ABSTRACT

The U.S. Department of the Interior Minerals Management Service Pacific OCS Region began a monitoring program conducted through the Environmental Studies Program in 1984 for the long-term effects of oil and gas production platforms on biological communities. Phase I, a broad scale geographic reconnaissance and baseline survey, has been conducted for the Santa Maria Basin offshore California where oil and gas production will begin in the near future. Phase II is beginning and will focus on time series measurements of a wide variety of biological, physical and chemical parameters at platform sites and comparison sites. Emphasis will be given to detecting changes in benthic communities and sublethal changes in life history parameters.

Introduction

The effect of oil and gas activities on the nation's outer continental shelf has been the subject of interest and concern by scientists and the public ever since the oil spill in the Santa Barbara Channel off California in 1969. Although evidence from that accident and other oil spills has demonstrated no lasting damage to the marine environment (Straughan, 1971; Cimberg, Mann, Straughan 1973), there still exists concern about the long-term effects of the activities associated with oil and gas production platforms. These concerns are now about one decade old and grew out of earlier and now mostly dispersed fears about the adverse effects of short-term and smaller scale impacts from oil and gas exploratory activities. A body of literature exists which substantially treats exploration impacts and short-term effects of oil operations such as routine operational discharges into the ocean. Two major synopses of a large part of this literature may be found in two recent publications by the National Research Council: Drilling Discharges in the Marine Environment (NRC, 1983) and Oil in the Sea Impacts, Fates, and Effects (NRC, 1985). The research and data regarding long-term or chronic impacts from oil and gas production activities is much less voluminous than the base for short-term or acute impacts and has only recently begun to be addressed in the Pacific Ocean in Southern and Central California.

The approach that has generally been taken in measuring long-term impacts or changes in the marine environment has been a monitoring protocol of some sort as opposed to manipulative or controlled experimental designs. The concept of monitoring is broad in technical scale, spatial scale, temporal scale as well as in the underlying uses of the monitoring results. Two examples of monitoring which span extremes of scale are the CalCOFI program in the California offshore spanning the area from Mexico to Northern California and operating over decades (California Cooperative Oceanic Fisheries Investigations, 1985) and much smaller localized monitoring programs being conducted for specific municipal sewage outfall locations with monthly or weekly sampling periods (Southern California Coastal Water Research Project, 1982). These examples also point up the differences in underlying use of monitoring; first as a tool to measure and ultimately understand variation and processes affecting the marine environment and marine resources and second as a tool for regulatory compliance with less emphasis if any on designs oriented to measuring and understanding driving forces in the ocean. Monitoring as it has been applied to oil and gas operations has primarily been aimed at measuring the extent in changes in marine chemistry and biology in local exploratory operations such as the Mid Atlantic Shelf Study (EGG, 1982) or in larger area studies such as the Offshore Ecology Investigation (Ward, Bender,

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Reish, 1979) and Buccaneer Gas and Oil Field Study (Middle ditch, 1981). These and other monitoring studies have emphasized more the detection of variation and understanding of processes rather than the strict compliance monitoring approach.

MMS Monitoring Studies

Two studies which have been funded by the Department of the Interior Minerals Management Service and which have built upon the experiences gained in other programs are the Georges Bank Monitoring Program and the Santa Maria Basin Monitoring Program. Both studies are integral and major efforts of the Environmental Studies Program of the agency as required by the OCS Lands Act as Amended (1978). These two multidisciplinary studies reflect the focus of the Program on what MMS believes to be the most probable environment for detecting long-term or subtle impacts from oil and gas production: the benthic environment around large-scale production platforms. The study on the Georges Bank (Battelle, 1985) is now essentially completed and because no commercially recoverable oil was discovered in the region, testing of the hypotheses about long-term effects is not possible. In the Pacific Region, however, the area around Point Conception, the Santa Maria Basin (geological basin) (see Figure 1) has demonstrated potential for production and the first phase of a long-term monitoring program was completed early in 1986.

The Santa Maria Basin Monitoring Study actually began in 1982 with a workshop held to review monitoring methodologies. Recommendations were received and a design for the long-term program was developed based upon these recommendations and additional review of previous and active programs in other agencies and other parts of the country including municipal sewage discharge monitoring programs. A three phase program was planned with the first phase a broad scale reconnaissance of the Santa Maria Basin and Western Santa Barbara Channel, areas with known hydrocarbon reserves and future potential for production. The first phase is now complete and the second phase is starting. The second phase consists of time series measurements of chemistry, geology, physical oceanography, and biology around oil and gas platforms in two different benthic habitats. One habitat is a soft bottom habitat of mostly sandy silt sediments and the other is a hard bottom habitat with exposed rock outcrops of varying relief from a few to ten meters above the surrounding sediment plane. A seasonal design of pre-impact—post impact sampling at experimental and comparison stations has been adopted. Phase two will last five years and be followed by a third phase in which sampling intensity is expected to be reduced depending upon the experience gained during the more intensive sampling of phase two. Both dose-response and pre-post impact designs have been incorporated into the basis for the experimental protocol (sensu Green's optimal experimental design (Green, 1979)) to test various hypotheses regarding impacts in time and space. In situ field experiments and laboratory investigations are planned to examine mechanisms of sediment dynamics and trace metal kinetions.
Phase I Reconnaissance

The first phase of the program has already yielded information of interest and value to MMS and the scientific community involved in nearshore marine ecology in the Eastern Pacific ocean. The sampling grid for the reconnaissance (Figure 2) included 107 stations and 142 box cores (0.1 square meter) in soft bottom habitats and 15 stations with 23 transects of varied length by manned submersible in hard bottom habitats (Figure 3). Depths of sampling ranged from 165 to 3000 feet for box cores and 180 to 790 feet for the submersible transects. Sediment samples from the box cores were analyzed for barium, chromium, total organic carbon, hydrocarbons (aliphatic, aromatic, and polar fractions), sediment grain size, sediment cohesiveness, and biology (1.0 and 0.5 mm screen size). Data and samples form the hard bottom survey consisted of 35 mm color photographs, color video, rock samples for epifaunal analysis in the laboratory, and voucher specimens of larger taxa for confirmation and verification of observer and photographic records.

The data analyses (ordination, cluster and discriminant techniques) were aimed at discovering patterns in the biotic and the abiotic data and also towards elucidating relationships among biological and physical factors (multiple regression). Of particular interest was identifying species assemblages in the region and assessing any spatial trends or patterns in biotic or abiotic data which could aid in designing the experimental program of impact and comparison sites.

RESULTS

Results of the sedimentological analyses indicated two main sediment types in the region and considerable potential reworking or dynamic processes operating leading to mixed sediments. Sediments appear to be derived from both pelagic productivity and subsequent sedimentation (area is well known as a persistent upwelling center. OPUS, 1982) and from terrigenous inputs from local rivers and longshore transport from more northerly areas. The patchy distribution of olive green mud derived from organic sedimentation with the brown to tan muds and sands derived from other sources suggests the ocean bottom in the area is subject to vigorous wave activity and current forces on the shelf and slope.

Trace Metals

Sediment trace metal measurements were made at all soft bottom stations. Values for sediment barium ranged from 162 ug/g to 1,180 ug/g with a mean of 709 ug/g & 163 ug/g. Generally stations in the northern part of the sampled region had barium values form 500 ug/g to 840 ug/g while the area south of Point Conception had some of the higher measured values between 870 ug/g and 1,180 ug/g at nearshore stations and the southeast portion of the Santa Barbara Channel. Correlation between sediment barium level and total organic carbon was low (<0.5) while the relatively high levels of barium in the Point Conception region corresponded closely with areas of previous exploratory drilling activity. The higher barium levels in the Santa Barbara Channel are probably due to transport processes within the Channel which has experienced years of oil and gas activity. Isolated high level barium stations in the Santa Maria Basin are probably the result of deposition of materials transported by the Santa Ynez River.
Chromium levels in the sediments ranged from 66 ug/g to 425 ug/g with a mean of 120 ug/g. The highest values of chromium observed were at stations where chromite minerals from onshore deposits are likely to be deposited. These results are consistent with the low correlation found between chromium and most of the measured environmental parameters except the larger sediment fractions.

Hydrocarbons

Total hydrocarbon concentrations in the sediments ranged from 14 ug/g dry wt. to 237 ug/g dry wt. Hydrocarbons were generally the lowest north of Point Arguello (40 to 100 ug/g dry wt.), next highest in the area between Pt. Arguello and Point Conception (70 to 170 ug/g dry wt.), and highest south of Point Conception (36 to 237 ug/g dry wt.). In the Santa Barbara Channel the hydrocarbon values ranged from 180 to 230 ug/g dry wt. The pattern for the aromatic fraction of hydrocarbons was similar to that for the total hydrocarbons. Total alkanes and aliphatics did not correspond consistently with the concentrations of total hydrocarbons suggesting that biogenically derived alkanes (which were not differentiated from those of petrogenic sources in these analyses) from plankton are spatially and temporally variable in their distribution in the region. The various ratios of hydrocarbon components indicate petroleum derived hydrocarbons are distributed throughout the region of the Santa Maria Basin and the Western Santa Barbara Channel with the higher levels in the areas nearest population centers and active oil and gas production.

Biology

Benthic infauna in the study were represented by 996 taxa in the box core samples. Twenty three percent of these were new species or similar to but not the same as described species. In addition to the box cores collected during this study, samples collected during the BLM sponsored baseline studies in the late 1970's (Science Applications Incorporated, 1978) were also reanalyzed for their taxa. Roughly 40 percent of the taxa in the earlier surveys in the Santa Barbara Channel (none were taken in the Santa Maria Basin in the previous efforts) were not encountered in the present reconnaissance survey. The order of numerical dominance of species in both surveys was annelid worms (primarily polychaetes), Crustacea, Mollusca, Cnidaria, and Echinodermata. These phyla comprised 96 percent of the reconnaissance taxa and 92 percent of the baseline taxa. Six major species groups or assemblages were determined in the present survey following clustering analyses of the data: Shelf Site Group (< 400 feet depth); Deep Site Group (lower slope, canyon, sea valley at Santa Lucia Bank, and Arguello Submarine Canyon); 1300 foot Site Group (a mid-slope assemblage); 660/990 foot Site Group (two partly distinct assemblages on the upper and mid slope); "Hesperone" Site Group (a small group of sites characterized by the scale worm Hesperone laevis); Basin Slope Site Group (primarily on the slopes in the Santa Barbara Channel). Depth was a dominant factor in replacement of assemblages along gradients while geography was usually only a minor factor. An exception to geography being...
a minor analyses were sites where local geomorphology dominated such as at submarine canyons. The number of species found in any single sample ranged from 0 to 110 for the 1.0 mm screen and from 0 to 143 for the 0.5 mm screen. The mean number of species per sample declined sharply between the shelf and upper slope, remained relatively constant between 660 and 1840 feet, and then increased on the lower slope and Santa Lucia Valley (deep) sites. The number of individual specimens per sample ranged from 5 to 437 in the 1.0 mm screen and from 9 to 1,137 in the 0.5 mm screen. The mean number of individuals per sample varied with depth in a pattern similar to that for the mean number of species per sample. The results of ordination analyses indicate that the biological groups mentioned above correlate only with depth to any significant degree ($R^2 = 0.72$). Total organic carbon correlated second in abiotic factors with the species groups but the correlation was poor as were the correlations for all other factors measured. These results suggest that abiotic factors which may act to structure the biological communities in the region were not measured or that biological interactions rather than physical or chemical factors are dominant in structuring the communities.

Hard Bottom Benthos

Of the 23 transects of "hard bottom" habitat surveyed during the reconnaissance only 17 showed at least 50 percent exposed rock substrate and only five showed greater than 90 percent exposed rock for the length of the transects. Extensive sediment cover (a few to 10 cm estimated) was observed in the majority of each transect area and over the range of depths and bottom types (outcrop, boulder, cobble, etc.) observed. 117 taxa were identified from photographs and by observers in the submersible. Echinodermata (33 taxa) and Coelenterata (31 taxa) dominated followed by Mollusca (22 taxa), Arthropoda (16 taxa), Porifera (16 taxa), Annelida (4 taxa), and Bryozoans (3 taxa). Three general species assemblages were identified associated with the degree of relief of rock substrate; generalists, high/medium relief; and medium/low relief. In contrast to the soft bottom assemblages, depth did not correlate as a major factor with changes in species groups. Geographic location was only a minor correlative factor in species groups distribution as was the case for the soft bottom organisms.

Discussion

The first phase of the monitoring program in the Santa Maria Basin has demonstrated that the area is a dynamic one which will involve careful measurement and interpretation of the sedimentary processes and physical oceanography in order to fully interpret any changes in biology observed around oil and gas platforms. The species endemism observed in the intertidal and shallow subtidal communities and species range limits which are responsible for the area being identified as the transition zone between the northern Oregonian Province and the southern California Province biogeographically, appear at this preliminary stage not to be a strong factor in the deeper shelf and slope in the region. This simplifies the selection of comparison stations for the long-term program. Measured trace metals and hydrocarbons in the region indicate that the area is not as pristine as previously expected but levels still are low enough to insure signals produced by oil and gas operations can be detected in community analyses and chemistry. Phase two of the program will concentrate on a platform in the north of the reconnaissance area so as to minimize possible interference from previous contamination.

References


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