Project Number 6

Influence of Hypoxia on the Interpretation of Effects of Petroleum Production Activities

Principal Investigator
Nancy N. Rabalais
Louisiana Universities Marine Consortium
Chauvin, LA 70344

Co-Principal Investigator
Edward B. Overton
Institute for Environmental Studies
Louisiana State University
Baton Rouge, Louisiana 70803

Collaborating Investigator
Dr. Robert P. Gambrell
Laboratory for Wetland Soils and Sediments
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana 70803

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ABSTRACT

The continental shelf of the southeastern Louisiana coast is the site of extensive oil and gas production activities as well as the largest area of seasonal near-bottom hypoxic waters in the coastal United States. Studies of the environmental effects of offshore oil and gas development on the Louisiana shelf have been confounded by natural phenomena such as seasonal hypoxia. We proposed to study the benthic environment and faunal communities of production platforms located in the hypoxia zone. We hypothesized that the effects of offshore development can be identified and placed in the context of natural, temporal variability, in this case as caused by hypoxic bottom waters. During year 1, a study design was developed which incorporated several production platforms surveyed during an initial reconnaissance research cruise. The full suite of chemical contaminants analyzed during the initial survey was narrowed in year 2 when the benthic community structure of selected sites was followed during the season of hypoxia. Supplemental funding from the NOAA NECOP (Nutrient Enhanced Coastal Ocean Productivity) Program, the Louisiana Sea Grant College Program, and LUMCON provided for post-hypoxia recovery period and spring recruitment period follow-up studies of the benthic communities.

PROJECT GOALS AND OBJECTIVES

In the extensively and intensively developed oil and gas production areas of the Gulf of Mexico, past studies of the effects of offshore petroleum development have suffered from (1) inadequate sample design and (2) the confounding effects of the Mississippi River as a source of turbid fresh water and anthropogenic pollutants, seasonally intense and widespread hypoxic bottom waters, and storm events. Still, within this area, differences in hydrocarbon contamination of sediments are evident, particularly where there are large amounts of operational discharges, i.e., produced waters. We proposed to test whether the effects of hypoxia can be separated from the effects of petroleum production contaminants incorporated into the sediments.

It is highly probable that an area of the southeastern Louisiana inner continental shelf where there are extensive oil and gas production activities will experience hypoxic bottom waters during the summer season. We originally proposed to locate two oil and gas production platforms within 50 to 100 km of each other in a 20- to 30-m depth range off Terrebonne and Timbalier Bays as study sites. One platform was to have a greater volume of produced water discharge than the other. A near-bottom continuously recording oxygen meter was to be placed at one of the production platforms. It was assumed that dissolved oxygen levels at the two sites would be similar throughout the season of hypoxic bottom waters. It was also assumed that concentrations of hydrocarbons and other contaminants from produced water discharges could be identified in the sediments along a gradient away from the platforms. We have documented from previous studies that benthic communities can be identified as being affected by low oxygen conditions by various measures including abundance, number of species, species composition, and age and size class structure. Given our knowledge of benthic community structure as influenced by hypoxia, we hypothesized that differences in benthic communities could be correlated to differences in petroleum production contaminants in bottom sediments where hypoxia occurs.

The first year's (June 1989- May 1990) goals were to:

1. Select potential study sites from the southeastern Louisiana continental shelf where bottom water hypoxia occurs and where oil and gas production platforms with significant production discharges were also located.

2. Conduct an initial reconnaissance of study sites during the summer of 1989 to determine the general patterns of variance in faunal, chemical, and environmental parameters. The

reduced scope of the original research plan called for a concentration of effort on the production or "primary" site with a reduced effort at the "reference" site.

3. Determine if any environmental signals that would indicate oil and gas production activities were present in the proposed study sites.

4. Narrow the field of chemical contaminants to be analyzed in the subsequent year's study and determine the number of radii, number of quadrants, and number of replicates necessary to test for an impact.

The second year's (June 1990- May 1991) goals were to:

1. Conduct monthly surveys during the period of hypoxia (June, July and August) at the two study sites. Stations at each site would be determined from the results of the first year's analyses.
- 2. Complete laboratory analyses of the second year's field effort.
3. Complete data analysis of the second year's field effort and begin publication preparation.

The third year's (June 1991- May 1992) goal is to:

1. Complete publications.

ACCOMPLISHMENTS TO DATE

Selection of Study Areas

The selection process for suitable study areas involved a lengthy series of information requests from several offices of the U.S. Minerals Management Service, Gulf of Mexico OCS Regional Office in New Orleans and the Denver office; and several oil and gas operators: Conoco, Mobil, Shell, Exxon, Unocal, Chevron, and Kerr-McGee. All parties were most helpful in providing information. We were delayed, however, in final selection of potential study areas until April 1990 by the disjunct sources of information and non-conformity of site information.

The platforms targeted as potential study areas are shown in Figure 1 and listed in Table 1 and were sampled in April 1990. Two of the platforms named in Table 1, Unocal's South Timbalier 53 A and A-Aux. and Chevron's South Timbalier 52A complex, were in close proximity to the instrument deployment at Unocal's South Timbalier 53B platform. One of the two (Chevron's ST52A complex) had a much larger produced water discharge (20,000 bbl/d versus 5,000 bbl/d). The Shell West Delta 32E platform, while significant in produced water discharged, was in a different sedimentary regime than those of the South Timbalier 52 and 53 blocks. Sediments in West Delta 32E are predominantly silts (85 to 90%) while those of the South Timbalier 52 and 53 lease block are predominantly sands with equal silt and clay fractions. Thus a dilemma was posed in a tradeoff between a large discharge that may provide more of an environmental signal in sediments of smaller size fraction (Shell's West Delta 32E) versus a large discharge (Chevron's ST52A complex) or a smaller discharge (Unocal's ST53A and A-Aux.) in a sedimentary environment that would be less likely to record chemical contaminants but that was located close to an existing instrument mooring. A second dilemma was posed with the information from Unocal that the ST53A and A-Aux. was scheduled for exploratory drilling in the area in 1990, and that the ST53B inactive platform was scheduled for removal in 1991. An additional problem was the necessity of confining the transect configuration at Chevron's ST52A complex to a single 15° NNE quadrant in order to avoid pipelines entering the complex.

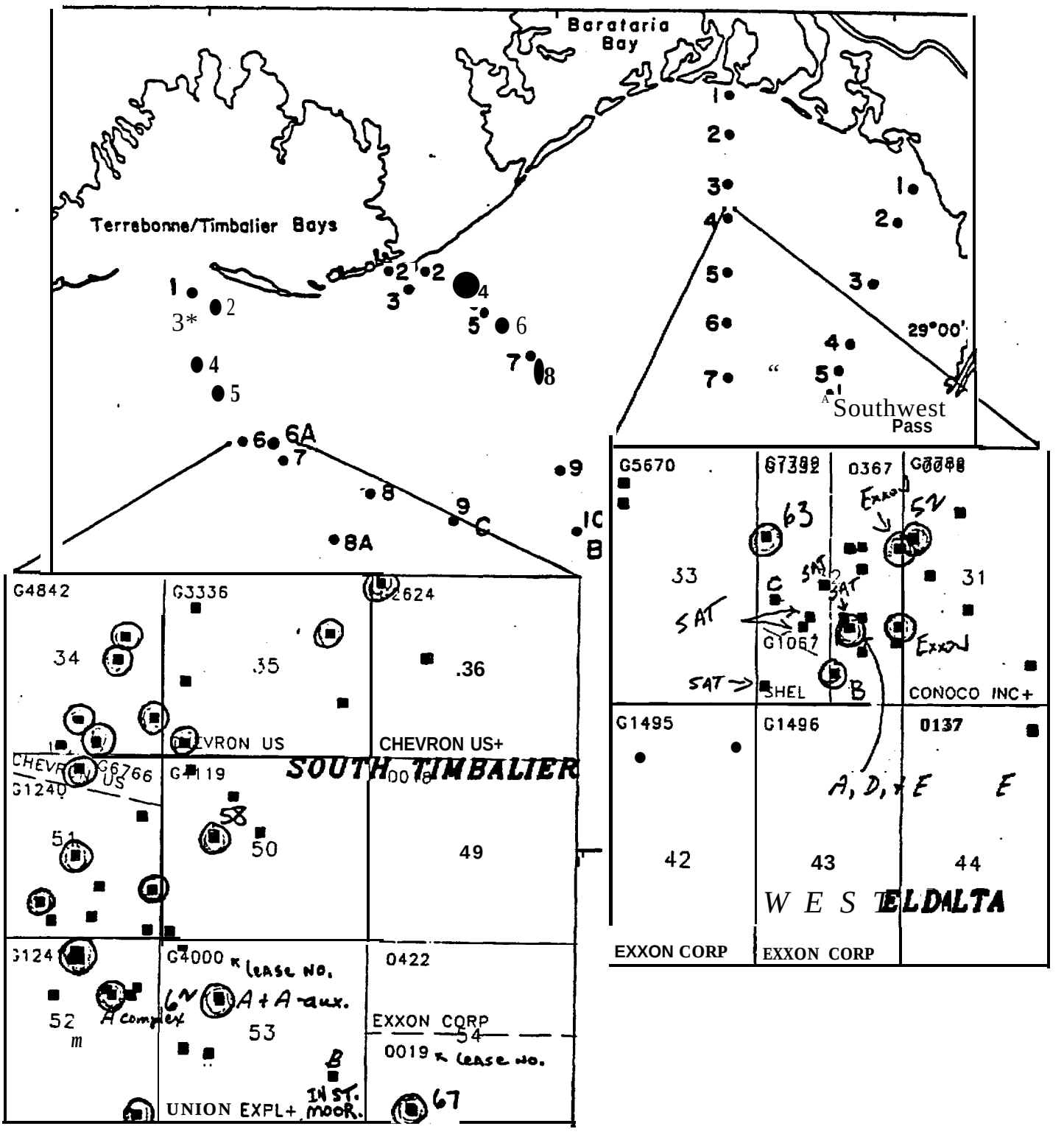

Figure 1. **Location** of hypoxia monitoring transects and South **Timbalier** and West Delta study areas.

Table 1. Potential study areas.

Company	Lease Block	water Depth (m)	Volume Discharged (bbl/d)
Shell Offshore Inc. (she of second oxygen meter)	west Delta 32E	19	19,000
Unocal	South Timbalier 54A and A-Aux.	19	5,500
Unocal (site of Rabalais et al., LEQSF and NOAA NECOP instrument mooring)	South Timbalier 53B	19	inactive
Chevron U.S.A., Inc.	South Timbalier 52A complex	19	20,000

Initial Reconnaissance Cruise

The research cruise was conducted on April 17-19,1990 aboard the LUMCON R/V *Pelican.* Details of this cruise were provided in last year's annual report. In summary, we were successful in obtaining samples from several stations at each of the platforms listed in Table 1, but with complicating factors at two of the four. Stations were located at distances of 20, 50, 100, 250, 500,750 and 1000-m from the platform where possible.

Stations at Chevron's ST52A complex were taken along the designated single 15° NNE quadrant. This was not in the expected *direction* of surface currents. Sampling at this platform was further complicated by the shell hash that covered the bottom at stations 100 and 50-m from the platform. Box coring was difficult at the 100-m station and impossible at the 50-m station. Because of the sea state and the seabed conditions, samples were not attempted at the 20-m station. The benthic community at the 100-m station was more typical of a hard substrate than the soil bottom benthic community that was collected at the 250-m station. Thus, while the Chevron ST52A complex had a large produced water discharge, the substrate and the quadrant limitations did not make it a suitable study area. Since the initial reconnaissance, we received from Chevron a pipeline drawing for the platform with an indication that pipelines located to the west of the "C platform were buried when installed so that risk of damaging a pipeline should be minimal. We conducted sampling along a different quadrant in June (see below).

Sampling around the Shell WD32E platform was complicated by sandblasting activity on the platform. Sediments from the station closest to the platform indicated that the sand from the sandblasting operations were the predominant sediments on the seabed. Sediments at the 50-m station were more typical of the silts expected. There were also indications of hydrocarbon contamination at the 50-m station (oily sheen seen while washing the benthic samples). A "reference" station for this platform was taken in the West Delta 33 block, about 1.6 miles to the west of WD32E platform in an area where there were no other platforms located.

Instrument Deployments

The instrument mooring with current meters, particle traps, and near-bottom continuously recording oxygen meter as part of the Rabalais, Turner and Wiseman hypoxia studies was

deployed in March 1990 at ST53B. Recovery of the oxygen meter in mid-May 1990 indicated a problem with the instrument and loss of the first two months recorded. Data was recovered from mid-May through mid-October, when the mooring was taken out of the water prior to the scheduled removal of the ST53B platform by Unocal.

The second oxygen meter was deployed at the Shell WD32E platform in mid-June. Data was recovered from mid-June through mid-October, when the mooring was taken out of the water.

Hypoxia Cruises in 199Q

Cruises were conducted at the platforms listed in Table 1 during mid-June, mid-July and mid-August. Preliminary chemical analyses for hydrocarbons and trace metals were completed for the samples collected during the April reconnaissance cruise so that changes in study design could be implemented during the hypoxia cruises.

Because of lack of a contaminant gradient along the 15° NNE heading from the Chevron ST52C platform, a second heading of 270° W was selected for subsequent collections in June-August. Sampling during the hypoxic period was conducted at Shell WD32E, Chevron ST52C, Unocal ST52A and Unocal ST53B, in June and July. Results from the June sampling along the 270° W heading at ST52C indicated hydrocarbon contaminants at the 50-m and 100-m stations with a decrease away from the platform and with change from petrogenic to biogenic hydrocarbons. Sediments at the 20,50 and 100-m stations were also different in texture from those farther removed from the platform. Difficulty in reoccupying the same sediment types during July at the Chevron platform and the gradient of sediment types, have caused us to drop this platform from the study. Sampling during the August hypoxic period was conducted at Shell WD32E, Unocal ST52A and Unocal ST53B.

Sample Analyses

All the benthic infaunal samples for the collections made in April, June, July and August 1990 of the MMS-University project (n= 355) have been rough sorted. Samples from the deleted transects (15° NNE and 270° W at Chevron's ST52C platform) will not be analyzed, unless time permits at the end of the project. Full taxonomic identifications have been made on 25% of the samples. The month of April has been completed; June-August remain.

[Benthic samples collected as part of the NOAA NECOP program for post-hypoxia recovery and recruitment periods during September and October 1990 have been sorted and identified by the collaborator from Texas A&M University, Dr. Don Harper. Similar collections for February 1991 are in his laboratory; those from March-May 1991 are being rough sorted at LUMCON.]

All sediment grain size, chlorophyll *a*, and TOC samples have been analyzed. Surface sediment hydrocarbon and trace metals analyses have been completed The hydrocarbon analyses have been quality controlled and the data reported. The trace metals remain to be quality controlled and reported

The samples for the Pb-210 analyses were shipped to International Technology Corp. in December 1990 and were projected for completion in May 1991. To date (5-28-91), these analyses have not been received

Hydrographic data from the April - August 1990 cruises has been entered into the computer. The data from July 1990 is still being reduced (SeaBird CTD in July versus Hydrolab Surveyor II in the other months). The data from the two Endeco 1184 deployments has been downloaded and is being quality controlled with post calibrations of the probes and cross-comparison with the CTD data.

Supplemental Funding

The principal investigator, N. Rabalais, collaborated with Dr. Donald E. Harper, Jr. of Texas A&M University of Galveston on a proposal to the NOAA NECOP program. This proposal was to follow the post-hypoxia recovery period and the spring recruitment period of the stations sampled for the MMS-University Initiative study. We further proposed to compare the results of the ongoing investigation with previous studies from the southeastern Louisiana shelf where hypoxia is recurring and persistent to areas off the southwestern Louisiana coast and the upper Texas coast where hypoxia is more of an ephemeral event. Additional aspects of the proposal were to supplement NOAA National Undersea Research Center (NURC) facilities funding of ship support and ROV (Remotely Operated Vehicle) to study benthic and demersal communities in relationship to hypoxic bottom waters. Funding was secured for the NOAA NECOP project. Additional funds were obtained from the Louisiana Sea Grant College Pmgrarn, LUMCON, and the Texas Institute of Oceanography to fired vessel rentals for some of the above-mentioned projects.

Supplemental vessel funding provided for cruises during post-hypoxia recovery (September and October of 1990) and during the following spring recruitment period (February, March, April and May of 1991) at the stations occupied during the MMS-University Initiative sampling.

SIGNIFICANT FINDINGS

We are at the end of the second year of study of a three-year project. Without a complete set of benthic community and chemical analyses, it would be premature to draw conclusions from the study. Some observations, however, can be made.

conditions of Hypoxia

First, the 1990 season of hypoxia was unusual from the previous five years studied in that hypoxia occurred earlier and more persistently in the spring, hypoxia was more severe through the summer months, hypoxic bottom waters occurred farther offshore and in deeper waters, anoxic conditions were documented for *long periods* of the record, and the generation of hydrogen sulfide in the bottom waters was recorded more often. The flow of the Mississippi River was high for 1990, with crests in March and another in June. The long-term average period of high flow is usually in April. Winds and currents were also different than the expected long-term average.

Benthic Communities

Initial results from the benthic work indicates that a healthy benthic community was present in April 1990. The species richness and number of individuals were high. Preliminary results from an undergraduate research project on the vertical sediment core sections taken along with the standard Ekman cores at the ST53B platform indicated a reduction in fauna in May and a dramatic decline during June and July.

Hydrocarbons

Sediments for hydrocarbon analysis were extracted using a sediment tumbled extraction method and analyzed using GC/MS (gas chromatography-mass spectroscopy). The mass spectrometer was used in selected ion monitoring mode to produce extracted ion chromatograms (EIC) in order to detect trace quantities of analytes in complex matrices. Results of analyses of analyte-spiked sediments verified that the analysis produced compound recoveries which were generally within EPA acceptance criteria. In the few cases of spike recovery data which were outside the acceptance criteria, the deviation was at the upper end (>100% recovery) in a sample for which the lack of duplicate analyses made the non-spike analyte concentrations less precise than in all other cases.

Results of sediment analyses indicate no clear progression of analyte concentrations with proximity to the platform at a given site and no clear temporal patterns in the summer of 1990. The analytes detected in all samples were likely from pyrogenic and petrogenic sources. The April 1990 samples from Chevron's ST52C showed no analyte concentrations above 35 ppb; and the June ST52C samples showed highest analyte concentrations at 50 m (5-300 ppb) and 250 m (10-100 ppb). [N.B. the relocation of the transect at ST52C between April and June, but the subsequent dropping of this site from the study.] The analyte concentrations in sediments from Shell's WD32E platform showed no pattern of temporal variations, but the June samples at 50 and 100 m had somewhat higher concentrations of higher molecular weight compounds (i.e., fluoranthenes, pyrene at levels of approximately 200 ppb). The Chevron ST53A site sediment samples had concentrations of analyte compounds below 50 ppb (dibenzothiophene) and showed no clear temporal pattern and no pattern of distance from the platform. Concentrations of analytes in the Unocal ST53B sediments were similar to or lower than those in samples from ST53A. In summary, the lack of clear patterns in spatial and temporal variations in neutral semivolatile organic analyte concentrations suggests that subtle effects of these compounds on benthic organisms maybe absent, hard to detect, or may be the result of some other factor and not discernible without prohibitively intensive sampling.

Trace Metals

Sediments for trace metal analyses were prepared by standard techniques for an inductively coupled argon plasma emission spectrometer (ICP). Standard quality control measures were conducted. Elements analyzed included copper, zinc, cadmium, lead, chromium, nickel, iron, manganese, calcium, magnesium, phosphorus, aluminum, potassium, sodium, barium, and vanadium. Additionally, barium and vanadium were analyzed on an adjustable emission wavelength spectrometer and detector, a supplemental analysis system built into the main instrument for analysis of elements for which freed detectors are not available. For the April 1990 samples, barium and vanadium were analyzed on two different ICP instruments on the LSU campus to confirm the performance of the primary instrument located in the Wetland Biogeochemistry Institute.

Metals content of sediments are dependent on sediment texture. Trace and toxic metals are more strongly associated with the fine, clay and silt particles and the naturally occurring organic matter that tends to be found with this size fraction. Textural variability in the study areas can contribute to considerable variability in observed metal levels which can be identified and corrected by normalizing to a non-pollutant element or elements typically found in weathered clays in high concentrations. Such elements include iron and aluminum. Thus, in the final analyses we plan to present the actual concentration of metals on a dry weight basis, and evaluate the data normalized to common elements found within the clay size fiction.

For purposes of a preliminary comparison to background levels, the metal concentrations measured have been compared to typical levels reported in the lithosphere and soils (Fuller and Warrick 1985) and granitic rocks, shales, deep-sea clays, and carbonates (Forstner and Wittmann 1979). None of the elements measured would be considered out of range of typical levels found in soils and sediments. Regional differences in natural levels, contamination sources, sediment texture, and other factors all contribute to the concentrations of metals found. Thus, from a preliminary comparison of the data between sampling sites, and with general levels reported in the literature, it is not possible to say there may not be some elevation in levels from anthropogenic activities in the sampling areas, but it is possible to say that excessively high concentrations of these metals are not present.

There are no strong trends for changing concentrations in metals with distance from the platforms. Upon further evaluation of the data as discussed above concerning metals association being dependent on particle size, we may see some trends. This evaluation is continuing and should be complete soon. At this point, there may be a weak trend for zinc concentrations that change as a function of distance from the potential source. A more thorough evaluation of the data and other site-specific factors will be conducted now for preparation of the final results.

PROBLEMS OR DELAYS ENCOUNTERED AND PROPOSED SOLUTIONS

Funding startup in June 1989 was inappropriate for staging an initial reconnaissance cruise for the 1989 hypoxia season. The timing of the initial cruise, however, was not necessarily dependent on hypoxia. The purpose, to characterize the sedimentary contaminant variables and the benthic community structure, could be accomplished in the cruise scheduled for and completed in the spring of 1990.

A delay of about six months in beginning the study was the result of the principal investigators pregnancy and maternity leave. More lead time than anticipated was necessary for obtaining all the information from the numerous sources for selection of potential study areas. This caused a delay in the initial reconnaissance cruise. This cruise and the subsequent cruises during the hypoxia period, however, were completed in a timely fashion.

Analyses of benthic infaunal samples are behind schedule. One of the infaunal taxonomists was called to active duty for the Marine Reserves and left LUMCON in mid-November 1990. A replacement was not found and hired until February 1991, and delays were encountered as he was trained and became proficient in polychaete taxonomy. The other taxonomist will return to work in June 1991, and we will double up on efforts to complete the taxonomy of the samples. This unexpected series of events has placed us about six months behind the schedule projected in the last annual report.

Trace metal analyses are scheduled for quality control and final synthesis within the next several months.

The removal of Brent McKee from the project for the radioisotope studies created a vacuum which was long in filling. The results from the Pb-210 samples done by International Technology Corp. should be received shortly.

Problems with the Endeco 1184 oxygen meter in the March-May 1990 deployment at ST53B were not anticipated, nor can they be corrected after the fact. We changed the maintenance schedule to a monthly change of the batteries and data cartridge and a bimonthly change of the probe. The delay in receipt of the second Endeco 1184 caused

problems in that not as complete an oxygen record was available for the Shell WD32E platform as was collected for the Unocal ST53B platform.

The above are logistical problems that were eventually corrected. A more substantial problem lies in the determination of an adequate study area in order to test the original hypotheses. As noted above, four study sites were sampled in the original reconnaissance cruise. The ST53B platform is a reference area for two platforms (ST53A and A-Aux. and ST52A) with substantially different volumes of produced waters discharged. These three platforms are located within an area of the continental shelf where background information exists, where an instrument mooring is located, but where sediments are less likely to incorporate a chemical contaminantt signal. The Chevron ST52C platform was eventually dropped from the study design because of too many confounding factors. The fourth platform (WD32E) has a substantial discharge, is located within a sedimentary environment where contaminants are more likely to be absorbed into the sediments, but is located a considerable distance and in a sedimentary environment than the preferred reference station with the instrument mooring. Also, there was more variation in the bottom water oxygen concentrations between the two study areas than anticipated. This is a complication of field studies that cannot be corrected. With data from the three platforms, it will be possible (in the event of minimal chemical signal) to at least characterize the benthic communities from a variety of sedimentary regimes where hypoxia is persistent and severe during the summer months. The usefulness of this data set will be extended with the samples being collected under NOAA NECOP during post-recovery and the following recruitment periods.

REVISED SCHEDULE FOR REMAINDER OF PROJECT

June - July 1991	Complete trace metal and Pb-210 analyses
June - Dec. 1991	Complete benthic sample analyses Complete benthic sample analyses for NOAA NECOP
Oct. - Dec. 1991	Data entry on computer
Jan. - May 1992	Data synthesis, publication preparation and completion

PROJECT PARTICIPANTS

The investigators listed on the title page, Dr. Nancy N. Rabalais of the Louisiana Universities Marine Consortium and Dr. Edward B. Overton of the Institute for Environmental Studies at Louisiana State University, were named as original participants as Principal Investigator and Co-Principal Investigator, respectively. Dr. Rabalais is directing the program and is the principal investigator for the benthic community studies. Dr. Overton is the principal investigator in charge of chemical contaminant analyses. Dr. Robert Gambrel has been asked by Dr. Overton to complete the trace metal analyses.

The proposal originally named Dr. Brent A. McKee of LUMCON as a co-principal investigator in charge of radioisotope studies. Dr. McKee indicated early in 1990 that he would be unable to fulfill his obligations to the study in the radioisotope analyses. The samples have subsequently been sent to International Technology Corp. for analysis.

Laboratory analyses for the project, including benthic and chemical samples, are conducted by a series of Research Associates (4-LSU), Research Assistants (6-LUMCON), Graduate Research Assistants (1-LSU), and Undergraduate Research Assistants (7-LSU, 1-LUMCON).

RELATED PUBLICATIONS AND PRESENTATIONS

No publications have resulted from this project. Sample analyses are still in progress.

The following presentations have been made for which some of the data generated in this research program have been shown:

Rabalais, N.N. 1990. Invited participant in EPA Workshop on Derivation of a National Saltwater Dissolved Oxygen Water Quality Criterion, November 1990.

Rabalais, N.N. 1991. Northern Gulf of Mexico Hypoxia: Effects on Benthic Communities, Seminar at University of Rhode Island, Graduate School of Oceanography, January 1991.

Rabalais, N.N. 1991. Hypoxia on the Louisiana Shelf: Biological Aspects. Seminar at Louisiana State University, Dept. of Oceanography and Coastal Sciences, February 1991..

Wiseman, W.J., Jr., **N.N. Rabalais** and R.E. Turner. 1991. Interannual and Intra-annual Variability of Hypoxia on the Louisiana Inner Shelf. The Oceanography Society, St. Petersburg, Florida, March 1991.

Rabalais, N.N. and R.E. Turner. 1991. Louisiana Shelf Sediments: Benthic-Pelagic Coupling, Marine Benthic Ecology Meetings, Williamsburg, Virginia, March 1991.

Rabalais, N.N. 1991. Hypoxia in the Northern Gulf of Mexico. Seminar at the University of Mississippi, Dept. of Biology, April 1991.

PROPOSALS SUBMITTED AND GRANTS RESULTING

Most of the proposals that have been submitted in the last year are related to studies of hypoxia or produced water discharges. A listing of these and the status follows:

Rabalais, N.N. and D.E. Harper, Jr. The Impacts of Hypoxia on Benthic Populations and Fisheries Resources. Submitted 1990, duration: Aug. 1990- July 1992, NOAA NECOP, funded.

Rabalais, N.N. and D.E. Harper, Jr. Supplemental Ship Funding for Studies of the Impacts of Hypoxia on Benthic Populations. Submitted: June 1990, duration: July 1990- Sept. 1990, Louisiana Sea Grant College Program and LUMCON, funded.

Harper, D.E., Jr. Supplemental Ship Funding for Studies of the Impacts of Hypoxia on Benthic Populations. Submitted June 1990, duration: July 1990- Aug 1991, Texas Institute of Oceanography, funded.

Patrick, W., R. DeLaune, N. **Rabalais,** E. Overton, R. Adams, J. Suhayda, A. Pulsipher, and M. Reams. Produced Waters in Louisiana Wetlands. Submitted: Jan. 1990, duration: 30 months, U.S. Dept. of Energy, pending.

Murray, S. et al. Physical Oceanography of the Louisiana-Texas Shelf. Submitted: June 1990, Dec. 1990, May 1991, duration: 56 months, U.S. Minerals Management Service, pending.

LITERATURE CITED

Forstner, U. and G. T. W. Wittmann. 1979. Metal Pollution in the Aquatic Environment. Springer-Verlag, Berlin, 486 pp.

Fuller W. H. and A. W. Warrick. 1985. Soils in Waste Treatment and Utilization. Vol. 1. Land Treatment. CRC Press, Inc., Boca Raton, Florida, 268 pp.