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ECOLOGICAL INVESTIGATIONS OF PETROLEUM PRODUCTION PLATFORMS IN THE CENTRAL GULF OF MEXICO

VOLUME III—EXECUTIVE SUMMARY

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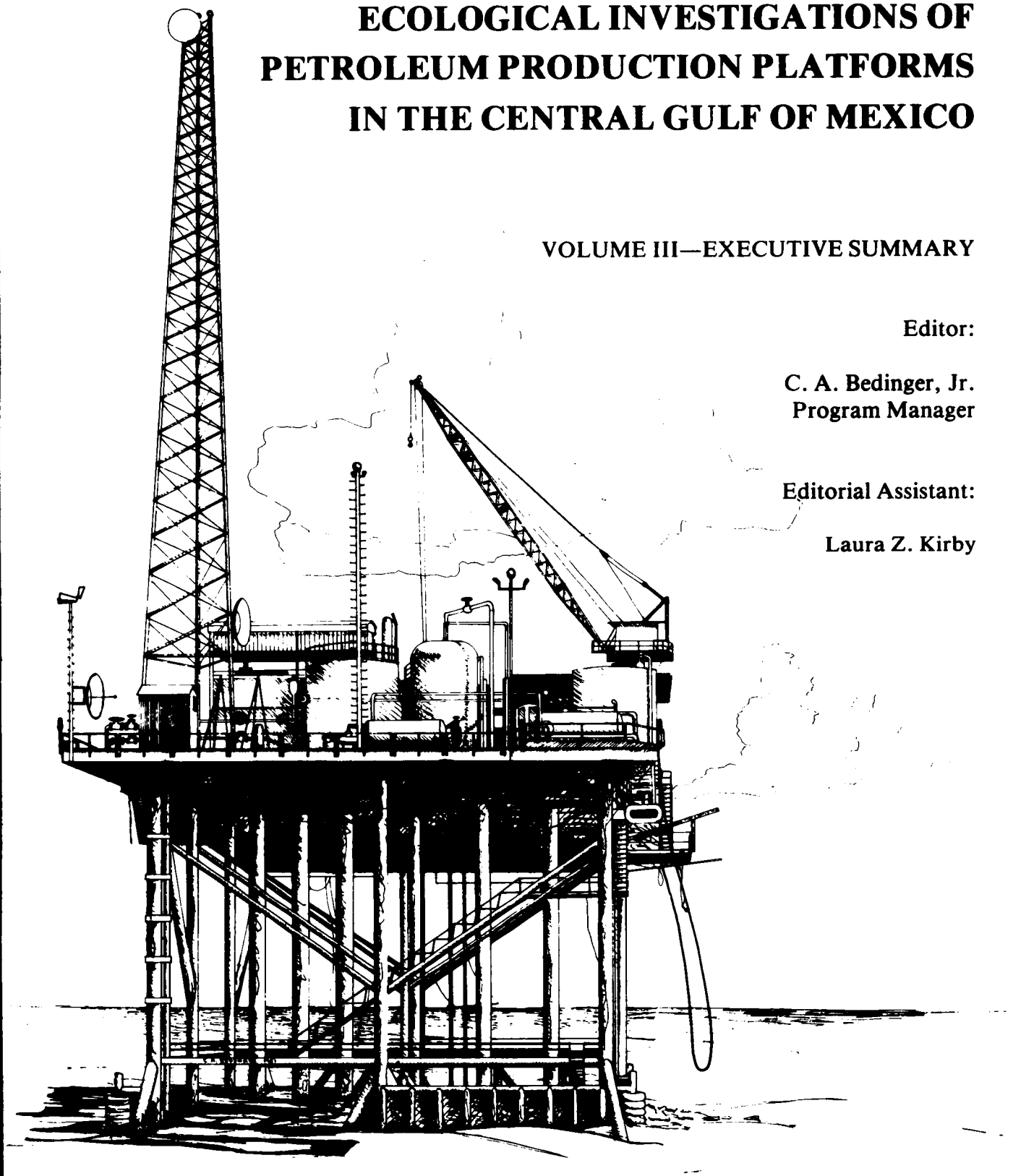

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ECOLOGICAL INVESTIGATIONS OF PETROLEUM PRODUCTION PLATFORMS IN THE CENTRAL GULF OF MEXICO

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In fulfillment of Contract
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by:

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San Antonio, Texas 78284

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  Part 2 —Sediment Physical Characterization
  Part 3 —Organic Chemical Analyses

2 VOLUME I —POLLUTANT FATE AND EFFECTS STUDIES
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VOLUME III—EXECUTIVE SUMMARY

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by

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I. INTRODUCTION

A. Purpose of the Executive Summary

This Executive Summary is written to provide better understanding of the conclusions stated in Volumes I and II of this report for the study Ecological Investigations of Petroleum Production Platforms in the Central Gulf of Mexico. It translates technical discussion into layman's terms and attempts to synthesize the biological and physical data and interpretations of the various Principal Investigators (PI's). The Program Manager has written this summary following intensive study of the entire report, and takes full responsibility for any statements made and/or misinterpretations of data or conclusions contained in Parts written by the numerous Principal Investigators. This summary is not intended to be entirely comprehensive; therefore, if further information is necessary, the reader should refer to the appropriate Part of Volume I, Pollutant Fate and Effects Studies, or to Volume II, The Artificial Reef Studies. Since this document is primarily intended for nontechnical readers, it is felt that those seeking technical information will benefit more from study of the individual Parts. They are as follows:

Volume I: Pollutant Fate and Effects Studies
Part 1—Background, Organization and Study Plan
2—Sediment Physical Characterization
3—Organic Chemical Analyses
4—Trace Metal Studies in Sediment and Fauna
5—Microbiology and Microbiological Processes
6—Benthic Biology
7—Normal Histology and Histopathology of Benthic Invertebrates and Platform-Associated Pelagic Fishes
8—Summary Data Set
Volume II: The Artificial Reef Studies

B. Reasons for the Central Gulf Platform Study

Under the laws governing offshore leasing and production of petroleum on the United States Outer Continental Shelf (OCS), the Bureau of Land Management (BLM), Department of the Interior, is responsible for the leasing of tracts for exploration and, consequently, has the charge to govern lease sales in the best interests of the country. The three mandated goals of the BLM are:

- to ensure orderly development of the marine mineral resources to meet the energy demands of the Nation
- to provide for protection of the environment concomitant with mineral resource development
- to provide for receipt of a fair market value for the leased mineral resources.

Under the second mandate, BLM has sponsored a series of studies to describe those environments which might be detrimentally affected by exploration and production. Further need to better understand the effects of long-term production leading to chronic, cumulative contamination predicated the present study of the most heavily developed offshore area in the world. This comprehensive assessment of physical, chemical, and biological features of the Louisiana OCS has attempted to show any effects from drilling fluids used in development of the area and from long-term cumulative petroleum discharges from platforms. Examination of the effects of such potential contaminants in a location that includes a wide range of available, developed, offshore habitats should make it possible to better regulate future leasing in undeveloped areas. It is not the intent of this study to answer all the questions about potential damage for all environments. Rather, it is to show where previous development has brought about problems and to point out those habitats and production techniques which need close monitoring or further study in a particular lease area.

C. Objectives of the Study

As part of BLM's program of investigation of petroleum and OCS ecology, several studies have shown the baseline conditions in prospective lease areas. The present study is the first comprehensive "fate and effects" study. The present information, when combined with benchmark data, will enable BLM to model the likelihood of problems occurring in future leasing. Drawing on previous work and needs for future leasing, the following stated objectives have been the focus of this work:

- Determination of the distribution and concentration of petroleum hydrocarbons, selected trace metals, and well drilling related substances in surficial sediments and tissues of commercially and/or ecologically important benthic and demersal species
- Examination of the microbial hydrocarbon degradation and nutrient cycling processes and related nutrient chemistry in surficial sediments
- Comparison of benthic communities, with emphasis on selected "indicators," in the immediate vicinity of platforms with those at control sites
- Examination of the distribution with depth in sediments of petroleum hydrocarbons, selected trace metals, and well drilling related substances (i.e. to provide some measure of persistence)
- Investigation of the biofouling communities and "artificial reef" effect associated with selected platforms representing a variety of production types and durations.

II. STUDY AREA AND DESIGN

A. The Louisiana Outer Continental Shelf

Several facts about the Louisiana OCS must be presented prior to discussion of this program. First, the shelf of the northern Gulf of Mexico is wide, up to 175 km, and gently sloping, with its predominant features the result of geological processes associated with very long-term deposition of sediments and salt along its rim. Such depositions have allowed much shifting of the original deeper layers due to the weight of subsequent sediments. The results are upthrusting salt domes and mud lumps which break through overlying fine-grained deposits and produce traps for petroleum in the creases between relatively permeable strata and impermeable zones. Because of the eons of favorable conditions for hydrocarbon genesis in the Gulf, these traps have developed deposits which are presently being exploited.

The Louisiana shelf is characterized by very fine-grained sediments in smooth deposits broken only irregularly by the mud lumps and domes associated with the underlying geological features described above. The source of the fine-grained material is the vast sediment load of the Mississippi River, which over geological time is the predominant contributing factor to the present bottom configuration. This is readily seen from the extent of the delta development both onshore and offshore, where it extends to the practical limits of the shelf. Such a high rate of sedimentation introduces potential problems in determination of contaminant loading because pollutants may simply be covered. Further, the high volume of the Mississippi in springtime causes significant areas of the nearshore OCS waters to be overlain with a turbid surface layer much lower in salinity than the underlying oceanic waters. The salinity differences lead to differences in specific gravity, and little mixing occurs. As a result, oxygen is depleted at the bottom and subsequently most bottom animals either undergo mass emigration or die. Some animals are less susceptible to low oxygen tensions than others, and some forms such as scavenging snails and certain nematodes actually increase under such conditions.

Another important aspect of Gulf coastal ecology is the periodic occurrence of cyclonic storms (hurricanes) and the subsequent effects of their passage. Depending on the size of the storm, sediments from the surface to a water depth of 100 m are churned up and redistributed. Physical features of the coastline are similarly disrupted. Relatively little comprehensive information on the damage to animals living in the nearshore waters is available; as shown in this study, even a small storm causes distinct disruption of normal populations.

B. The Study Area

The twenty platforms and four control sites visited during this program are contained in a roughly rectangular area lying west of the Mississippi Delta and extending from 5 km (3 miles) to 120 km (75 miles) offshore and about 320 km (200 miles) west (Fig. 1). Within this region depths of platforms studied range from 6 to 75 m and waters at the surface span the spectrum from low salinity, highly productive, estuarine in character to extremely clear and oceanic. Currents are extremely variable as a result of the complex combination of winds, river outflow, and deep oceanic intrusion from the south. Overall, there is a general trend for river outflow to split as it exits Southwest Pass with most of the flow extending directly into the Gulf in a southwesterly direction. The extent of this tongue into the Gulf is a direct result of the amount of river volume. The other major westward flow exits Southwest Pass and other distributaries, remains nearshore and flows north and west. This low salinity mixture of sediment laden river water and Gulf water is highly productive and rides over the high salinity oceanic water at the bottom for many kilometers. As stated previously and shown in this study, the result is a smothering of the bottom due to loss of oxygen in the deep layers and a subsequent emigration or death of the bottom fauna. The phenomenon has been described before; however, this study reveals that during periods of very high river flow the extent of damage can be extreme. The occurrence of such an oxygen depletion during the study year greatly detracted from the planned success of the program. The effects of extreme river outflow are shown in Fig. 2, taken from satellite imagery of the eastern half of the study area during Cruise I, May 1978.

An important feature of the environment produced by the complex pattern of currents in the study area is the area of apparent upwelling and intrusion of high salinity, deep oceanic waters just west of the Mississippi Delta. This heightens the disjuncture between estuarine conditions at the surface and deeper oceanic conditions at those study sites under the influence of this water. Some platforms within a relatively short distance of each other thus differ greatly in attached fauna and fish residents according to how much they are influenced by oceanic or river water. The contaminant picture might also be expected to be quite different at these sites.

In general, the west and southwestward flow of river water allows gradual diminution of sedimentation from east to west in the study area. Since the Mississippi is known to carry a large burden of contaminants, including hydrocarbons of all types, it would be expected that deposition of pollutants would also decrease in a westerly direction.

Hydrocarbon production in the area includes natural gas, distillate fractions, and moderate weight crude, plus the associated formation brine. Any platform may produce any or all of these, in varying amounts. Thus, study platforms have potential for widely differing pollution levels.

Because of the wide range of variables offshore Louisiana, the spectrum of production platform environments produced is broad. This study has attempted to include them all, from nearshore to deep, from highly contaminated to clean.

C. Program Design

The study plan was rigorously designed by BLM so that site selection, field sampling, sample analyses, and data synthesis could be used to answer specific questions within a short time span. These are briefly discussed below.

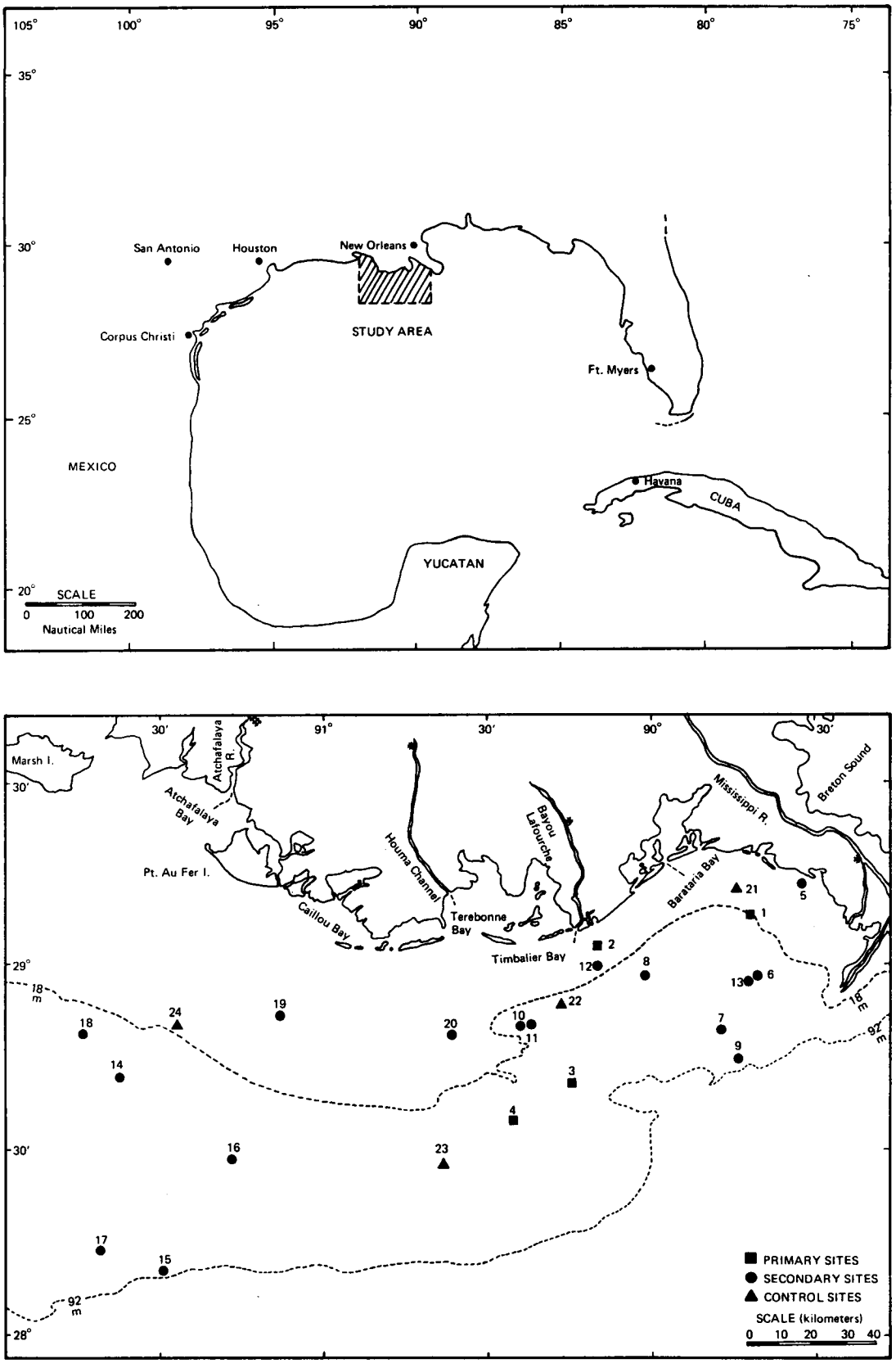

FIG. 1. Maps of the study area—(Top) Location of study area (Bottom) Study area showing sampling sites.

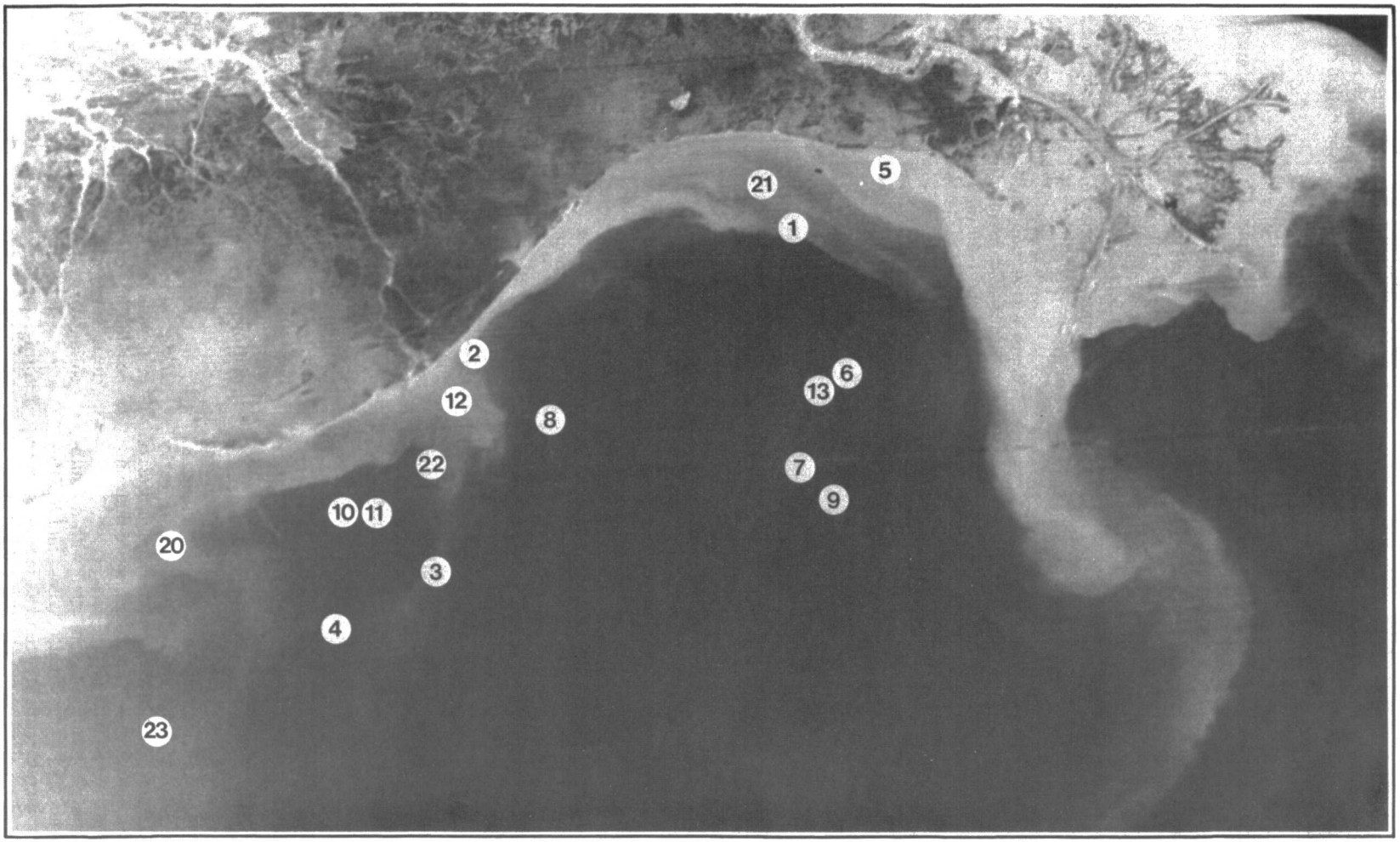

FIG. 2. The eastern half of the study area as seen by landsat imagery 5 May 1978, during Cruise I.

1. Sampling Seasons

Weather in the northern Gulf is dominated by two sets of wind conditions. In spring strong southerly inflows produce windy conditions, turbulent waters, and rapidly warming conditions on the OCS. In summer waters are calm and except for the occurrence of intermittent cyclonic storms, very hospitable. With the onset of fall "northers" conditions change to those characteristic of fall and winter. Thus, climate in the area is really divisible into three seasons. The present program was designed to sample in each: April-May, 1978, August-September, 1978, and January, 1979, Cruises I, II and III, respectively.

2. Sampling Locations

Four platforms (P1-4) were selected as primary sampling locations and were visited in each of three seasons. They were complemented by four control sites (C21-24) selected to be as far away from production as practicable yet with similar environments. Sixteen secondary platforms (S5-20) were sampled during the late summer season. It was necessary during the course of the study to change some locations to avoid drilling operations in order that the study reflect cumulative effects and not actual drilling influences on the environment.

It is well known that platforms produce effects in the immediate vicinity of the structure; therefore, this program was designed to sample at some distances from platforms in order to show any long-term buildup of contaminants in the sediments and whether these had found their way into the food web. At the four primary platforms, transects were established along the four points of the compass and sampling stations located at 100, 500, 1000, and 2000 m from the platform. Secondary platforms were sampled only on a north transect. Due to satellite drilling, pipelines and other underwater obstructions, it was necessary in some cases to modify this idealized grid and still take samples near the desired site. Locations were plotted and analyzed according to actual distances from potential sources of contaminants. Industry cooperation contributed to the knowledge of pipelines and other obstructions away from study platforms. Precision electronic navigation aids were used to allow subsequent repositioning on each preplotted sampling location.

At each sampling location within the platform sampling grid, and at each control site, samples were taken for one or more parameters. Collections for one or more purposes were made at every location.

3. Methods

Program elements were subcontracted and executed in a discipline or supportive task manner. Each Part of the report contains a complete technical discussion of methods and materials used. No extensive discussion of methods is given here, but the following points provide basic information about techniques in order that the discussion of results be more easily understood. Some Parts present interdisciplinary data syntheses and results may be discussed more than once in this summary for sake of clarity.

Samples for study were collected with a Smith-McIntyre grab, and by trawling, angling, and SCUBA diving. Considerable quality control measures were incorporated throughout the study to avoid sample contamination and to insure uniform sample collection.

a. Hydrographic Measurements

Each site was measured by standard hydrographic techniques, including salinity, temperature, dissolved oxygen, light transmission, current direction and speed, and sea state. These data were used in both statistical evaluation and for explanation of unusual findings in the data.

b. Geological Analyses

Samples for geological analyses included a subcore from every Smith-McIntyre grab taken. These cores were analyzed for grain size distribution so that subsequent correlations with other results could take into account the variability in potential for contamination or population differences brought about by different sediment types. Other sediment analyses included examination of clay minerals at selected locations for presence of drilling mud minerals.

A study of surface sediments to a 50-cm depth was attempted in an effort to date layering and subsequent chronological ordering of contaminants back to the 1920 time period. This lead 210 dating of "downcore" samples was to be related to both metals and hydrocarbons at various depths and ages. Results of dating and contaminant analyses indicated that sediments to the depths tested were thoroughly mixed and no chronology of contamination could be established.

c. Hydrocarbons

Gas chromatographic (GC) determination was the standard method used to indicate presence of hydrocarbons, and GC/mass spectrography was used for confirmation of contaminants in water, sediments, and fauna. Locations for physical samples and organisms corresponded with those for trace metals. Correlation analyses for hydrocarbons and trace metals as well as other physical factors was done in an effort to determine interactions. A number of pollution indicating hydrocarbons (alkylated aromatic compounds), in addition to normal petroleum derivatives, were found.

d. Trace Metals

Trace metal studies made use of atomic absorption spectrometry (AAS) and neutron activation analysis (NAA) to determine occurrence of nine metals in the study area. Samples were taken from both sediments and biota in an effort to determine contamination at a site, concentrations at varying distances from the structure, and whether trace metals had come from drilling, production of oil, spills, or from the structure itself. As in the case for hydrocarbons, significant data manipulation was done to determine any interaction with other abiotic factors and the organisms around a platform.

e. Biological Studies

Biological studies were performed to determine whether production has affected the species composition of bottom dwelling forms such as worms (meiofauna), clams (macroinfauna), and crabs (macroepifauna); to characterize the microbial populations and processes of the sediments, and to characterize platform-associated fauna (taxonomy, biomass, histopathology), including both attached fouling communities and fishes. Studies of the artificial reef fauna and

flora have also included classical descriptions of fouling and fish communities. These studies have considerably expanded our understanding of the biota of the Louisiana continental shelf.

III. RESULTS

All of the results from this study cannot be given in a document of this size. Also, many of the findings are not directly related to stated objectives. Therefore, the topics discussed are those selected by the Program Manager as important in addressing program goals. All pertinent results are summarized, but no extraneous findings are included.

A. Oceanography and Meteorology

The results from a limited number of hydrographic determinations give a picture of the area much as was expected. The Mississippi River exerts an extraordinary influence over all of the shoreward half of the area and is significant in sedimentation processes affecting the whole Louisiana OCS. This influence was especially important during 1978 because of extreme flooding and runoff. This apparently led to an especially widespread occurrence of lowered dissolved oxygen affecting nearshore bottom environments, which resulted in death or emigration of much of the fauna. The occurrence of low oxygen and depleted bottom faunas was documented up to 45 km (28 mi) offshore (Control Site 24) and in water depths up to 27 m (Secondary Platform 8). Further, literature and personal communications with various researchers in the area indicates that the "dead bottoms" extended west to south of Calcasieu, Louisiana, or over 300 km from the main distributaries of the Mississippi River. Therefore, during the spring and late summer cruises in this study, significant portions of the study area were under natural stress at the bottom; this precluded taking of enough bottom fauna for the program planned. Figure 3 shows the area documented to have "dead bottoms" during the summer cruise. (The apparent discontinuity around S19 is not adequately descriptive. The platform is on Ship Shoal and therefore elevated somewhat from the surrounding bottoms; it lies in oxygenated waters. However, waters off the shoal were oxygen depleted.)

Observations of water clarity, currents, salinity, and other physical factors indicate that there is considerable intrusion of oceanic waters just west of the delta. As a result, the general trend for currents to sweep north and west along the coast causes a virtual division between a nearshore grouping of study sites (with high river influence) and further offshore sites (with significantly diminished impacts); this is readily seen in Figure 2. Similarly, the farther west one goes, the more both hydrologic and pollution impacts from the river impacts diminish. Overall, this disjuncture between nearshore and oceanic sites is seen in differences in sediments, contaminants, bottom fauna, and platform-associated biota.

Occurrence of a cyclonic storm, Tropical Storm *Debra*, at the end of August, 1978 afforded an unexpected opportunity to learn of the significance of such an event. *Debra* was neither very large nor strong; yet after her passage, bottoms which had previously lost most of their populations started receiving immediate immigration of fauna such as shrimp and crabs. The actual depth or extent of sediment mixing due to this storm was not determined; but based on observations of before-and-after conditions, it is reasonable to assume complete mixing of surface sediments to the depths sampled (at least 5 cm) at all of the shoreward sites (approximately 50 m). Weather records show that 20 hurricane strength storms have hit the Louisiana coast since 1899. This frequency of one every four years does not take into account the numerous minor storms such as *Debra*. It is apparent that storms frequently disturb the bottom sediments over much of the area and where summer stratification and oxygen depletion occur, help to restore healthy bottom water conditions.

B. Geology

Geological studies for this program consisted primarily of sediment grain size determinations for every bottom grab taken. The size of particles in the sediment is extremely important to both the capacity of the sediments to hold contaminants and to the kinds of organisms that live at a specific site. In general, the finer the grain size the greater the capacity for pollutant holding; however, this does not necessarily mean a greater availability of pollutants to the organisms therein. Overall, sediments of the study area are dominated by silts and clays from land origin which give way to coarser sands only under special conditions such as at residual sandbars or other nearshore areas which have received significant nearby riverine outflow in the recent geological past. The primary use of this geological data has been in interpretation of other information to show which study sites appear to have been impacted by contaminants.

Studies of clay minerals were done at selected stations in order to determine if barite, typical of drilling fluids, was present. Because this program was directed toward regional influences of production activities, these samples were taken no closer than 500 m from a platform. In no instance was evidence of drilling fluid minerals such as barite and sodium montmorillonite found at a distance of 500 m. Readers should note that this study avoided active drilling sites and that significant redistribution of bottom sediments within a relatively brief time has apparently occurred. Therefore, it appears that the dynamics of the study area preclude detection of long-term accumulation, if it occurs.

The attempt to core strata to a depth of the 1920 horizon, which is prior to any drilling activities, was unsuccessful. Implications are that extensive sediment mixing and redistribution and rapid sedimentation rates on the Louisiana OCS preclude layering of hydrocarbon and trace metal contamination at depths down to 50 cm below the mud line.

C. Hydrocarbons and Organic Chemistry

Determination of organic contamination in the region around study platforms included these analyses: quantity of low molecular weight hydrocarbons (LMW-HC) in the water column; total organic carbon (TOC) and high molecular weight hydrocarbons (HMW-HC) in sediments; and HMW-HC in organisms at and around platforms.

1. Low Molecular Weight Hydrocarbons in Seawater

Organic chemistry of the water column reveals that LMW-HC occur in a wide range of concentrations

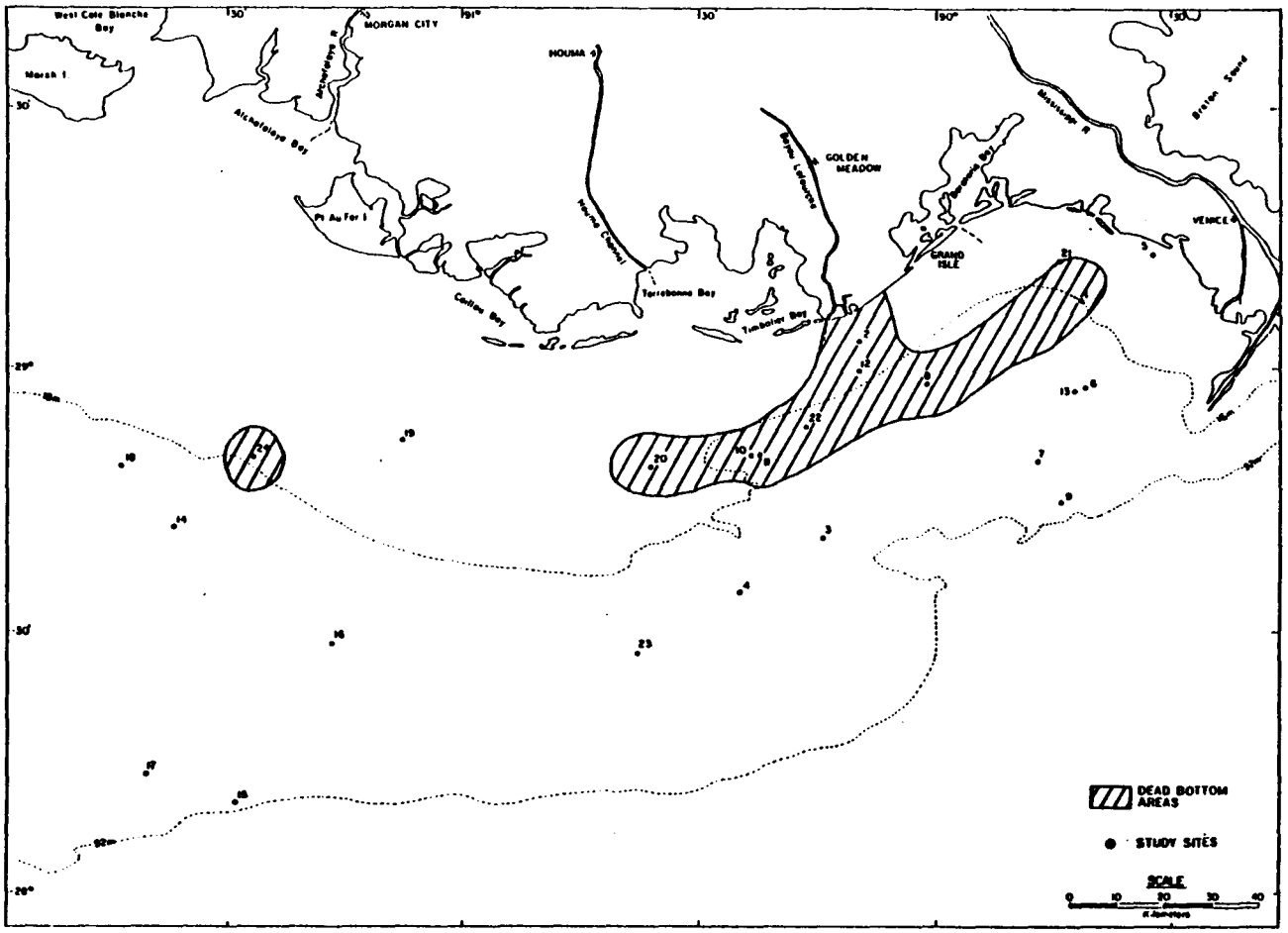

FIG. 3. Areas with dead bottoms as evidenced by trawl catches and hydrographic data taken at platforms during Cruise II, August/September, 1978.

with upper levels extremely high and apparently associated with natural submarine seepage, leaks of natural gas from platforms and pipelines, and normal underwater venting of excess gas during oil production. Analyses of LMW-HC in seawater were limited and the data insufficient to describe long-term levels of contamination. The highest levels of methane and saturated[1] hydrocarbons of two to four carbon length were in samples taken immediately after Tropical Storm *Debra* in areas of obvious pipeline leaks (short-term phenomena). It is apparent that during normal operations, levels of LMW-HC are significantly higher offshore Louisiana than in any other documented region due to chronic minor leaks and natural sources, and that during accidental releases, the high levels occur over a wide area. Biological activities may be important in releasing some of the LMW-HC as evidenced by the indicator compounds being higher during summer months than during the winter.

A notable finding was the apparent layering of highest quantities of LMW-HC in midwater. This was also noted during the South Texas OCS study, when it was postulated to result from turbulent stripping of gases to the atmosphere near the surface, or from decomposition of suspended particulates at mid-depths. Offshore Louisiana, absolute levels are so high as to strongly implicate petroleum activities as a source.

2. Total Organic Carbon in Sediments

The study of TOC levels in sediments showed that no gross organic pollution occurs at any site. Absolute TOC levels found ranged from about 0.1 to 1.0% and were highly correlated with grain size and location with respect to riverine outflow. Finer sediments close to the Mississippi show higher levels. The percentages of TOC are well within the normal ranges for other Gulf of Mexico areas.

3. High Molecular Weight Hydrocarbons in Sediments

The occurrence of HMW-HC in sediments follows the TOC trend except at certain unique sites and provides evidence of platform-related effects (i.e., reduction in total HMW-HC with distance from the structure at several sites). Where platform-related effects occur, they are seen in both nearshore, near-river (higher absolute amounts), and offshore or very sandy bottoms (lower absolute amounts). The weathered unresolved complex mixture (UCM)[2] in gas chromatographs indicates that there may have been long-term petroleum contamination over the entire study area, though concentrations vary widely.

The technique of calculating odd-carbon preference indices[3] from data was used in this study to show trends of HMW-HC sources involving either terrestrial or petroleum sources. The results of these calculations indicate that petroleum contamination is likely to be areawide even at those sites where absolute levels of TOC or HMW-HC are low.

Unsaturated HC were analyzed to determine if compounds from sources other than natural crude oil were present. The results indicate that an extensive mixture of polyunsaturated hydrocarbons, often in a UCM, occurs over the study area. Many sites demonstrate petroleum contamination (petrogenic); many also show contamination from burned petroleum products or terrestrial sources (pyrogenic), and man-made complex molecules such as pesticides (anthropogenic) were also common. Overall, the platform sediments show a trend toward greater contamination in areas nearshore or in the eastern sections of the study area, in areas of the greatest production, and in areas where low background levels make any contamination obvious.

Hydrocarbons in sediments around platforms occur at different concentrations, reflecting many factors affecting the contaminant levels. Absolute levels of contaminants are higher in areas with very fine sediments than at sandy sites. Some platforms with high levels of contaminants associated with long production life, multiple wells, and high amounts of discharged produced water show definite trends of decreasing hydrocarbon contamination as distance increases up to 2000 m. Conversely, at some locations with high levels of background hydrocarbons from terrestrial sources and areawide high levels of oil production, it is difficult to cite the platform as contributing to area contamination. Other platforms at locations with extremely low background levels of contamination (i.e., far offshore or with very sandy sediments) also show indications of increased contaminant concentrations near the structure. Because of the extremely sensitive techniques used in hydrocarbon detection, it is possible to discern polluting platforms in very clean areas even where absolute levels of hydrocarbons are extremely low.

4. Hydrocarbons in Organisms at or near Platforms

Analysis of animal tissues for hydrocarbons revealed little accumulation in those organisms studied. It is confirmed that compounds of petrogenic and pyrogenic origin were found in study area organisms; however, levels were low and the petrogenic compounds were not traceable to any one production practice or set of practices. Neither were specific segments of the food web of the area revealed as the important hydrocarbon incorporators. Pyrogenic compounds may be from atmospheric fallout from terrestrial burning (Louisiana has extensive burning of marshes as a production control practice) or from fossil-fueled industry. The extensive power requirements of production facilities at gathering platforms and boats may be implicated as sources. The

[1]In order to avoid confusion in terminology (i.e., aliphatic, paraffinic, saturated) all hydrocarbons with single carbon bonds are referred to as "saturated" and those containing double bonds are called "unsaturated" in this report.

[2]UCM is the term applied to tracings on a gas chromatogram which show a relatively large number of higher molecular weight hydrocarbons to have appeared during the analytical run. Because of their similarity and number, the hydrocarbons cannot be individually identified. Therefore, the descriptive term UCM is applied to samples to putatively indicate petroleum contamination.

[3]An abundance of organic material in sediments derived from geologically recent terrigenous sources leads to a preponderance of odd-numbered, long-chained hydrocarbons. No preference for odd or even numbers is associated with petroleum hydrocarbons. Odd carbon preference indices for hydrocarbons of n-C_{14} to n-C_{20}, n-C_{20} to n-C_{28} and n-C_{24} to n-C_{32} (CPI_A, CPI_B and CPI_C, respectively) are used to determine sediment hydrocarbons as follows. CPI_A gives an evaluation of the carbon preference excluding the influence of the predominately terrigenous longer-chained molecules. CPI_B reduces the effect of the generally high n-C_{29} and n-C_{31} alkanes. CPI_C amplifies the effect of the longer-chained forms presumed to be from terrigenous plant waxes. Comparison of CPI numbers at a site reveals probable hydrocarbon origins and pollutant loading according to the differences between indices and magnitude of the numbers.

benchmark studies offshore the eastern Gulf and Texas rarely found these pyrogenic compounds; therefore, it appears that their relatively frequent occurrence in Louisiana may indicate production as a source. It should be pointed out that all findings of these exotic compounds in fauna have been in the 1-20 ppb range (except in one fish where a monophenoxybiphenyl has been found at about 1 ppm). The ecological significance at these levels is unknown. However, since the fish surveyed in this program are commercial and sport, the occurrence of carcinogenic compounds, at any level, is cause for concern.

Results of these studies indicate that identification of saturated fractions and analysis for higher aromatics (3+ rings) are not as effective in demonstrating petroleum derivatives as is looking for benzene, naphthalene, and their alkyl substituted derivatives (derivatives with short chained simple carbon compounds attached to available carbons in the main ring structure).

5. Synthesis of Hydrocarbon Findings

Data synthesis efforts for determining impacts focused on correlating the environmental parameters from sample locations around each site. Based on the overall results of hydrocarbon analyses, the environments surrounding the following platforms contained hydrocarbons which apparently came from drilling, operations or accidental releases at those sites.

Sediments—P1, S6, S7, S11, S13, and S16.
Biota—P4, S9, S11, S16, S19, and S20.

No statistical proof of these strong implications can be shown from the present data.

Based on apparent decreases of hydrocarbons with distance from the structure, the following platforms are implicated as pollution contributors:

P1, S6, S7, S10, S11, S12, S13, S14, S16, and S17.

On the basis of all hydrocarbon analyses and extent of platform-related effects, the platforms are ranked in the following order:

High (high apparent pollution)—P1, S7, S11, and S16.
Medium—P4, S5, S8, S9, S15, S17, S18, S19, and S20.
Low (low apparent pollution)—P2, P3, S6, S10, S12, S13, and S14.

Several statistical tests were done to determine the effects of platform age, type of production, volume of production, and number of wells at a site. No statistically significant correlation between any of these factors and apparent hydrocarbon contamination at a platform was found.

Two platforms in the study area were chosen for sampling because they were near the sites of previous large spills. One of these sites, S12, appears to exhibit a gradient of hydrocarbon concentration away from the structure; however, since this gradient is to the north and the spill was 2000 m west, it is impossible to ascribe the source either to the spill or the platform. Platform S13 is cited as showing a trend toward decrease in HC away from the structure; however, the trend is weak, i.e., total HMW-HC ($\mu g/g$) values were 105, 85, 87, and 54 at 100, 500, 1000, and 2000 m, respectively. Platforms 12 and 13 are both identified as ranking low in overall HC contamination. It is possible that the contamination found in the area is from previous spills. It was also pointed out that S13 is also in the area of apparent maximal Mississippi River impact. Therefore, the implication may be that the river is contributing the hydrocarbons.

Overall, the study area has been demonstrated in numerous instances to be the recipient of a considerable amount of industrial chemicals. These come from a number of sources including the production platforms. The levels found are quite low and have not been shown to cause biological effects in this environment.

D. Trace Metals Studies

Analyses were done by AAS for cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), nickel (Ni), lead (Pb), and zinc (Zn); and by NAA for barium (Ba) and vanadium (V). This suite of metals was chosen for the following reasons. As a standard indicator of the potential of fine-grained sediments to bind metals, Fe was used for comparative purposes. Lead and Cu were included as "standard" pollutant metals for further reference on absolute contaminant levels. The fluids used in exploratory and development drilling are variable in content but consistently are implicated in contribution of some metals. This study focused on Ba, Cd, and Cr to demonstrate drilling mud accumulations. Petrogenesis in ancient sediments brings metals incorporated by the organic progenitors of oil into the pool of produced substances. As particular determinants of oil contamination, Ni and V were quantified. Zinc is also reported as an indicator of contamination by ancillary production activities such as cathodic protection and other anticorrosion measures on structures.

1. Trace Metals in Sediments

Sediment type is very important in determining the potential trace metal burden which may be incorporated into the sediments. Normal sediment trace metal levels may also vary widely in a single sediment type at different geographical sites. It is necessary, therefore, to find a way to normalize sediment metals data. Since Fe is normally high in sediments relative to other transition metals, it is used as a standard for comparison. This study normalized concentrations of other metals against iron. Because of sediment variability, percent clay was also used as a reference parameter. Total organics were considered since they may cause increased binding of metals to the substrate.

2. Trace Metals in Organisms

A major problem in trace metals analysis in organisms is the wide range of levels likely to be found within a species. This intraspecific variability means that large numbers of individuals must be taken to obtain statistically significant results. Unfortunately, the design of the present project was not sufficient to provide adequate numbers of individuals. As a result, a number of different species were taken and in relatively low numbers. This problem was further complicated by the difficulty in collecting any organisms at a number of

stations with "dead bottoms" and by the variability in faunas as sampling proceeded offshore. As a consequence of these problems, the data for metals in organisms is of limited value. It does appear that some sites show species with levels of specific metals higher than those at similar nearby platforms.

3. Synthesis of Trace Metals Findings

The overall manipulation of trace metals data led to the following classification of the study sites:

Probably affected: P1, S6, S7, S11, S17, S18, and S19
Possibly affected: P2, P3, P4, S13, S14, S15, S16, and S20
Probably not affected: S5, S8, S9, S10, and S12.

This list with some exceptions tends to parallel the grouping of hydrocarbon-contaminated stations. Apparently such locations as P1, S6, S7, and S11 have significant contaminant levels in both parameters. Other sites such as S17 appear to have trace metals contamination but very low levels of hydrocarbons. Reasons for the variability were sought, but not found. The platforms at which structure-related effects are strongly implied are S7, S11, and S17.

Statistical manipulations of the results were done according to the same techniques used for correlating hydrocarbons with platform age, history, production type, and other factors. Overall, no relationship can be found between these parameters and the likelihood that a platform will show trace metal contaminant effects. Apparently, individual platform sites are so different in the burden of hydrocarbons and trace metal contaminants that no correlation between production history and contamination at a limited number of sites can be seen.

All levels were well below levels for public concern and, based on comparison with other Gulf of Mexico studies, no bioaccumulation appears to be taking place.

E. Microbiology and Microbiological Chemistry of Sediments

Microbiology studies can be reported in four phases; (1) counts of different types of microbes including oil consumers, (2) experiments on the capacity of sediment microbes from the study area to degrade oil, (3) experiments to determine the effects of added oil on physiological processes, and (4) simple determinations of six sediment inorganic micronutrients.

Because of the numerous tests done and the variety of results within stations, between sites, and over seasons, it is not possible to summarize the results in a meaningful brief treatment. Essentially, the observations were that at times (seasons) there were statistically significant microbial differences between platforms and control sites based on some parameters (colony counts or microbial processes), while at other times there were no differences. Since the program was designed to look at only the top 1-2 cm of sediments, the effects of recent sedimentation and redistribution from currents and storms were magnified. Therefore, while differences in microbial populations and activity may have been brought about by man's activity, they appear to be masked by nature's activities. As an example, some sets of data were highly correlated with geographical location and follow trends of other contaminant data indicating that the closer to the river samples were taken, the more the hydrocarbon contamination appears.

1. Microbial Counts

The results from microbial counts were quite variable; however, several conclusive statements made by the PI have significance with respect to hydrocarbon contamination. First, Cruise I counts indicate a significant increase in microbial activity of some parameters at platforms over control sites (4 Primaries and 4 Controls). Cruise II data contradict the earlier results and indicate that there were no significant differences between microbial activity at platforms and control sites (all 24 locations). Cruise III data were extremely variable and only one microbial parameter, presence of oil utilizers, was higher at platforms than at control sites (4 Primaries and 4 Controls). Overall, the implications are that at times platforms show higher oil utilization and higher overall microbial activity than control sites. One significant finding from Cruise II, when 24 sites were available for comparison, is that there are definite trends toward increasing microbial activity with movement eastward (toward the Mississippi River) within the study area.

When microbial counts were correlated with dissolved oxygen, salinity, inorganic nutrients, total organic carbon, and sediment type, no direct associations were found.

2. Microbial Oil Degrading Potential

Experiments on the oil degrading potential of Louisiana OCS sediments were done only at the four primary platforms and four control sites. The results are inconsistent and PI conclusions were drawn with difficulty. (Interference from hydrocarbons produced by the microbes, oil perhaps already in test sediments, and instrument techniques are examples of complicating factors). The fact that sediments showed the highest potential oil degradation at a time when numerous stations were under stress from oxygen depletion at the bottom (Cruise II) may invalidate comprehensive evaluation of the data. Several PI statements are pertinent to future planning and studies:

- Sediments studied appear to have a maximum determined oil-degrading potential of 56 μg of hydrocarbon-carbon/ml of sediment per day and this was field limited by availability of oxygen
- Under the various test conditions, all oil added in experiments was consumed within 20 days
- When test conditions including temperature (15, 20, and 27 C), nutrients (added nitrogen and phosphorus), and oil (concentration increased 10 X) were varied, essentially no differences in results were seen.

There was essentially no difference between the oil degrading potential of sediments from control sites as compared to platforms. While laboratory data indicated a maximum oil degrading potential of 56 μg

hydrocarbon-carbon oxidized to carbon dioxide/ml of sediment per twenty-four hr, the actual rate *in situ* would probably be significantly less due to lack of adequate oxygen. The variability in results and inability to distinguish environmental conditions which influence oil degradation strongly suggest that considerably more research needs to be done on degradation potential prior to using these data for predictive purposes.

3. Microbial Processes

Examination of 12 microbiological processes provides potential for obtaining significant information about the microbiological environment of the study area. However, test conditions concentrated on simulating natural conditions and responses of processes to chronic presence of oil. Results have been analyzed so as to provide an understanding of the effects of the presence of such oil.

In summary, the major rate-limiting factor for non-carbonaceous processes in marine sediments from this area seems to be the low level of available, useable carbon sources. Of the six processes (cellulolytic, chitonolytic, heterotrophic, lipolytic, proteolytic processes and sulfur oxidation) which showed significant activity under the environmental conditions used in this study, there was little observable impact of chronic low levels of oil contamination, and there was no difference detected between platforms and control sites except for lipolysis (platforms demonstrated less activity than the corresponding control sites). No correlations were indicated when activity rates were compared with sediment type or with geographical location. Also, the total organic carbon and the sediment inorganic nutrients were present in such low concentrations that variability within these parameters did not affect physiological activity. No evidence was obtained to indicate that any of the reasonably active microbial processes were adversely affected by low levels of oil.

4. Inorganic Nutrients in the Sediments

Tests for levels of six micronutrients (phosphate phosphorus, total phosphorus, ammonia nitrogen, nitrate nitrogen, nitrite nitrogen, and total Kjeldahl nitrogen) in sediments indicated a high degree of variability between sites and few definite trends. As for other program elements, Cruise II data (during lowered oxygen levels at the bottom) contradict findings for several parameters during other cruises.

F. Histopathology of Invertebrates and Fish

Histopathological studies for this program examined invertebrates and fishes from platforms and adjacent soft bottoms. The invertebrate species were clams, shrimps, and crabs, with emphasis on commercial shrimps and crabs when possible. Because of the depleted bottom populations during Cruise II when the bulk of these samples were taken, much variation occurred in the species and numbers of individuals which were available for study. At a number of locations either no organisms were present or those that were collected were severely stressed by the low oxygen conditions. Because of this variability in quality of tissues available for analysis, results from invertebrate studies are not particularly useful in assessing effects of contamination. This summary will focus on fish.

Fish examined included a number of species, and various individuals within a species may have been of significantly different ages and sizes. Consequently, data are quite varied with respect to histopathological "conditions" (presence of parasites, tissue degeneration, eosinophilia, etc.). This report uses examples of findings to indicate where future concern should be placed and gives results which illustrate apparent platform-related "condition" phenomena.

All fish species and all histopathological "conditions" were considered in correlation of platform-related effects, and numerous sets of data appear to implicate a site or sites as contributing to occurrence of "conditions". However, knowledge of the species and comparison with similar collections often signal that mitigating circumstances may be in effect. An example of strong correlation is shown by a comparison of all study sites with the total number of histopathological "conditions" found in the two species of pelagic fish from the sites. In this comparison, Sites P1, S6, S11, and S13 (platforms strongly implicated as contaminated by hydrocarbons and trace metals) occur among the top seven in total number of "conditions". Conversely, the four control sites occur in the bottom seven. However, the bottom ten in total number of "conditions" include Sites P2, S5, S7, S9, S14, and S16, of which S16 ranks "high" in platform-related effects from hydrocarbons and metals. In assessing such disparate information, one must consider the species which show the highest levels of occurrence of "conditions". During this study, it has been confirmed that the spadefish consistently demonstrates a high frequency of histopathological conditions. This may be due to the fact that the spadefish lives most of its adult life in association with a structure such as a production platform, or it may reflect a natural proclivity of this schooling species to acquire parasites and disease conditions.

A significant finding consistent throughout the comparisons made in the study is that Platforms P1, S6, S9, S13, and S20 are high in histopathological conditions, and Sites S14, C21, C22, C23, and C24 are low. This strongly suggests that the set of platforms in the eastern part of the study area which consistently show contamination, whether from production, the Mississippi River or other sources, are those locations where stress is greatest on fish. Conversely, the supposedly least stressed sites show the fewest histopathological conditions. However, it must be kept in mind that spadefish and sheepshead, the species with the greatest average number of "conditions" per individual, were collected only at platforms and never at control sites.

G. Effects of Offshore Production Platforms on Benthic Populations

Of the variety of analyses made during this study, the assessment of bottom organism populations was the most complex and costly and is the central set of data for comparison with other ecological factors. The results of statistical evaluation of the benthic populations and abiotic factors is comprehensively given in Volume I, Part 6 of this report and is much more complex than can be covered in this brief treatment. Therefore, the results given in this summary have been selected as those which are most important to planning of future research of a similar nature and to governing of further offshore petroleum production.

A total of 560, 8.0-cm^2 cores for meiofauna; 840, 0.09-m^2 Smith-McIntyre grabs for macroinfauna and 40, 9.0-m otter trawls for macroepifauna and demersal fish were collected in the three separate cruises. These collections were taxonomically described to the lowest level practicable and enumerated. The 1029 different taxa were statistically correlated according to ecological affinities, producing graphic evidence of interrelations with each other and abiotic factors such as contaminants. After thorough numerical processing the definitive results of comparisons were relatively few and are summarized in the following sections.

1. Physical, Chemical, Sediment and Microbiological Variables

The physical environment inhabited by the organisms collected in this study was quite diverse, as evidenced by the significant geographical area covered, and difference in water masses from nearshore to oceanic and from virtually freshwater Mississippi River outflow to oceanic salinities. As expected, the physical factors causing population differences were distance from shore, dissolved oxygen (especially hypoxic bottom conditions), depth, salinity and sediment grain size. Overall, this set of factors is governed by the Mississippi River. This was especially noted in the present study since quite high discharges in 1978 brought extensive areas of the relatively nearshore Louisiana OCS under the influence of lower than normal salinities, increased sedimentation, and expanded the annually occurring area of reduced dissolved oxygen at the bottom.

2. Total Organic Carbon and Hydrocarbon Variables

Because of the diversity of organismal types described in this study and the multiplicity of their lifestyles, significant correlations were shown for a number of taxa, taxonomic groups and chemical factors. The list of these correlations taken out of context from the complete discussion of the report could not adequately report findings. For example, "...T.O.C. increased as number of species and Pielou and Heip evenness for macroinfauna increased. As Macroinfauna Taxa Group Association No. 3 and its member *Tharyx marioni* increased, T.O.C. decreased. As *Nereis* increased total unsaturated hydrocarbons decreased." Explanation of these correlations, where possible, is given in the original report, and it is strongly recommended that the same be read for adequate understanding by those specialists who need to know. The Program Manager's understanding of findings in this analysis is thus summarized as follows.

With the exception of certain correlations, i.e. as shown above, the T.O.C. levels found in this program did not influence benthic populations adversely. The levels found, averaging 0.65% with a high of 1.08% at S13 and a low of 0.11% at S19, are similar to other studies in the Gulf of Mexico and reflect an organic-rich environment as would be expected in an area with significant river runoff. No long term T.O.C. influence on populations was seen such as might be surmised to occur at locations with high chronic petroleum inputs or significant spills.

Low molecular weight hydrocarbons, while occurring in relatively high amounts in the research area, cannot be shown to influence benthic populations. High molecular weight hydrocarbons and contamination indices did correlate with certain biotic variables, but again, these are not shown to be ecologically significant. The important finding for future planning is that six locations, P1, S6, S11, S13 and S16, did show amounts of total hydrocarbons in the sediments which have been previously cited as detrimental to benthic populations, >96 ppm. The implications are that the previously mentioned riverine influences masked effects or that this study did not sample adequately.

3. Trace Metal Variables

As in the correlations with hydrocarbons data the results of statistical treatment showed that a number of trace metals could be correlated with certain biotic variables. However, these correlations do not show a pattern or strong link of metals occurrence with effects on the populations. The important demonstration of this study is that "Average sediment trace metal concentrations listed in Table 172" (Vol. I, Pt. 6) "for chromium, copper, lead and zinc in this study are above those values previously reported to cause adverse effects in some benthic organisms."

4. Summary of Findings from Benthic Population Studies

As previously indicated, the occurrence of two irregularly occurring phenomena, a tropical cyclone and hypoxic bottom conditions, demonstrated readily in the data that the benthic populations of the Louisiana OCS are quite impacted by natural forces. Substantial review of these phenomena by the PI during benthic studies proves that over much of the study area the frequency and areal impact of storms and "dead bottoms" causes so much disruption of faunas as to make it impossible to clearly describe benthic populations. Along with and causing the decreased oxygen conditions is the effect of overall Mississippi River outflow. The amounts of freshwater, sediments, natural organic materials and contaminants affect the study area to such an extent that showing significant population differences definitely attributable to platform operations cannot be done with the present data. The most effective description given by the PI in benthic studies is that the entire Louisiana OCS is experiencing chronic contamination from the Mississippi River and probably production activities, but that the periodic flooding of the river and irregular but relatively frequent tropical cyclones cause such serious effects that they mask any platform related effects. The study indicates a "highly disturbed and very unpredictable environment, which results in a stressed community structure."

H. Artificial Reef Studies

The value of offshore production platforms as hard substrate for attachment of sessile reef organisms and attraction of fish is well documented. The purpose of artificial reef studies in this program was to further present understanding of the artificial reef "effect" in conjunction with other research parameters so that the overall value or effect of structures in the central Gulf of Mexico would be known. The results of the studies are quite comprehensive in their implications of diverse and productive habitats associated with platforms. For this report findings have been combined with findings from other similar studies presently being done in Texas waters in order to better document results.

The platforms offshore Louisiana are separated into three distinct biotal zones based on differing water conditions with increased distance from shore. A "coastal" set of fauna and flora is characteristic of areas under significant impact from terrestrial runoff and includes numerous species dependent on estuaries during their life cycles. Sites in this "coastal" zone appear to include all with water depth up to 27 m. Between the coastal and the next zone, an "ecotone" or transitional zone occurs between 27- and 37-m depths. This "ecotone" is followed by an "offshore" zone characterized by certain shelf species. The outermost zone is described as "bluewater" by investigators based on the dominance of Caribbean fauna in the attached and resident fish communities. The inner boundary of this zone has been arbitrarily set at the 64-m contour.

This set of biotopes is not restrictive in depth or distance from shore and would undoubtedly be redefined with more research; however, the trends in species changes are well defined within the sets of platforms visited and the implications for differences in contaminant-related effects are significant. For example, the nearshore structures receive significant visitation from sport fishermen who take numerous specimens of the drum family such as spotted seatrout. Contamination of these fish presents potential for a nearly direct pathway to man. On the other hand, far offshore platforms are visited less, fished most often for fish which are more for sport than food, and thus are less likely to affect man through contaminated fish. In between are the offshore platforms which contribute nearly all of the commercial red snapper catch in some markets.

A number of taxonomic findings indicate that platforms are providing havens for certain species which either have not been previously documented in the Gulf or were thought to occur only on natural hard bottoms. The implications are that in the northern Gulf, where few natural coral reefs are established and few topographic highs have been shown to provide opportunity for attachment of such reef communities, the platforms are contributing to the overall diversity of the OCS. While the documentation of new taxa or new locations for otherwise distant fauna are not significant in the larger picture of contamination effects from petroleum production, such findings do take on a larger meaning than satisfaction of scientific curiosity. It is not within the scope of this study to understand the significance of all occurrences of species which would not be in significant numbers were it not for the presence of platforms, nor is it feasible to explain any changes in the total ecology of the Gulf of Mexico by such slight shifts in habitat availability.

Research indicates that the concentration of organisms at a platform may not change the areawide populations of some species; therefore, the apparent positive contribution of structures in providing larger numbers of organisms for observation does not have positive meaning for regional production. For example, red snapper may represent a species which, because of attraction to platforms and ease of harvesting of the resource at the site, may be detrimentally affected when regional populations are considered. Conversely, when platforms provide new habitat for habitat-limited species, such as blennies, thereby allowing population levels of increasing magnitude as compared to those normally resident on natural hard bottoms, then the contribution of the structure may be judged to be positive.

One undocumented observation made during the diving efforts done at platforms studied in this program was that several platforms (S6, S7, and S13) near the Southwest Pass of the Mississippi River were "less rich" in biota than similar structures farther west but still in the same biotal provinces. The stated implication is that influence from the river may be depressing development of a typical fauna.

IV. SAMPLING SITE DESCRIPTIONS

Platforms in the Louisiana OCS provide such an array of environments that it is not possible to give a generic description of them which includes adequate discussion of the findings of this program. Therefore, in order to make the conclusions more meaningful, individual platforms studied will be discussed and interesting or pertinent points given about each. Since a more detailed discussion of each platform's history and physical environment was presented in Volume I, Part 1, this summary is primarily a description of contaminants and biota. It is again emphasized that these descriptions were prepared by one writer, and though all statements are based in fact, personal impressions about individual platforms will surely be reflected in the narrative. The reader should refer to the various technical discussions in other Volumes if additional information is desired.

A. Platform 1

Primary Platform 1 has been previously described as being in an area where significant effects from contaminants might be found. The sediments contain 60 to 70% silt and 14 to 16% clay, indicating a relatively high capacity for sorption and binding of contaminants. Knowledge of the currents and discussions with platform operators indicate that riverine influence can be great, especially in the spring. Since this site was visited three times in the present study, it is likely that more effects would be discovered here than at the secondary platforms visited only once. In fact, Platform 1 is cited as ranking high in platform-related effects based on (1) the finding of a gradient of decreasing hydrocarbons in sediments away from the structure, (2) relatively high absolute hydrocarbon amounts in sediments, (3) hydrocarbon contamination of biota.

Carbon preference indices (CPI_A, CPI_B, and CPI_C) were calculated for three classes of molecular size (C_{14}-C_{20}, C_{20}-C_{28} and C_{24}-C_{32}, respectively) for hydrocarbons found in sediments. Platform 1 was highest among study sites in all three categories. The implications from this finding are as follows: First, the high level of CPI_C indicates considerable influence from terrestrial sources since the plant waxes contain high levels of C_{29} and C_{31}. On the other hand, the CPI_A value, which is less affected by terrestrial input, is relatively low for P1 (1.46 compared to 3.1 found for the South Texas OCS) and indicates petroleum contamination.

Platform 1 surficial sediment HMW-HC levels were among the highest for the sites visited. Several samples were in the 300 $\mu g/g$ class. The average total HMW-HC value for three cruises was second highest of all values, saturates were second highest, and unsaturates were fourth highest. Values at the nearby Control Site C21 were roughly half in each category.

While sheepshead taken from P1 were confirmed by GC/MS to contain alkylbenzenes, naphthalene, methylnaphthalenes, and phenanthrene, samples at this site also contained polychlorinated biphenyls, pesticide derivatives unrelated to petroleum production, and other exotic hydrocarbons. The scope of this project was not sufficient to confirm by GC/MS techniques all of the compounds seen by chromatography or to sample widely enough to insure analysis of all types of organisms. Therefore, the biological significance of these findings at P1, as at other sites, is unknown.

Trace metals indicated as pollutants in sediment samples at P1 are Ba, Ni, and Pb. Due to the complicated set of factors describing data synthesis of metals information, it is difficult to definitively ascribe contamination to individual platforms. The scientists examining the present data indicate P1 as "probably affected" (i.e., probably a contaminated site). No strong gradients were confirmed at the site; however, gradients in Ba, Cr, Cu, Ni, Pb, V, and Zn are indicated. Interestingly, these gradients are most often in a northerly direction, where at 2000 m the prescribed sampling site is quite close to another large production platform. This observed interference with the "bullseye" approach to sampling around the subject platforms was one of the most significant problems in analysis of all of the data.

An in depth assessment of bottom dwelling organisms indicates that the meiofauna and macroinfauna at P1, as on the whole Louisiana OCS, include dominant species which are opportunistic and thus indicative of stress on the environment. The generally stressed condition of the nearshore Louisiana OCS has been discussed, and the conditions at P1 confirm the influence of the lowered dissolved oxygen from river runoff and damage from periodic cyclones. No stress at individual sampling locations around this platform, or any other site, has been definitively associated with contaminants at these locations.

Consideration of other biological parameters gives further evidence of platform-related effects. P1 ranked highest among all 20 platforms in number of histopathological conditions found in fish. The microbial populations in the sediment indicate a high potential for oil degradation and also rank high in parameters which implicate terrestrial nutrient sources. Studies of the produced water discharge at this platform confirm that attached barnacles and other associated biota are stressed in the zone of discharge.

As an ameliorating counter to these numerous examples of negative platform-related effects, it should be noted that divers (Cruise I) observed heavy turbidity in the surface 3 m and bottom 5 m of the water column with a very clear mid-layer from 4 m through 12 m. The turbidity was ascribed to riverine influence. This observation, descriptions by divers during Cruise II, operator information, and the fauna all serve to confirm that P1 is a unique example of a coastal platform subjected to a multiplicity of environmental influences (i.e., drastic salinity changes with time and depth, concomitant recruitment of both nearshore and offshore species, significant reduction of light penetration and other turbidity-related effects at the surface, and reduced dissolved oxygen at the bottom).

B. Platform 2

Platform 2 is near the center of a very large oilfield developed around what has been described as the largest piercement salt dome in the northern Gulf of Mexico. It has all the characteristics of a potential pollution contributor; age, degree of development, sediment type,

production history, and location.[1] Further, its location only 5 km offshore and near the mouth of Bayou Lafourche, would implicate the site as likely to accumulate sizeable terrestrial inputs. Therefore, the relatively clean environment at P2 is enigmatic. This site ranked "low" in terms of evidence of contamination based on levels of platform-related effects from hydrocarbons and trace metals.

Reasons for the failure to find contamination at the site are unknown; however, some speculations can be made. Because of its nearshore location and the known currents, P2 receives a large contribution of terrestrial sediments from the Mississippi River distributaries, though apparently not very much from Bayou Lafourche. This may be a location which receives a considerable amount of sedimentation with each successive flood without also acquiring fresh contaminants in the form of anthropogenic compounds or petrogenic derivatives. Because of the shallow water depths, any contamination of the bottom is assimilated into the continually resuspended sediments. Divers describe P2 as having the highest turbidity and lowest visibility of any platform sampled. Therefore, it is likely that any contaminants emanating from the structure would be adsorbed or otherwise bound to the suspended particulates. Whether these particulates would then be carried out of the area taking pollutants with them can only be speculated, as can the likelihood of some kind of active transport to the nearby sediments. The relative cleanliness of the nearby sediments may be an argument for the former type of process. It may also be further evidence for the hypothesis that active transport is the mechanism for deposition in very clear, deep, offshore waters where contamination has been linked to platforms for which low contaminant levels and high dilution potential would suggest a low potential for platform-related effects.

The biota of this platform is typical of nearshore environments, with a strong estuarine component. Bottom fish are of the drum family and sea catfish. Considerable commercial shrimping is done in the area. The organisms on the structure (barnacles predominate) are typically of low relief and small compared with those farther offshore. The dominant spadefish are relatively small, indicating recent immigration. Platform 2 has been described as ranking low in number of histopathological conditions. This may be due to actual low levels of factors influencing pathologies, or it may be a result of the site's location near the coast and; therefore, due to a dynamic community which changes too fast to display acquired effects. It may also reflect the youth of the spadefish, one of the species carrying the greatest burden of "conditions" per individual as they approach full growth.

With all due respect to the platform operators, P2 was dubbed "old ugly" by this writer during first sampling in an effort to describe the site (an old platform with numerous structural members, a barnacle fouling community, dirty water, relatively colorless fish residents, and a general development which gave the impression that it would be a much contaminated location). That the opposite is the case reflects one of the major findings of this study; the perceived potential for contamination at a production platform is seldom reflected in actual results. The implication is that a greater understanding of the causes and effects of contamination must be gained before the worth of the present and similar data will be fully realized.

C. Platform 3

Platform 3 was selected for comparison with P1 to show any differences caused by greater distance from shore and freshwater influences, with other factors being relatively equal. Actually, the platform designated for study had to be changed in the initial phases of the study in order to avoid drilling operations being conducted at the site originally selected. As a result, the structure sampled is in a relatively large offshore oil and gas field, has a history of being primarily a gas producer, and, because of its position on the northern flank of the dome, is probably not in the primary current pattern to receive contaminants from other platforms on the field. Therefore, the actual level of contamination expected may not be as high as that at P1. The results bear this out.

Platform 3 is heavily used for commercial snapper fishing and was one of the three most productive angling sites visited during Cruise II efforts to catch red snapper as a representative platform resident. Discussion with the operators indicates that surface waters show a distinct riverine influence in spring and that the flow apparently comes from the north. Close examination of Fig. 2, discussed previously, shows a tongue of turbulence extending directly offshore from the mouth of Bayou Lafourche and surrounding P3 during spring runoff. The site lies in the transition zone between coastal and offshore zones as defined by the artificial reef studies. This designation is borne out by the observed physical characteristics given above and in descriptions of benthic and fish communities.

Platform 3 has one of the sandier bottoms (67-73% sand) and, as would be expected, the bottom accumulation of contaminants is low. Data synthesis ranking of P3 was low in terms of evidence of contamination, based on levels of platform-related effects from hydrocarbons and trace metals. Microbiological counts are similar to those of other offshore locations with low hydrocarbon levels and to those of S5 and S19 where sand content of sediments is high. Platform 3 is ranked as moderate in number of histopathological conditions in fish, but because of the species present, is not directly comparable with other sites.

Platform 3 is an example of a platform with both coastal and offshore affinities, as is demonstrated by the fish fauna, which are characteristic of a transition zone. This information should be noted and used in classification of such sites during future studies. For example, dominant fish were bluefish and spadefish along with less numerous lookdowns. But the sheepshead and gray triggerfish, normally numerous on more shoreward platforms, were few in number, and the reef fish, which were quite numerous at P4 only a few miles further offshore, were similarly scarce. Large croaker were caught by angling at the bottom, indicating that this is near the edge of the seaward zone of their occurrence as adults.

[1]The salt dome size directly influences the number of potential petroleum traps developed in overlying layers of sedimentary structures when the dome, in pushing towards the surface, dislocates the naturally horizontal layers.

The snapper-grouper assemblage was a major component of the ichthyofauna at this site, as it was at other similar platforms which were neither too much influenced by coastal waters nor limited to deep shelf species. Overall, the fish population observed during diving was judged to be of lower abundance and diversity than at sites farther offshore or nearshore, and invertebrate species showed similar reductions. The appropriate sections of Volume II give further descriptions of this ecological transition zone.

D. Platform 4

Primary Platform 4 was initially selected for comparison with P1 and P3 but was located in a gas field in order that any differences between oil and gas production could be ascertained, other factors being similar. During cruise planning, drilling activity anticipated during sampling required changing platforms. Consequently, a site that was primarily an oil producer was selected; therefore, the overall requirements that led to selecting P3 and P4 were met, but the actual site characteristics were reversed and P4 should be more like P1.

As might be expected, P4 (oil producer) is ranked as more contaminated with hydrocarbons than P3 (primarily a gas producer) but levels of hydrocarbons are much lower than P1 and actually lower than most other sites. The sediments at this location contain considerably more silt and clay than those at P1 or P2 and significantly more than those at P3, and one would expect significantly more accumulation of hydrocarbons under the same loading of the system. However, the contamination level was relatively low, considering the potential binding capacity of the sediments and comparison to other similar sites. Other parameters (microbiological counts and histopathological conditions) tend to confirm a low contamination ranking.

During Cruise II, P4 produced many croaker in trawls, and red snapper and spadefish at the structure. While diving activities were going on, a commercial snapper boat tied up at the site and within a brief time boated perhaps two hundred fish. During the dive, numerous reef fish were noted as well as various jackfishes, lookdown, blue runner, barracuda, and others which made this fish fauna the most diverse of any of the primary platforms.

Invertebrate species demonstrated a similar diversity, with bivalves dominating the attached fauna. It is noted that the biomass dominants were *Chama macerophylla* and oysters (probably *Hyotissa thomasi*), organisms which were associated naturally with Caribbean reef biomes. This points out the importance of production platforms serving as artificial reefs in the northern Gulf where similar natural environments are limited.

The fauna at P4 is quite representative of offshore structures, and further study of the technical sections of this report will provide better understanding of the community structure.

E. Platform 5

Secondary Platform 5 was selected for study because of its location in an area receiving considerable sport and commercial fishing pressure. It is only 6 km offshore at the extreme east end of the study area, in shallow water (only 9 m deep) and is in a quite well developed oil and gas field which includes the largest number of emergent structures seen at any of the study sites during this program. (This observer counted 60 structures in a scan of the horizon from the aft deck of the research boat without being able to see forward). Because the location is directly offshore from several bayous and has a sandy littoral bottom, it apparently receives a relatively high volume of freshwater and thus a considerable contribution of terrestrial inputs. This was readily apparent during Cruise II sampling, when immediately after Tropical Storm *Debra*, very turbid estuarine water was flowing from shore into the area.

Due to its location in a very active field, S5 might be expected to exhibit contamination effects. However, it has been shown to be a quite clean environment with regard to the sediments, which is probably a reflection of the high percentage of sand. Perhaps S5, like P2, receives enough sedimentation of heavier-grained material and resuspension of fines that pollutants are not physically trapped in nearby bottoms but are sorbed by finer fractions which are propelled further offshore prior to deposition. Platform 5 had resident organisms which contained petrogenic aromatic hydrocarbons.

When S5 was visited in early September 1978, the largest number of shrimpboats observed in any one locale during this program were working just shoreward of the platform. They, along with one menhaden boat, appeared to be taking advantage of a heavy migration of organisms from the delta just after passage of *Debra*. The research trawls at this location produced the largest catch per effort of any in the cruise and catches included numerous shrimp, croaker, hardhead catfish, spot drum, and spotted weakfish as well as numbers of whiting, bluecrab, ribbonfish, and one large (approximately 5 kg) red drum.

Platform 5 is similar to P2 and S19 in having a structure-related fauna dominated by smaller individuals (spadefish and sheepshead) which have low levels of histopathological conditions and an attached fauna dominated by many small acorn barnacles. These very nearshore sites have in common a tendency to exhibit a fish fauna which is probably in transit either into or out of closeby bays and is, therefore, not representative of long-term platform associations.

F. Platform 6

Secondary Platform 6 was selected for comparison with S5 as a highly fished location but is presumably more productive of the snapper and grouper assemblage. On sampling the platform in September 1978, quite unexpected observations about the resident fish fauna were made which tend to preclude worthwhile conclusions about the structure. Divers reported only a few, quite large, red snapper at depths near the bottom. (They were "skittish" when approached). Very few grazers were seen around the structure (especially in the upper 15 m), though those present were spadefish representative of the transitional assemblage one might expect. Blue runners represented "ninety-nine percent of the biomass" and along with a few large crevalle jacks gave divers the impression that most long-term resident specimens had either been killed or left the area. This impression of it "being like no other platform I've seen" could have been partially due to the activity of a large steam crane which was anchored alongside the platform and appeared to be doing heavy dismantling of living quarters.

Secondary 6 is notable in that it showed the highest average levels of absolute HMW-HC in sediments of any location and in that this level tended to decrease with distance from the structure. Thus, a definite platform-related hydrocarbon contamination is indicated. However, this contamination failed to appear in biota samples, or as LMW-HC in the water column. Therefore, this site was given a "low" ranking in terms of levels of platform-related effects from hydrocarbons. This contradictory result is an indication of the complexity of contamination interactions at each platform studied. In fact, S6, because of its location near the Southwest Pass of the Mississippi River, may be receiving a considerable portion of its contaminants from that source. Because it is only a few kilometers from the site of a large 1967 oil spill near S13 (also with high sediment HC), it may be contaminated from that source.

Platform 6 shows evidence of platform-related concentration of Cr (indicative of drilling mud pollution) and of Ni (indicative of oil pollution) in the sediments. The implication is that in any area with a high level of background contamination, whether from terrestrial sources or a large spill, it is still possible to show additive effects from production platform operation.

G. Platform 7

Platform 7 was slightly farther offshore than S6 but in the same general type of environment; therefore, it was selected to be productive of similar fauna. Located in a small oil and gas field, S7 was thought to have a lower potential for contamination than S5 or S6. Apparently, the site does receive some riverine influence for about two months each spring but the rest of the year is quite oceanic. When visited during Cruise II, the water was extremely clear.

In view of the contradictions between the expected results and actual results for several of the platforms previously discussed, it may not come as a surprise to the reader that S7 is one of the most contaminated sites studied in this program. Hydrocarbons in sediments decrease with distance from the structure, absolute HMW-HC averages in sediments were the sixth highest of all sites, and the sediment hydrocarbon index (HCI) was sixth highest of all sites (1.52) (though the CPI was also high indicating significant terrestrial inputs). Red snapper and croaker were confirmed by GC/MS to contain aromatics in the tissues.

Trace metals studies revealed S7 as one of three locations highest in platform-related contamination effects. Five metals (Ba, Cr, Cu, Pb, and Zn) decreased in concentration with distance away from the platform. It should be pointed out that percent clay at S7 was the second highest of any platform (35.2%); this would account for some increased ability of the sediments to capture and hold pollutants.

As might be expected, the higher organic content is reflected in counts of sediment microflora. This location is one which divers have arbitrarily described as lacking the complete faunal development which might be expected from its offshore location.

Some facts about the general population health and development are noteworthy. Histopathological conditions were quite low in number, the largest fish taken in this study was caught at this location (50-kg grouper), a spiny lobster was taken, and red snapper fishing was among the best at any site.

Implications are that at locations where contaminant loading is perceived to be low, significant levels may accumulate (whether from the platform or outside sources) when the sediments have a high potential for binding pollutants (high clay content). It appears that the overall biotal community may be somewhat less developed at S7 than at physically similar locations farther west, but whether this is due to low levels of freshwater influence or contamination can only be speculated. No matter what the source, the community does appear to be stressed.

H. Platform 8

Platform 8 was a relatively nearshore location at the edge of the coastal zone and was selected because of its history as a popular fishing location, especially for snapper and grouper. When visited, it reflected fouling and fish faunas typical of its depth and distance from shore. The site was apparently heavily influenced by the low dissolved oxygen at the bottom noted prior to passage of Tropical Storm *Debra*. When sampled, just after *Debra's* passage, trawls caught recently dead clams that smelled bad when brought on deck. Catches of croaker, crabs and shrimp were good. However, the catch appeared to be in patches, indicating that migration was going on at the time.

This location was one at which a significant level of dissolved LMW-HC was detected in the water column. This was almost certainly the result of a large gas pipeline leak near the platform. Other than the high levels of dissolved gases found in the water, no detrimental environmental effects were seen from this leak.

Platform 8 does not show definite platform-related hydrocarbon or trace metal effects in the sediments or biota, and overall was ranked as a medium site in terms of apparent contamination.

I. Platform 9

Prior to data synthesis but after gaining considerable background knowledge and experience in the field, the Program Manager made a personal evaluation of the "potential" for contamination at each study platform based on a number of observed and intuitive factors. In that ranking, he judged Secondary Platform 9 to be the least likely to show contamination. It is close to the edge of the shelf, under the influence of an incoming stream of deep oceanic water and has had only seven wells drilled, of which five were dry. Results of research on the platform reveal a contradiction between expected and actual results in relating contamination to platform activities.

Interpretation of trace metals results indicates that the relatively low levels found are not related to the platform. In fact the four sampling stations exhibit a trend toward increase in metals with distance away from the structure. Overall levels are comparable to other sites with a high silt content (88%). High molecular weight hydrocarbons also exhibited the same trend toward increase away from the platform and absolute levels were low (average total HC = 30.7 $\mu g/g$) and comparable to those at sites with similar bottom types, though not nearly as low as at nearby P3 with sandier sediments. During sampling at this location drilling was going on and a mud plume was observed in the water. What effect this mud had on the findings is open to conjecture.

Platform 9 is clearly implicated as contributing to contamination in the associated biota. Both fish and invertebrates were shown to contain petroleum hydrocarbons. However, it should be understood that the fish contaminated was the croaker, which at this distance offshore has traversed the whole OCS and grown to adulthood prior to being caught. Thus, the association of fauna in such far offshore areas with platform conditions calls for discretion.

J. Platform 10

Platforms 10 and 11 were designated for study in this program because they were included in the Offshore Ecology Investigation (OEI), a study of environmental impacts due to production platforms done by the Gulf Universities Research Consortium (GURC) in the 1973 to 1974 time period. At the time of that study no particularly heavy contamination was noted at either location and both were considered to be of no environmental concern. The findings made during this study are significant in the differences in pollution levels between the two closely adjacent sites.

The physical environments of both S10 and S11 are nearly identical; sediments, distance from shore and depth are nearly equal, operations are comparable and production histories show no reason for contamination differences. Analysis of data shows that the faunas in the surrounding bottoms and resident at the platforms are equitable. No difference can be shown in statistical treatment of benthos or from observation of resident faunas during diving. Yet significant differences in pollution levels of hydrocarbons and trace metals were found in both sediments and biota.

Secondary Platform 10 ranks as one of the "cleanest" locations sampled. It is fourth lowest in total HMW-HC in sediments and fifth lowest in the HCI of the sediments. There is some indication of decrease in HC concentrations in sediment samples taken on the single north transect, but with regard to all factors S10 is ranked as low in platform-related hydrocarbon effects. Similarly, it is cited as probably not contaminated by trace metals from the platform.

K. Platform 11

Comparison of S11 to S10 reveals several significant parameters which confirm the more highly polluted nature of Platform 11. Absolute levels of total HMW-HC in sediments were fifth highest among stations sampled and decreased with distance away from the structure. Organisms contained alkyl homologues of petroleum and pyrogenic compounds and several fish taken from the structure exhibit the greatest number of unsaturated hydrocarbons of any fish in this study (squalene, methyl- and dimethylnaphthalenes, phenanthrene, fluoranthene, alkylbenzenes and others). It was noted by the PI that while only one of six fish tissues examined at S10 contained aromatic HC, five of seven at S11 were confirmed by GC/MS to be so contaminated.

Trace metals data indicate S11 to be one of three locations exhibiting platform-related effects as defined by decreasing concentrations with distance from the structure. Five metals (Ba, Cd, Cu, Pb, and Zn) were so implicated. The microbiological parameters signal the biological response to differences between S10 and S11 in that the total anaerobic plate counts and average hydrocarbonoclasts were lower at S10.

This convincing case of platform-related effects at a site is not explained. Operations and history offer no clues to the differences, and comparisons of the biotic and abiotic factors at the sites show no outstanding differences which relate to contamination sources.

L. Platform 12

Secondary Platform 12 was selected for this study because it had been subjected to a significant oil spill located about 600 m WSW of the structure. In 1971, a blowout and fire resulted in loss of an estimated 53,000 barrels of crude. Overall, the hydrocarbon contamination level at the site is equitable with that of other similar sites with predominantly fine sediments (88% silt, 10% clay). Based on total hydrocarbon determinations, it appears to exhibit a gradient of decreasing contamination away from the structure. Since the spill was WSW of the platform and the four samples analyzed in this study were taken on a north transect, it is not possible to conclusively determine whether the decrease in concentration was due to the platform or the spill. However, since levels of sediment HMW-HC are relatively low and in the range of nearby platforms and C22, it seems that the apparent platform source is likely and that the earlier spill has not caused a remaining residue higher than surrounding sites.

The environment at S12 has been cited as probably not affected by trace metals from production activities, not contributing to contamination in biota and not definitively (according to criteria established in this study) contributing hydrocarbons to the area; therefore, it has been ranked low in an overall estimate of effects on the area.

M. Platform 13

Platform 13 is located near the site of a spill of an estimated 160,000 barrels of crude caused by a pipeline break in 1967. It was selected as a more offshore location for comparison to S12. Hydrocarbon determinations demonstrate that the site is similar to nearby P1, S6, and S16 in actual amounts of HMW-HC in the sediments (the four highest levels), but amounts are not indicative of gross levels as might be expected from a spill. It is noted that the PI cited the relatively high incidence of a UCM in these sediments as possible evidence of residues from the spill.

The absolute levels of total HMW-HC in sediments were the third highest found but the trend toward decrease with distance from the platform indicates that platform-related contamination is probably superimposed on any long-term contamination from other sources. The site is listed as one exhibiting some evidence of contamination in organisms but it is not confirmed as being affected.

Biological parameters indicate the site is one which is probably receiving significant influence from the Mississippi River. It was described by divers as being in that group which has not developed a fauna which might be expected from its location. This could be due to extensive sport diving (they said it gave that impression) or to sport fishing (three boats visited the platform during the brief Cruise II sampling). Secondary Platform 13 ranks relatively high in number of histopathological conditions and the overall benthic biota is in a stressed condition.

It is apparent that the long-term effect of a relatively large oil spill on the Louisiana OCS may be an added HC load to the sediments which may be demonstrated by the weathered UCM. This site and S12 show no distinctive long-term ecological damage.

N. Platform 14

Platform 14 was selected for the purpose of determining the effects of drilling muds on the clayey-silt sediment at the site. Correlation of the several metals with Fe in the sediments and with other locations reveals that S14 shows an apparent accumulation of Cd and Zn at the 100 m sampling location, indicative of oil and structural sources, respectively. The presence of Ba in relatively high quantities (240 $\mu g/g$) at the 100-m station is evidence that effects from drilling muds have been felt at this close in location. Though this one piece of evidence appears weakly indicative of pollutant effects, it may be significant when considered with the relatively few positive correlations found when all sediment trace metals data were analyzed. The same correlation effort revealed only P4, S7, S10, S11, and S17 as locations with metals accumulation. Since all but S10 are also strongly implicated in other contamination indices, it is logical to assume that this platform has low level drilling mud residue within 100 m.

Other parameters give no apparent indications of pollution. The HC levels in the sediments are low and the site is ranked low overall in HC-related effects. The platform is one of the lowest in histopathological effects and microflora indicate that sediments are relatively free from HC pollution. Fauna observed in diving are typical of the ecotone between coastal and offshore sites. Apparently the location is not heavily used by sport divers or fishermen (perhaps due to relative inaccessibility). Efforts to capture organisms for analyses were productive.

O. Platform 15

Platform 15, selected as the farthest offshore (115 km) and in the deepest water (98 m), is near the edge of the OCS in an area where the physical environment suggests that little contamination from outside the area would be present. Therefore, very low background levels would not interfere with demonstration of pollution from the structure at the lowest levels. Twenty-one wells have been drilled at the site signifying that high levels of production effects may be present.

As evidence of the ability to detect contamination even in very low background conditions, the trace metals and hydrocarbon analysts rank the site as "possibly affected" and "medium effect", respectively. The designation with regard to trace metals is based on the trend toward decrease in some metals on a transect away from the platform, but is not based on strong correlations. The hydrocarbon PI does not give specific reasons for his ranking and in fact the site is fifth lowest in total HMW-HC in sediments. Only dolphin fish (not likely a long-term resident) were shown to have significant HC contamination, though a creole fish from the structure also contained aromatics in the gonad and croaker from trawls contained aromatics in the flesh.

The contribution to overall platform-related effects cannot be assessed, but it should be noted that a major fire had recently occurred at S15 prior to sampling and numerous barges and boats were in the area during repairs. No matter what the source, it is evident that low levels of hydrocarbons and metals are in the immediate vicinity of S15 and may be due to structure-related activities. The techniques used in data synthesis of study results preclude confusion of naturally occurring contaminants with anthropogenic or petrogenic; therefore, it can be stated that effects on the physical environment have taken place in a previously pristine location.

Platform 15 shows no outward effects of contamination on the biota present. The species at the site are characteristic of the oceanic zone with no major connections to the shoreward habitats such as are exhibited by forms which require estuaries as habitat at some time in the life cycle. The fact that the top predators, such as the dolphin taken at the site, are contaminated indicates that the overall food web of the Louisiana OCS is probably affected by industrialization of the region.

P. Platform 16

Platform S16 was selected in the original program design to be the counterpart to P3 as both an oil and gas producer. Because of the platform changes made for P3 and P4 in the initial stages of the study, S16 should be compared to P4, an oil producer with a gas flare. Since S16 is a triple producer of oil, condensate and gas, the comparison would determine if further distance from riverine influence would affect study findings.

It should be noted that on 4 September 1978, S16 was observed to have an apparent leak of light liquid hydrocarbons which intermittently surfaced downcurrent approximately 10 m from the platform. The approximately 0.5-m diameter sheen formed largely dissipated within the length of the research vessel while moving downcurrent. Several hundred meters to the west of the platform a large gas leak erupted at the surface. (It is conjecture as to whether this was caused by Tropical Storm *Debra* or by anchor damage since a number of drill ships and semisubmersible drilling rigs were in the area).

Comparison with P4 shows that S16 is considerably more implicated as a contributor of hydrocarbon pollutants. Absolute levels of total HMW-HC in the sediments are fourth highest of all sites and much higher than at P4, and the HCI is one of the sixth highest. There is a distinct decrease in HC concentrations with distance from the structure. Platform 16 has been rated as definitely exhibiting platform-related effects in both sediments and biota, and ranked "high" in overall effects during data synthesis.

Further findings strengthen the argument that S16 is polluting the regional environment. Aromatic compounds have been confirmed by GC/MS to occur in croaker and amberjack from the site. All sediments contain relatively high amounts of a compound identified as a monophenoxybiphenyl. This obviously anthropogenic HC was also found in an amberjack at the site in a tissue concentration of approximately 1 ppm, considerably higher than other levels of HC contamination found in organisms in this study. There are some evidences of trace metals contamination, but the site is ranked as "possibly affected". Counts of aerobic hydrocarbonoclasts[1] were higher than at P4 or nearby S14 and S18.

[1]Aerobic hydrocarbonoclasts are microbes which degrade oil in the presence of oxygen.

While there is considerable indictment of S16 as a pollution source, it should be noted that the flora and fauna at the site are luxuriant and diverse, and indicative of a well developed population structure. This platform typifies the offshore zone, has a better developed community structure than either S6 or S13 near the Mississippi River, and is comparable to P4. The platform operator indicates that S16 is frequently used by sport divers and produces red snapper which are sold to the restaurant trade.

Perhaps the most significant finding at this platform with respect to areawide ecological impacts is the occurrence of the monophenoxybiphenyl. The source of this compound is unknown, but levels in sediments are high enough to indicate that it is large. The monophenoxybiphenyls are not produced for any known use in petroleum production. Originally they were to be used as dielectric fluids and perhaps in coatings, which gives rise to speculation that similar uses on platforms may have resulted in spills and resultant identification. The absolute levels indentified and the isolated occurrence around the deep water western platforms suggest sources might include previous dumping of unused industrial stocks. The environmental significance of these man-made compounds is that they are probably very slowly degraded in nature, are most probably toxic and likely carcinogenic. The physiological effects of this material on biota are unknown, but it is reasonable to assume that they would not be favorable. Since monophenoxybiphenyl is found in both sediments and fish at S16, and fish from the site enter directly into the restaurant trade, the implications are that contamination of the Louisiana OCS may hold a potential for human health effects. This type of contaminant and its relationship with commercial fisheries should be further investigated.

Q. Platform 17

Platform 17 was chosen for comparison with S15 as a similar bluewater location but in the largest deepwater oilfield on the Louisiana OCS. In general it might be said that the environment at S17 is slightly more contaminated than that at S15 with respect to hydrocarbons and that sediments are considerably more impacted with respect to trace metals.

The data show that moderate amounts of HMW-HC occur in the sediments and the HCI is a reflection of the contamination levels. There is some indication of a decrease in HC concentration with distance away from the structure. No important associations were found for the resident fish fauna and overall ranking based on platform-related effects was medium.

Trace metals analyses indicate that S17 is one of three sites most probably contributing to pollution. Five metals, Ba, Cd, Cu, Pb, and Zn, are concentrated in sediment samples taken near the structure. The presence of Ba and Cd strongly implies drilling mud contamination and the Zn is probably from anticorrosion measures at the structure. The Cu and Pb cannot be ascribed to a specific platform activity.

Review of diving activities at this site reveals several points which should be made about deepwater platforms. First, the diving is spectacular at such sites and surely sport divers will find increasing means to enjoy the beauty of these structures. Second, angling for sport species such as snapper and grouper is not successful with typical sport equipment or, based on the present writer's experience, with much of anything else. (The fish, observed and hooked, are just "too big, mean, and fast" to be successfully boated). The implication is that commercial fishing at "bluewater" sites is not as successful as at more inshore platforms (27- to 64-m depths). Bluewater platforms are productive for large pelagic gamefish. A last overall observation on the biota of these bluewater sites is that there is considerable difference in species available for analysis of tissue contaminants as compared to the more inshore locations. It is not practical to compare the analytical results for the species found at the offshore platforms with those from more neritic ones. Data generated are therefore useful only when considering stations at equivalent distances from terrestial influences.

R. Platform 18

Platform 18 was selected for study to represent a relatively large oilfield a moderate distance from shore and somewhat removed from riverine influences. The silty-clay bottom type was chosen because of the relatively high potential for contaminant capture. The operator indicates that with a produced water rate of 12,000 to 15,000 barrels per day (bpd), significant quantities of hydrocarbons may be released (15 to 19 gallons per day), despite the good treatment at the platform (30 ppm allowable oil).

Based on observations of a gradient away from the structure, this location is listed as one exhibiting probable effects from platform contributed Cu and Zn. This is not a strong implication and absolute levels of trace metals are comparable to those of nearby sites. Overall, the platform shows moderate hydrocarbon effects. The LMW-HC index (LCI) for LMW-HC in seawater was high relative to that of other sites; the sediment CPIs for HMW-HC were similar to those of other sites in the area; no definite structure-related effects such as HC gradients along the sampling transect were seen, and no definite contamination of resident biota was found. A single lane snapper (*Lutjanus synagris*) was found to exhibit petroleum contamination. Overall, the site has been ranked as "medium" based on platform-related effects from hydrocarbons.

S. Platform 19

Secondary Platform 19 was chosen for the particular purpose of determining ecological effects in an area with a very sandy bottom (95% sand). Three findings about this platform are of considerable significance. First, there is a distinct indication of Zn accumulation in sediments and second, the levels of sediment hydrocarbons are the lowest of any site. The history of the platform offers a probable explanation for the first observation and the sediment type is probably important in the latter. This very shallow location (6 m) allowed construction of a facility which was designed around large storage barges resting on the bottom and acting as a foundation for the platforms on top. According to operators, during the first few years of platform production the foundation tanks were used for storage of oil by displacement of the water in them. Barging of the oil to shore was done every 2 to 3 days when tanks were full. Since 10,000 to 11,000 bpd were produced, the potential for significant loss of oil with the displaced water in the storage barges was probably high. It is also reported

that 10-12 years ago a "whole pile of Zn anodes" were put inside the barges as an anticorrosion measure.

The third significant finding is that despite the low levels of hydrocarbons in the surrounding sediments, this location is cited as one in which fish fauna are contaminated with petroleum hydrocarbons. The implications are that even very low levels of long-term accumulation in nearby sediments may lead to bioaccumulation in resident organisms or, conversely, that the fish taken for study may have acquired their contamination at some other location enroute to the platform. At this particular site spadefish and sheepshead were the platform residents analyzed. The spadefish were small, probably recent immigrants, and did not exhibit HC contamination. The sheepshead were larger and contaminated with alkylbenzenes, naphthalene, methylnaphthalene, and two dimethylnaphthalenes in the gills and dimethylnaphthalenes and squalene in the liver. Since this species is habitat faithful and the gills capable of rapid cleaning and regeneration, it is the opinion of this writer that the contamination was acquired at S19. The implication is that sites with very low sediment hydrocarbon accumulations may offer opportunities for biomagnification of HC contaminants in the closely resident biota or that cycling of hydrocarbons from produced waters through the platform associated attached fauna to grazers is likely.

T. Platform 20

Platform 20 was selected as primarily a gas producer in a predominantly sandy bottom for comparison with S19, an oil producer. The results show that effects are probably more related to sediment sorption capacity than to actual platform-related contamination. This platform has HMW-HC in the sediments in quite low levels that compare with those at farther offshore P3, which has a significantly higher proportion of sand and less fine sediments. However, S20 is still much higher in overall amounts of hydrocarbons than nearby S19, which has a much higher proportion of sand. The CPIs indicate that there is likelihood of petroleum-derived contamination and show a level comparable with nearby C22 and C23. There does appear to be a gradient of decreasing hydrocarbons in the sediments with distance north from the structure. Trace metals data are inconclusive, but show indications of concentration of Cr, Ni, and Zn around the platform. Platform 20 has been described as possibly influenced by trace metal deposition, and overall is considered to have a "possibly affected" environment.

U. Control Sites

Unfortunately, this study was designed prior to a general knowledge of the chronically stressed condition of the Louisiana OCS. As a consequence, the sampling design did not incorporate enough Control Sites and sampling redundancies to differentiate and quantitate the very large area of riverine effect, the cyclonic storm results and oil production activities. As shown in the benthic studies, meiofaunal species diversity was higher at the Primary Sites than at the Controls during Cruises I and II, and the reverse was true during Cruise III. The data are not sufficient to explain why. Similarly, species diversities were higher at Primaries than at Controls during all cruises. The probable explanation for this is that each Primary Site had 16 sampling locations associated with it while only one sampling location was occupied at a Control. The more complete effort would result in more thorough sampling of patchy organisms and contaminants in microniches. Conversely, if the common notion of platforms acting as concentrators or multipliers of biomass is true then the results shown in this comparison of Platforms and Controls may be correct; again, the data are insufficient to prove the correct case.

The four Control Sites chosen for this program reflect the best available from the basic design constraints given. They were selected in areas in which no exploration or production had taken place but with physical characteristics similar to the closest study Sites. The Controls are briefly described below.

1. Control 21

This Control is adjacent to Primary 1 and is intermediate in location and at the same approximate depth as P2 and S5. It is the sandiest bottom type and varied considerably between cruises (Cruise I, 45% sand; Cruise II, 10% sand; Cruise III, 30% sand). The hydrographic parameters varied similarly, and this location was one which apparently showed maximal effects from hypoxic bottom conditions. These variables show that this relatively nearshore location is receiving a higher amount of terrestrial influence than other study sites. This Control, along with C22, was shown to be contaminated with unsaturated HMW-HC by GC/MS (3,6-dimethylphenanthrene, fluoranthene, pyrene, chrysene/triphenylene), which indicates the widespread occurrence of industrial pollutants over the study area.

2. Control 22

This Site is intermediate in location, and at the same approximate depth as P2, S8, S10, S11 and S12. It also experienced the heavy impact of riverine runoff and reduced bottom populations. As evidenced by the relatively high sand content of the sediment (ave. 23%), it probably is frequently impacted by terrestrial influences. As with C21, absolute levels of contaminants were not high, but evidence of industrial pollution was found.

3. Control 23

Control 23 was picked as the most offshore representative of the controls and is intermediate in location and at about the same depth as P3, P4 and S16. It showed exceptionally good water quality, evidencing the apparent intrusion of oceanic water in the area. Sediments were fine grained, mostly silt, and were not shown to contain any production related contaminants. Bottom organisms taken from this location showed a distinct difference from the preceding two Controls and were indicative of the outer shelf assemblage expected.

4. Control 24

Intermediate in location and at the same approximate depth as S14, S16, S18, S19 and S20, Control 24 was representative of Sites toward the western end of the study area, and was thus more removed from riverine influence. The clayey, silt bottom is representative of the outer shelf type, and the organisms present reflect the physical environment. No apparent gross contamination from production activities was found; however, as shown for C23, GC retention time indicated slight

presence of a broad range of aromatic compounds. This Site and all other Controls appear to have experienced some regional chronic petroleum contamination, either natural, man-induced, or both.

V. CONCLUSIONS

The following is not a list of the final observations made by individual PI's but is rather a personal discussion of the most important information gained in this study with regard to needs in management of the OCS. It is written following careful examination of the research findings in this study.

The occurrence of two natural perturbations during the course of the study, massive flooding of the Mississippi River and Tropical Storm *Debra*, brought two things very much into the consideration of all research. First, the flooding from the Mississippi apparently contributed significantly to the previously observed phenomenon of hypoxia (absence of dissolved oxygen) in bottom waters and sediments over much of the study area and thus to a natural stress on benthic populations at numerous platform sites. This precluded the taking of a number of the scheduled species and individuals as dictated in the sampling scheme; therefore, much potentially useful information was not incorporated into the final data synthesis. Second, both the flooding and the storm clearly demonstrated how normal populations can be much more greatly affected by natural perturbations than by the current industrial development of the Louisiana OCS.

It is apparent from study of all parameters that the entire region studied is contaminated with pollutants from man's activities. This contamination varies in both type and degree, and study sites exhibit ranges in actual amounts of hydrocarbons and trace metals. The hydrocarbon contamination is from petrogenic, pyrogenic, and anthropogenic sources and, depending on distance from terrestrial inputs, especially the Mississippi, may be related to activities at a particular production platform or to regional production. It is concluded that production on the Louisiana OCS is contaminating the area and that this contamination can be demonstrated in areas with a high degree of industrial pollutants from other sources as well as in pristine regions.

While studies show that long-term contamination of the area by hydrocarbons has taken place, it is apparent that long-term residual buildup of hydrocarbon loading is low, and no significant biological effects are apparent. This statement is based on studies which show that regional sediment dynamics have tended to mix sediments to a degree which precludes stratification. This is evident from the actual redistribution of sediments after a storm surge and the apparent disappearance of effects after large spills. The dynamics of the Louisiana OCS are such that apparently no long-term mass pollution loading has occurred. It is speculated that the long-term natural seeps of hydrocarbons in the area have led to development of microbial flora and resident faunas which have the capability of assimilating relatively high petroleum loading.

In consideration of platform characteristics as contributors to different levels of pollution, data synthesis efforts attempted to show whether age, degree of development, and type of production was reflected in actual contaminant levels. Neither hydrocarbon levels nor trace metals levels could be positively correlated with any of the production characteristics. The conclusions are that production practices differ so greatly at individual platforms that the limited data available for statistical evaluation were not sufficient to discern any characteristics which were consistently important in causing pollution. It may be that platform differences are so great that no particular factor is most important in determining pollution potential.

Overall, it is apparent that the sediment type at a platform is the single most important determinant of actual levels of contaminant accumulation. At those sites with very fine-grained sediments, levels of contaminants evidently will accrue which are significantly higher than those at a site with sandier bottoms, no matter what the production history of the platform.

Although sediments at a site may show evidence of contaminant accumulation, this has no bearing on the contamination of the organisms collected at the site. This holds true for all types of specimens examined. Numerous problems of collecting the target species and sufficient numbers plagued the researchers in this project; however, review of the complete suite of specimens and analyses shows that emphasis in future similar studies should be placed on sessile invertebrates and habitat faithful fish. This means that molluscs should be the target invertebrates, either in the mud near a platform or attached thereto, and that fish should be spadefish and sheepshead at coastal sites, red snapper at more offshore locations and perhaps creole fish at bluewater platforms. Evidence from this study shows that taking a number of species, even when they are the only ones available, in order to fill a gap in sampling requirements, is of little value. One thing learned from taking a spectrum of fish species is that at the higher predator level, i.e., dolphin and amberjack, absolute contaminant levels appear to be the result of biomagnification of hydrocarbon contaminants. The significance to this study is that absolute levels are still quite low (ppb range) and the biological significance is unknown.

VI. ACKNOWLEDGEMENTS

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.