses deduced on the basis of correlations or observations. Manipulative field experiments which are playing a central role in the development of ecology, may be especially useful in this regard. Investigators applying field experiments require substantial latitude in their approach, especially in such a difficult environment as the continental shelf. Experimental failure rates are high, but the payoff of successful experiments in terms of new information and robust understanding is great.

Some effort in baseline studies should also be devoted to determining the ecological role of susceptible biotic components. Earlier, examples were given in which impact to portions of the biota could be demonstrated, but the significance of these impacts to ecosystem health or resource values could not be shown (e.g., in the New York and Southern California Bights), so the effects were termed "insignificant." Considerable effort (and money) is spent in quantifying basic data and statistically testing the significance of effects on the biota, whereas the process of interpreting the meaning of observed effects is most often frightfully non-quantitative and subjective.

PREDICTION STUDIES

The evolving definition of susceptibility as redefined by the early results of baseline studies will act to focus attention on relevant studies concerning the fate and effects of pollutants of habitat modifications. Actually, some "fate" studies, (e.g., general circulation studies), should start in the beginning of the baseline studies program. They may then serve to quickly redefine susceptibility and thus influence the direction of other baseline studies.

Surveys of pollutant such as trace metals and petroleum hydrocarbons in the environment are heavily emphasized in most baseline and monitoring studies. The problems of interpretation of the biological implications of contaminant levels (aside from the omnipresent analytical problems) are in understanding the fate of the materials (e.g., bioavailability and biodegradation) and their effects. There often results an imbalance between contamination surveys and biological interpretation.

More experimental work is clearly needed to assess the effects of pollutants on continental shelf species. However, these studies need to be closely integrated with ecological studies in the field, preferably through the iterative process of redefinition of susceptibility discussed above. Effects studies, if they are to be applicable, must be relevant to the continental shelf environment, using indigenous biota under near-realistic environmental conditions. In this regard, field experiments may be most appropriate, especially for some biotic components, e.g., the benthos. Furthermore, studies on sublethal effects should be directed at physiological or behavioral processes which affect the survival and maintenance of populations. Finally, the predictive limitations of experimental bioassays must be recognized. Used intelligently they can serve to delimit the relative effects of various pollutants, provide an understanding of effects witnessed in the field and indicate that effects are likely if a certain concentration of a contaminant occurs in nature. The experimental null hypothesis that effects do not occur below given toxic levels cannot be extrapolated to the field because it is specific to the individuals on which the test was performed and the test conditions.

MONITORING

Dynamic baseline data are useful in monitoring, both because they serve to redefine susceptibility and thus influence monitoring strategies and because they can be directly compared with monitoring data. The success of monitoring, however, depends on the choice of suitable controls. Finding good control habitats is difficult, partially because no two places are exactly alike and partially because it is frequently difficult to determine if the habitat selected for a control is beyond the effect of the impacting activity. Baseline characterizations can serve the useful purpose of delimiting potential control habitats. Fate and effects studies should help define the extent of potential impact. As in the case of baseline sampling, parallel experimental studies are helpful in interpreting the results of sampling and observations involved in monitoring.

The self-modifying integrated approach outlined here ideally will produce (1) an understanding gained in dynamic baseline studies of the causes of natural population variability, rather than only statistics describing this variability; and (2) an understanding of the effects of pollutants or habitat alterations based on ecologically pertinent experiments. Armed with such an understanding, investigators are more likely to detect impacts and evaluate their importance to the ecosystem and to resources exploitable by man, than with the mainly descriptive and poorly integrated approaches currently employed.

RESEARCH MANAGEMENT

A truly integrated approach to impact evaluation may be incompatible with current research management procedures. Federal sponsors of applied research have moved to the RFP and specifically-worded contract methods of research procurement. This has been due to the necessity of assuring performance standards, increased competition for research dollars and federal procurement policies. On the other hand, the traditional approach of research grants without obliged performance is clearly too loose to assure timely attainment of impact evaluation goals. Some middle ground is needed, so that progress is obliged but there is flexibility to modify research methods and strategies in response to changing perceptions of susceptibility.

Similarly, although the desire to insure minimum performance standards by specifically outlining research stategies and methods is understandable, such specificity can stifle rather than enhance ecological understanding. As Hedgpeth (1973) (irreverently) puts it: "the danger of legislating a current fashion in ecology, or one dimly remembered by an administrator who perhaps did not do so well in the course, is obvious to anyone, or should be." What will be required is a balance of responsibility for the design and conduct of research between the researcher and the research manager.

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