BIOLOGICAL EFFECTS OF PETROLEUM EXPLORATION AND PRODUCTION IN COASTAL LOUISIANA

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INTRODUCTION

This report is an attempt to organize and summarize various opinions and conclusions concerning the effects of extensive oil exploration and production on a unique and unstable ecological area which, in addition to petroleum, is also one of the most productive marine nursery areas in the world. The observations, discussions and conclusions presented herein are based upon twenty years of field investigation and observation, some controlled laboratory and field experiments and the resulting practical administrative procedures developed to regulate the petroleum industry in the coastal area of Louisiana.

In dealing with the problems of the total impact of oil exploration and production on the ecology of the area under discussion, some of the more spectacular aspects of oil production that affect the environment such as accidental blowouts, fires and pipeline ruptures will be de-emphasized. Such de-emphasis is relative, however, and is not because of any lack of importance or concern over such apparent disastrous occurrences but because in Louisiana other factors associated with oil production have proven to have a far greater impact on the environment.

Finally, the presentation while calling attention to numerous ways in which oil production may affect the environment is not an indictment of the total petroleum industry nor will it lend credence to the necessity for a system of total preservation of coastal and marine areas. In essence, it is an attempt to summarize some of the many problems and a few of the answers involved in the practical administration and technical management of a highly productive but delicate and unstable ecological area subjected to large scale petroleum exploitation.

LOUISIANA'S COASTAL AREA

Along Louisiana's entire coast from Texas to Mississippi stretches a unique area of some seven million acres of marshland which is interlaced by miles of bayous, ponds and embayments. This area, generally uninhabited, averages from twenty to forty miles in width and separates the higher land from the gulf. The water area in this coastal belt has been determined to be 3,378,942 acres while the low-lying marshlands occupy 3,695,000 acres.[1]

Geologically, this vast area was formed from the wandering of the Mississippi River delta, from the deltas of its numerous distributaries and from the deltas of several lesser rivers. Land was built as silt deposited over the years, later subsiding to form much of the marsh area. Once formed, the drainage pattern in the marsh, running usually from north to south, developed into a network of numerous meandering bayous and streams which open into a series of interconnected bays, the latter draining into the gulf proper through narrow passes formed between an outlying chain of barrier islands. Because of the slow movement of drainage from the north and because the barrier islands to the south tend to retard the entrance of excessive sea water, the thousands of acres of brackish water bays and marshes are vast mixing bowls of salt and fresh water. With small extremes of tides and tortuous water courses, transition from one salinity range to another is gradual and large zones of relatively stable conditions are common. These ecological zones may range from nearly fresh on the inner edge to quite salty near the gulf, and thus afford a wide range of environmental characteristics for many important forms of marine life.

The Louisiana coastal area has been noted for its high production of oysters, shrimp, fish, fur and waterfowl for many years, but few people realize the total magnitude and value of these natural resources.

Statistically speaking, Louisiana produces between eight hundred million and 1.2 billion pounds of commercial fish annually or more than twenty percent of the total U. S. production. This staggering production of protein does not include the poundage taken for recreational fishing, that poundage lost and thrown away incidental to shrimp fishing, nor does it take into consideration the normal attrition which would occur in such a dense population of animals. The total value of the commercial fishery of Louisiana approaches a hundred and fifty million dollars annually and this figure does not include the economic value of recreational fishing and tourism. The area also supports a significant fur production which in peak years exceeded the combined production of the other forty-seven states. Each year it serves as a wintering ground for from five to seven million waterfowl.

The exact mechanics and ecological basis for such a continuing staggering production of seafood and wildlife is not completely understood, particularly in view of the fact that the impact of industrial activity on the ecology of the area has been severe. As noted above, various types of large ecological zones occur in the area. The Mississippi, Atchafalaya, Pearl, Vermilion and Calcasieu Rivers feed the area with nutrients, and the many bays and flooded marshes serve as a vast nursery ground for the young of many important bay and gulf species of crustaceans and fishes. Our knowledge of the detailed basic ecology of the area, the mechanics of its productivity, and the effects of natural and man-made ecological changes on production leave much to be desired, but long association with the area coupled with continuing observations, investigations and research has resulted in a reasonably clear understanding of the Louisiana coast and its productivity as it relates to the petroleum industry.

HISTORY OF PETROLEUM EXPLORATION AND ASSOCIATED POLLUTION PROBLEMS

The production of oil in the coastal estuaries of Louisiana began in the late 1920's but reached its greatest intensity during and shortly after World War II. Offshore production was established off Creole, Louisiana, in 1937, but major offshore discoveries did not occur until 1947 and reached a high level in the late 50's and throughout the 60's.[2]

During this long period of petroleum activity a great many wells have been drilled and miles of pipelines have interlaced the estuarine and offshore areas of Louisiana. Statistics from the Louisiana Department of Conservation indicate that the accumulative total of active and plugged wells in the intermediate zone and the offshore areas was 24,588 in 1969.[3] U. S. Geolcgical Survey data indicates a total of 6,556 active wells in Zones 2, 3 and 4 off Louisiana and Texas.[4] Additionally there are some 207 inactive underwater stubs in offshore areas which will eventually be developed. Offshore platforms number 1792 on the Louisiana and Texas coasts of which 1742 are in Louisiana. There are 1089 single well structures and 703 multiple well platforms that have been constructed in water depths ranging up to 350 feet but the bulk of these structures occur in water depths from 0 to 150 feet.[5]

Actually the exact number of wells drilled, the number of producers and the miles of pipeline laid over this long period of time can only be estimated. Accumulative statistics are kept only on active and temporarily inactive wells and the available figures fluctuate from month to month.[6] Dry holes and depleted wells are not listed. Similarly the extent of pipelines is not clear. Larger trunklines and feeder lines are mapped but the myriads of gathering lines, many of which have been abandoned over the years, were not recorded.

It would be of interest to know the total number of drilling operations that have taken place on the Louisiana coast since the first well was drilled in 1927. Possibly between thirty and forty thousand or more separate operations may have occurred each of which caused some disruption of the local ecology and no doubt resulted in localized pollution which lasted for various lengths of time.

The history of oil pollution on coastal Louisiana parallels the rise of the petroleum industry. Though fewer wells were involved in the early years, pollution per se (i.e., oil slicks, spillage, waste and oil-based mud) was more or less rampant and uncontrolled. This is not hard to understand if it is recognized that until after World War II the coastal region of the state was a virtual trackless wilderness. Except for several thousand commercial fishermen and trappers who used the vast area on a transient basis, it was largely uninhabited and to the layman valueless except for possible mineral production.

We find, therefore, that oil waste, leakage, sludge and other materials were dumped into the marshes and bays without regulation or control. This uncontrolled pollution of embayments and marsh areas reached a peak during the war years with the great demand for petroleum. It culminated in litigation when the oyster growers filed a thirty million dollar suit against the petroleum industry alleging that massive oyster mortalities that occurred in 1943 and 1944 were a direct result of oil and bleed water pollution.[7] This action resulted in several significant accomplishments.

1. A massive research effort by the petroleum industry to determine the relationship between oil and oyster mortalities was carried on for a number of years.
2. A similar but smaller research effort was made by the Louisiana Wild Life and Fisheries Commission.
3. The establishment of a pollution control system, the passage of pollution laws and the formation of the Stream Control Commission and the Coastal Waste Control Section of the Wild Life and Fisheries

Commission was completed by 1950.

4. Finally a complete surveillance and direction of coastal management by means of permits and letters of no objection on all industrial activities was instigated in 1960.

Since 1950 oil pollution control and associated coastal management has become well established and under the authority of the Wild Life and Fisheries Commission and the Louisiana Stream Control Commission. The effectiveness of these regulations and the control of pollution is readily apparent to those familiar with early uncontrolled conditions. Nonetheless, with twenty thousand or more active wells in the area, chronic oil pollution is a fact and spectacular accidents as the Chevron fire occasionally occur. Furthermore, continuing exploration and production require constant management and surveillance in order to prevent a breakdown of the ecology and possibly serious losses of environmentally dependent resources.

AN ANALYSIS OF ENVIRONMENTAL AND ADMINISTRATIVE PROBLEMS ASSOCIATED WITH ESTUARINE AND MARINE PETROLEUM PRODUCTION

Any analysis of the manner in which oil production affects the coastal environment and productivity requires that various aspects of the petroleum industry be examined separately in order to determine the specific problems associated with each activity and to compare the relative impact of the separate operations on the ecosystem.

The types of petroleum operations and associated activities vary considerably with respect to their effect on estuarine ecology. Some operations directly affect and degrade the ecosystem. Others involve conflicts of interest and competition for space and some apparently cause only esthetic degradation without seriously damaging the production of natural resources.

Seismic Problems

The first problem encountered when serious petroleum exploration is undertaken in a marine or estuarine area is the effect of seismic activities on local fish and game populations. Usually considerable antagonism rapidly develops between the fishing industry and seismic crews because the area historically belonged to the fishermen and the detonation of explosives at frequent intervals in fishing waters is viewed with great alarm. Louisiana was one of the first areas to be faced with this problem and a considerable number of investigations were carried out in order to determine the effects of seismic explosions on fish and fish populations.[8, 9, 10, 11]

These studies and numerous field investigations of complaints of seismic damage indicates that seismic problems may be divided into three major types. They are a) the direct effect of blasting on fish life and bottom configuration; b) damage to the ecosystem by equipment transport and traffic; and c) navigation conflicts between seismic vessels and fishing fleets in offshore areas. All of these problems present different characteristics in offshore and inshore shallow areas.

<u>Blast Effects</u>:

Initial seismic activity in any area usually generates grave concern over the loss of fish life because of the explosive factor. Numerous studies in this area indicate that fish kills will not normally occur from blast effects more than 150 to 200 feet from charges up to one thousand pounds.[8, 9, 10, 11] Fish kills of significant size rarely occur unless the charge happens to be placed in or near a large school of fish, on or near a reef frequented by fish, or in shallow, semi-enclosed water bottoms densely populated by fish. Practically all significant fish kills are eliminated with the following procedures:

1) In offshore or deep waters all charges must be suspended by flotation bags and fired as near the surface as practical.

2) In shallower waters shots should never be fired closer than fifteen feet from the bottom.

3) Charges should never be fired directly on the bottom to avoid trenching and spoil piles which damage otter trawls and other types of towed fishing gear.[11]

4) In shallow waters (ten feet or less) floating shots are not permitted; instead, all shooting is done at a depth of 100 to 200 feet in subsurface drilled holes.

5) The smallest charge consistent with acceptable recording should be used.

This type of procedure has never resulted in fill kills large enough to affect fish populations or future production. It has resulted in minor kills in offshore waters that caused problems when a few of the dead and decomposing fish were unknowingly caught and included in shipments of freshly-caught fish used for mink food. Later chemical analysis detected excessive decomposition and resulted in rejection of the shipments.

The results of seismic procedures described above are based on twenty-five years of observation on the coast of Louisiana where shooting has been carried out almost on a continuous basis and in some cases where as much as one ton of explosives is frequently detonated per linear mile of shot line.

Though to date no significant changes in fish populations or production have been detected, there are unknown factors associated with blast effects on fish stocks. For example, it is not known whether frequent blasting reduces fishing success because of a disturbance factor. Fish could be driven from the area or caused to sound by concussion and vibrations associated with detonations. The effects of frequent shots on spawning activity and success have not been studied, but present shrimp and fish production in Louisiana would tend to indicate little if any disturbance occurs. Extensive seismic activity in unstable marsh areas with organic substrates results in the release of gases (methane and hydrogen sulfide) that may be harming the local area. Since seismic records are confidential, repeated shooting by different interests occur in the same area; this should not be necessary. Excessive shooting may eventually prove to be detrimental and the number of problems could be reduced if seismic information was pooled.

Other Seismic Problems

Both from the ecological position and that of regulation and management of seismic operations, numerous other problems take precedence over the blast effects. For example, there is a significant amount of damage to marsh areas, the substrate in shallow nearshore waters and intertidal oyster beds by the vehicular traffic used in seismic operations. Marsh buggies, boat propellors and pushed barges can so damage an area that the local fauna and flora are destroyed or driven away. The extent of such operations in the coastal marshes of Louisiana is hard to realize without aerial inspection.

Another and different problem in offshore areas involves undetonated floating charges which may drift onto beaches or be accidentally picked up in trawls if they sink to the bottom. The consequences of this could be fatal to unsuspecting persons. Furthermore, the offshore area also presents navigational problems between seismic boats and fishing fleets. Serious confrontations can and do develop on the high seas over the right-of-way of one group of vessels over the other, where enforcement of regulations is difficult, and because the International Rules of the Road were not designed for such navigational procedures.

Gas Guns, Sparkers and Other Types of Seismic Devices

In order to avoid the problem of blast effects and fish kills seismic engineers have developed several new systems for creating vibrations or sound waves suitable for seismic investigations. Most of these have far less effect on fish life than do high explosives and in most cases serve to allay much public concern. They do not eliminate navigational conflicts or vehicular damage to marsh and shallow water areas, however. Nor will this type system work well near old deltas and river beds that have unconsolidated organic substrates that must be penetrated. In such areas only high explosives seem to be satisfactory.

Finally, seismic operations in coastal zones like other phases of the petroleum industry create ecological and management problems that require technical investigation and data upon which to base regulations and management decisions. Like other multiple-use systems, it can be done without apparent permanent effect on the ecosystem but compromises must be made to create an equity among all of the users.

Pollution

Pollution problems are many and varied. They involve differences between the effects of oil in offshore and inshore areas, accidental and chronic oil loss and special pollution problems resulting from the use of oil emulsion drilling muds and clean-up chemicals. Each is discussed separately since the control and management of the problem may require a different procedure.

Offshore vs Inshore

The effect of pollution in inshore estuarine waters and offshore deeper areas is essentially the same except that in shallow estuarine and marsh areas less water volume, slower tidal exchanges and semi-enclosed bays result in a longer duration of the problem and a greater intensity of pollution per unit of oil lost. Furthermore, the most serious effect from floating oil occurs in the inter-tidal zone and in tidal marshes where it coats the substrate and vegetation. In such areas clean-up procedures are difficult and support of living organisms is reduced until all of the oil is degraded or removed.

Accidental vs. Chronic Pollution

In evaluating pollution effects in any area, one should immediately make a distinction between accidental and chronic pollution. While accidental pollution can be catastrophic, unsightly, costly and result in a considerable public outcry, from an objective standpoint we must recognize that accidents are never intended to happen and that all efforts are made to clear up such breakdowns as soon as possible. With this in mind we should recognize the following:

1) Very rarely will accidental oil pollution have a gross permanent and lasting effect on the ecosystem. Whether minor or long range accumulative effects occur are not readily demonstrable.

2) Seldom is there significant fish or animal mortalities associated with oil spills.

3) Even should extensive and catastrophic loss of animal and plant life occur, once the environment recovers, populations of living things will also return to normal in a reasonable length of time and in some

instances in a very short time. This has been frequently observed when serious mortalities occur from natural causes or toxic pollutants.

4. This does not mean to ignore accidental oil pollution. We should insist that accidents be cleaned up as quickly as possible; that the liability insurance of the companies involved be adequate to compensate any direct loss to the public or to private citizens and that steps be taken to prevent such accidents in the future.

5. The frequency of accidents is a function of the intensity of petroleum operations, the condition of the equipment in use and human error or carelessness. While the first of these will remain constant, the latter two are subject to control with proper regulations, surveillance and enforcement.

6. The principal problems associated with accidental oil spills involve contamination of filter-feeding animals (oysters) and esthetic considerations, including the fouling of beaches or private property. The high cost of cleanup procedures and claims for property damage is of serious concern to the polluter.

By contrast, of more critical concern is the continuing low-level chronic oil pollution associated with intensive operations in shallow inshore embayments and marshy areas. In such instances production from separate well heads, numerous gathering lines, tank batteries, separators and sludge pits all offer opportunity for leakage, spillage, minor breakdown and faulty operation. This coupled with human error, carelessness or total disregard for compliance with pollution regulations can result in a continuing chronic introduction of oil into the ecosystem. As an example, the State of Louisiana has made over one thousand citations of such cases in the last six months even though we have a rather successful pollution control system. There are also numerous local areas of high petroleum production where chronic oil loss and mechanical obstructions have resulted in a biological desert or have ruled out any other use of the area. Unfortunately a considerable number of these areas of intense production were once valuable oyster reefs or shrimping grounds.

Oil Emulsion Muds

One of the most serious and long lasting types of pollution associated with the petroleum industry occurs when diesel oil is added to the mud system to enhance the drilling of deep wells. If the excess or used mud or cuttings from such an operation is lost overboard, there results a serious oil pollution of the substrate since the oil is adsorbed onto the heavy mud particles and settles to the bottom. Visible oil slicks may not occur and the pollution may go undetected. If oysters or other filter-feeding animals are in the area, they soon filter out and concentrate the oil and develop an unpalatable oily taste. As little as five hundred parts per million of oil in mud will cause serious taste problems in oysters and even one part per million added to a running-water system will be concentrated by oysters kept in the system for several weeks.[12]

Detergents, Dispersants and Other Chemicals Used to Clean Up Oil Spills

Usually when oil spills occur, public outcry and concern on the part of the industry to reestablish good public relations result in rapid and costly attempts to clean up the area or to make the visible oil disappear from sight. From our experience with oil emulsion muds this may be the worst approach possible to the cleanup problem for these reasons:

1) Detergents or dispersant chemicals may cause the oil to adsorb on mud and silt particles which sink to the substrate or float in the water column where they are more available to filter feeders.

2) Adsorbed oil on bottom particles appears to take longer to degrade.

3) The use of chemicals to disperse the oil involves placing an additional load of foreign and undesirable material in the ecosystem. Many of the dispersants tested proved to be far more toxic than oil.

4) Dispersal of oil does not allow proper mapping or study of polluted areas.

5) Floating oil is probably the least damaging position for oil to occur in the ecosystem. Here it degrades more rapidly--its only effect is at the interface and, except in intertidal areas and marshes, will usually dissipate, degrade and be mechanically dispersed by wave action with little apparent effect on the ecosystem.

Generally we do not permit the use of such chemicals for the cleanup of oil spills unless the area is so badly polluted that nothing is living anyway, or unless the esthetic value and effect on private property outweighs consideration for the local ecology.

Other Problems Associated with Petroleum Activities or Multiple Use of the Estuary

Aside from pollution, industrial activity within the estuary and on the continental shelf presents numerous associated problems which must be taken into consideration when one considers the total impact of the petroleum industry on our nearshore and offshore waters. These problems fall into several categories and their effect on the ecosystem in Louisiana has proved to be far more damaging and permanent than that of oil pollution. These various activities may be outlined as follows:

A. Direct physical damages to the estuary or to the animals therein such as:

1) Dredging and silting effects from the construction of navigation canals necessary for the placement of drilling rigs and pipeline construction.

2) Direct loss or disturbance of water bottoms, marshlands and sessile animals occuring in and along pipeline rights-of-way.

3) Localized damages from dredging and land fills to establish mineral production sites (oil and sulphur.)

4) Direct loss of oyster or clam producing areas to industrial competition for the same water bottoms or physical damages to beds by the construction of nearby facilities.

5) Physical damage to water bottoms from improper seismic operations with attendant fish kills.

6) Navigational problems and hazards from improperly placed spoils.

B. Indirect damages resulting from dredging, leveeing and spoil deposition may be more serious, affect larger areas and be harder to assess than the direct types. For example, improper spoil placement, damming of natural drainage patterns and uncontrolled dredging of navigation channels or pipeline flotation canals can result in the following types of ecosystem degradation:

1) Changes in the velocity and volume of water exchange on tidal cycles and a redistribution of saline or fresh water over estuaries.

2) Increased or decreased mean salinities or more rapid and greater extremes of fluctuations in the salinity pattern frequently develop from interruption of the normal drainage pattern.

3) Indirect silting and startling changes in bottom characteristics, as a result of changes in current direction and/or velocity, may occur at a considerable distances from the site of the cause of the problem.

4) Complex and permanent ecological changes may develop as a result of one or more of the above specific hydrographic changes.

5) A serious loss of land from erosion may result from industrial dredging in unstable estuarine areas.

There is not much question that these types of petroleum industry-associated activities have had a far greater effect on the ecosystem than has the spillage of oil per se. All of this type damage is permanent and irreversible. Furthermore, once broken by canaling unstable marshlands continue to erode. Some canals dredged to a width of sixty feet after fifteen years are now over three hundred feet wide and eroding at a greater rate as they widen. The annual loss of land to erosion in Louisiana is calculated to be 16.5 square miles and the total loss over the past thirty years is 316,797 acres.[13] It also has been established that actual canals make up 13.3% or 42,104 acres of this loss which is indicative of the extent of the dredging operations.

As a result of this disruptive activity in the ecosystem--salt and fresh water intrusion is common. Tidal flow rates have changed. Whole embayments have silted up in some areas while in others new lakes are formed. The ecological zones have shifted further inland and the brackish and fresher zones have been compressed against the higher land. How long can this important nursery area withstand such changes is questionable. As will be pointed out elsewhere, its productivity is still as high as it ever was though the location of various types of production has shifted and the production of fur animals has definitely declined.

At this point in time, it is difficult to predict the future except to point out that there must be a breaking point in the equilibrium of the ecosystem and none of us know how near we are to it. Fishery statistics indicate little change in the productivity of the Louisiana coast over the past thirty years but one does not have to be a professional ecologist to realize that this type of environmental abuse cannot continue forever. On the other hand, the occurrences on Louisiana's coast demonstrate the apparent resilience and buffered nature of marine ecosystems and gives some idea of the amount of abuse that such areas can withstand. If nothing else, these areas should be studied in as much detail as possible to determine the mechanics of the system. They also should serve as an example of what may be in store for other coastal areas if a national coastal management system is not developed soon and if priorities and standards are not set for multiple-use programs.

BIOLOGICAL AND ECOLOGICAL EFFECTS OF THE PETROLEUM INDUSTRY IN LOUISIANA

The Effects of Oil Pollution on Biological Productivity

The gross biological effects of oil pollution in Louisiana have been rather well-established by years of observations, field studies and controlled laboratory and field experiments. Microbiological and sublethal effects of oil on the micro-fauna, larval forms and the lower elements of the food chain are not well-known but the annual production of commercial fish in Louisiana would tend to indicate that to date there has been no serious breakdown in the food chain or animal life cycles. Whether or not a gradual accumulative effect of sublethal elements will some day prove disastrous is unknown. With less than full knowledge of the effects of oil on the ecosystem, certain facts about Louisiana's estuarine production are available and should be taken into consideration as we attempt to evaluate the impact of oil pollution on the area.

Fishery production as measured by shrimp and oysters gradually increased to maximum levels in the late 1930's and early 1940's. This rise in fishery production paralleled that of oil production but can be attributed mainly to improved boats and equipment.

The 1944 oyster production dropped to 700,000 barrels from a high of 1,290,000 barrels in 1942 and this low rate of production continued for several years. This occurred at a time of maximum and largely uncontrolled oil pollution and resulted in litigation between the oyster and oil industries. Considerable research developed because of this litigation. A research unit from Texas A & M University did extensive research for the petroleum industry during the mid and late forties* and considerable research was also contracted by the Louisiana Wild Life and Fisheries Commission. Results of this research indicated that the heavy oyster mortalities were caused by the fungus Dermacystidium marinum and not by oil. It was never made clear, however, why D. marinum suddenly reached epidemic proportions in the 1940's when it was demonstrated to be endemic in the oyster population from oysters preserved in the 1920's. Since D. Marinum is more prevalent in areas of high salinity and high temperatures, salt water intrusion resulting from navigation and pipeline canals associated with the oil industry may have been a major cause of the oyster losses though oil per se did not prove to be excessively toxic.

Surprisingly the extensive research of the late 40's directed at determining the effects of oil on oysters failed to bring out the significance of taste and odor problems in oysters contaminated with oil. This writer demonstrated in 1955 that a serious taste and odor problem developed when oyster beds

*Publication of this work has been limited and much of the information was not released.

became contaminated with oil-based muds. Such areas can remain contaminated from three to six months in open bays and as much as thirty-six months in small semi-landlocked ponds and bayous.[12,14] This type of contamination results in serious financial losses to the oysterman since he has no sale for his product and the oysters eventually die from predation or disease if left in the beds more than eighteen months.

Oily taste resulting from oil slicks on the surface is not nearly so prevalent as in the case of oil emulsion muds. With slicks the oil must first become adsorbed on silt in order to become suspended in the water column or settle to the substrate. In most instances this occurs only with significant wave action, principally near shore or in the intertidal area and the bond between the oil and silt is not so strong as in the case of oil emulsion drilling muds. Thus we find less contamination and that which does occur tends to clear up more quickly. This does not hold true, however, in areas of constant chronic pollution. In such instances enough oil is always present to be a problem.

Oysters will purge themselves of oily taste if removed to uncontaminated areas or depurated but as in the case of bacterial decontamination, it takes longer for the oyster to cleanse itself of oil than it does to accumulate it. Furthermore either the concentrating of oil by the individual or the purging of it appears to occur differentially in an oyster population. Some individuals will retain the taste much longer than others which makes it very difficult to state categorically when a bed is free of pollution.

Though the oyster industry did recover from the mortalities of the 1940's, it only did so by a complete change in the system of planting and cultivation in order to avoid serious losses from the fungus disease. Nevertheless, ecological changes resulting from the petroleum industry have had a serious impact on the oyster industry though oil per se has never been demonstrated to kill oysters except in cases of extreme contamination.

Shrimp, though much more delicate than the oyster, have never appeared to be affected by oil pollution or slicks at least from the standpoint of population density and production statistics. Some of the maximum shrimp production years occurred during the mid-1940's when oil pollution was rampant and at a time when oyster mortalities were maximal. In 1970 production was again the highest in ten or more years though the Chevron blow-out and fire occurred along with several major pipeline breaks in the nursery grounds. Since 1939 shrimp production in Louisiana has averaged between sixty and seventy million pounds annually and though it does cycle, the peaks and troughs of the cycle have been shown to be controlled by seasonal environmental changes.[15, 16]

In the early 1950's menhaden stock on the Louisiana coast came under exploitation. This fishery has now grown to a volume of 600,000,000 to 1,000,000,000 pounds annually, and has raised the total commercial fisheries production of the state to a peak of 1.2 billion pounds in 1970, or 23% of the total U. S. catch. This productivity has not been affected by the petroleum industry insofar as we can determine.

Significant mortalities of other types of fish and animals which may be directly attributed to oil pollution have never been observed in Louisiana. Fin fish, crabs and other motile forms apparently are able to leave seriously polluted areas. Some fin fishes have been known to develop unpalatable oily taste presumably from feeding on lower forms which had ingested and concentrated the oil.

Heavy oil spills occasionally result in the loss of waterfowl and shore birds if they become entrapped in floating oil. Thus far, no extensive bird losses have been observed. On several occasions oil losses in marshlands proved detrimental to fur production causing muskrats to leave the area or die but with one complete season such contaminated areas usually return to normal.

The greatest gap in our knowledge of the effect of oil on marine life involves the question of chronic and minimal pollution levels. How can we define oil pollution? Shall a monomolecular film constitute pollution? Does it materially affect the ecosystem? What does the chronic and accumulative effect of oil pollution have on a local area? Does this effect extend beyond the local site? These and many related problems should be investigated before final conclusions are drawn about the mechanics of oil pollution in marine ecosystems.

Certainly the significance of the continual addition to and accumulative effect of sublethal pollutants on the environment is probably the most important ecological question facing us today. While this question remains unanswered, environmental management decisions based only on our present knowledge of short-term gross effects of pollution and/or environmental manipulation may eventually prove to be disastrous.

Mechanical Effects of Petroleum Production on the Biological Productivity of the Marine System

As described earlier numerous associated activities and construction practices of the petroleum industry affect the ecosystem. Most of these activities cause permanent changes in the system, the bulk of which are detrimental; some appear to have little or no effect; and a few may be classed as beneficial. Furthermore, the construction of platforms, pipelines, navigation channels and the location of drilling sites have a different effect in offshore and inshore waters. Generally speaking the offshore problems are far simpler and have less permanent effect on the environment. Inshore is an entirely different situation. Many and varied changes occur in the ecosystem as a result of petroleum industry activities. The biological effects of such changes will be discussed for each area separately.

Offshore

In offshore deep water areas the ecosystem is more stable and the placement of physical structures such as platforms appear to have little effect on marine fauna in the area. In fact the numerous offshore platforms have been highly beneficial to recreational and sport fishing on the Louisiana coast. Rig and flare fishing is a new and valuable industry to the state.

Myriads of fish congregate under and around offshore structures and fishing success near the rigs is phenomenal. Night fishing in the vicinity of structures where waste gas is burned is excellent. Without doubt the numerous offshore structures serve as the most expensive artificial reefs in the sea and for the small boat sport fisherman and the charter boat captain the rigs in the gulf have opened up a new area of relatively safe and highly successful fishing.

On the other hand, to the commercial fisherman, particularly shrimp trawlers, offshore operations have created several types of problems some of which are serious and costly. The principal difficulties for fishing fleets involves navigational problems and seabed obstructions. The producing platforms and other above-water structures are well marked and lighted but when they become extremely numerous, significant fishing area is lost. Occasionally boats collide with structures but, for the most part, with fishing gear down they must stay well clear of the rig in order to avoid possible collision or the entanglement of gear in underwater junk and garbage discarded from the rig. This means that a considerable area around each site cannot be safely fished and significant fishing area may be lost to them.

Offshore pipelines usually do not create a hazard if the construction is regulated to prevent exposed pipes on the seabed.

Usually the pipes can be buried beneath the sea floor or will wash into the substrate automatically. New construction can be a navigational hazard to trawlers before the seabottom can return to its normally consolidated state. Occasionally lines will erupt above the waterbottom and become a hazard--this is usually corrected in a short time.

Until recently underwater completions and inactive stubs were a serious problem. These obstructions, if in water greater than eighty feet above their highest point, do not have to be marked or buoyed. More than two hundred such structures clutter the sea floor off Louisiana and this has resulted in the loss of a considerable amount of expensive fishing gear. New rule changes now allow the pipes to be cut off below the mudline and it is expected that most of these hazards will be removed within the next year or two.

Inshore

In inshore shallow embayments and marsh areas most mechanical effects resulting from petroleum activities are detrimental. Aside from changing the environmental parameters of the ecosystem, these activities have seriously damaged the oyster industry in Louisiana. Much of the destruction has been a result of direct physical damage from dredging, silting, barge and boat traffic to oyster beds. A prime problem is a competition for space when extensive oil fields are developed in highly productive oyster areas. In other cases indirect effects of such activities may seriously damage oysters or shrimp nursery areas some distance from the point of the activity either by indirect silting or changes in water cycling, salinity and the volume of water flow. Serious changes in the characteristic ecological zones on the Louisiana coast result in a direct loss in acreage of optimal nursery areas and a corresponding loss in productivity.

One change has been a serious loss of acreage of productive oyster seed grounds from saltwater intrusion. High salinities have increased predation from oyster drills and mortalities from the fungus D. Marinum to a point where the oyster life cycle cannot be completed. Salt intrusion has been gradual over the years and is not solely a result of oil operations. Some of it results from natural geological change but most of it is hastened by man's activities. Leveeing of the lower river, deep water navigation chanels; hurricane protection structures; industrial canaling and pipelines all contribute to the problem of changing salinities.

On the other hand, oyster mortalities from fresh water intrusion is sudden and catastrophic and usually can be traced to an activity that suddenly allows too much fresh water into an area.

Those ecological changes which affect oysters may be expected to also affect all sessile and bottom-dwelling fauna in the ecosystem. By contrast, the effect of such changes on motile fish and crustacea is more difficult to assess. Basically, the productivity of such species is a function of the fertility and optimal acceptability of the environment as measured in area. Thus a large number of acres of good fertile nursery area will produce a high density of animals but if the ecosystem is degraded permanently, this reduces the per acre productivity and, if carried to the extreme, can reduce it to zero. At this point little change in overall productivity of motile species can be detected. Some ecological zones have shifted positions increasing optimal nursery grounds for some species and decreasing it for others.

One significant change in shrimp production has occurred coincidental with the rise of the petroleum industry. The comparative population densities of the white shrimp <u>Penaeus setiferus</u> and the brown shrimp <u>Penaeus aztecus</u> have changed in the past thirty years. Until the late 1940's and the early 1950's, white shrimp made up 95% of the annual catch. In more recent years the population of browns has increased to a point where frequently they make up more than fifty percent of the total catch. While the exact cause of this change is not clearly understood, it is thought to be a result of increased saltwater intrustion since the brown shrimp is known to be less tolerant of very low salinities. If this is the case, it may have resulted in part from petroleum activities which hastened an increase in salinities in the estuary as a result of dredging and canaling needed to meet industrial requirements.

The effects of industrial activities in marshlands is even more startling than has been described for estuarine water areas. Land loss from erosion after canals are dredged is serious. Changes in the saline characteristics of marsh areas is reflected by changes in vegetation types. This in turn has drastically reduced fur production as muskrat populations declined. Waterfowl feeding and wintering areas are similarly depreciated as the marsh ecology is subjected to such stress.

LEGISLATIVE AND ADMINISTRATIVE SUGGESTIONS

Determination of Government Agency Involvement and Authority of Each

It should be recognized that the impact of the oil industry on the coast of Louisiana has resulted in a situation unique in coastal problems. First, the state government has attempted to exploit oil production to its maximum degree and as an afterthought has developed a rather effective system for protecting a very valuable fishery and renewable natural resource. At this point in time, both industries have apparently survived. However, there is much evidence that localized and extensive ecological damage did occur. Fishery and renewable resource production has been maintained in spite of the ecological changes. One of the problems which becomes immediately apparent when governments attempt multiple-use programs in a coastal area is that various agencies of the government are designated to regulate and develop the various uses and that these agencies have varying degrees of regulatory power. It is not too unusual to discover one agency of the government granting permits and even sponsoring one type of use which is extremely detrimental to the estuarine environment while another agency of the same government may be working "tooth and nail" to prohibit this use and/or at least to prevent as much estuarine damage as possible. Certainly, any approach to an overall establishment of effective policy and action concerning estuaries must include an evaluation of the involvement of the various agencies which might be concerned with the estuaries and the establishment of the authority of each.

Establishment of Sufficient Authority in the Agency Having the Greatest Expert Knowledge, Experience, and Responsibility for Protecting the Natural Resources or Production of the Estuaries

This proposal will probably the most difficult to accomplish. Nevertheless, it is apparent that if the natural resources and production of an estuary is to be protected, that agency (usually the Marine Conservation Commission) charged with the responsibility of protecting the estuary should be placed in a position of high authority in making rules and regulations controlling the area. This agency also should be given some veto or advisory powers over the function of other agencies concerned with the estuary, if at all possible. It seems obvious that only an agency having factual knowledge about and experience with problems that change the ecology of the estuary would be in a position to make recommendations most likely to successfully protect the area. Such powers may require simply issuance of permits or letters of no objection after the agency has had a chance to study project plans.

Proper Interagency Coordination

Even with the establishment of strong authority in the marine fishery agency, it is also essential that dynamic and cooperative interagency coordination is necessary among all agencies concerned with the estuary if a large amount of success is to be expected. In my experience, the extent of interagency coordination and the success is to be expected. In my experience the extent of interagency coordination and the success of such a program is largely proportional to the amount of interest, understanding and sympathy received from high-level policy makers in government toward the aims and needs of an estuarine management program. In other words, if we cannot obtain the backing of the high-level men in government our program will probably fail to achieve its principal aims.

Other Important Factors Involved in the Control of Estuaries

Once interagency coordination is established and the proper agency designated to protect the estuarine environment, certain other details will have to be accomplished in order to achieve an efficient program. These may be enumerated as follows:

A. Expert knowledge and/or research toward determining the most efficient type of prevention, control or mitigation of damages to the estuary must be determined. This, of course, may require a significant research staff involving numerous specialties, particularly in areas involving oil pollution and related problems. A relatively large expensive research staff may be necessary.

B. Certainly, no program will get off the ground unless it is operating under effective legislation which adequately provides for the proper regulatory authority being divested in the agency charged with control. The law should be specific, clear and contain adequate powers for enforcement and the assessment of penalties.

C. It goes without saying that sufficient funds will be necessary for proper administration and enforcement of any regulations. Even where adequate and efficient enforcement becomes a reality, maximum emphasis should be direct toward prevention of damages to the estuary or the reversal of detrimental effects where possible.

Outlook for the Future

In conclusion, it may be stated that it is possible to set up rules and regulations to adequately protect estuarine and nursery areas, but it will not be easy to obtain such a goal and the difficulty will mount as more and more vested interests begin to find need of the estuary. Certainly one of the most important factors will be the selling of the importance and value of the estuary and the need for its preservation to the public at large and particularly to those vested interests which might damage the estuary through their activities.

Five years ago I would have said that the long-range outlook for protecting estuarine areas in the face of population and industrial expansion was not good and that the outlook for maintaining the fishery in a manner similar to its original form was becoming dimmer and dimmer. However, with the recent upsurge in public interest at both national and international levels in environmental management and ecosystem protection, it now appears that a system can be developed whereby competent professionals are placed in charge of managing the estuarine area; the result being that certain levels of multiple use can be obtained. However, in all probability, fisheries and other environmentally dependent renewable resources must be given priority over those uses which are likely to degrade the environment.

Conclusion

In summary, the Coast of Louisiana is a unique, geologically unstable, highly productive area of both petroleum products and environmentally dependent living resources. The rise in petroleum production coincidentally parallels a rise in fisheries production. Because of the great value of oil and gas reserves, both to the state and Federal governments, intensive and extensive mineral production has developed. During most of the early production and throughout World War II, there was no regulation of the industry with respect to pollution and environmental management. After 1950, the impact of petroleum industry activities on fishery production, particularly oyster growing, became evident; this lead to a pollution control system, the development of a marine research program and the birth of an administrative procedure designed to protect the coastal environment.

An understanding of the effects of extensive petroleum activities on an unstable coast has gradually developed as a result of many years of field investigation, observations and research. Much of this work, however, necessarily dealt with the gross and more immediate effects of industrial activities on coastal ecology and natural resource production. The accumulative results of the introduction of sub-lethal amounts of oil or other pollutants into the environment for long periods of time and the additive effect of apparently innocuous ecological changes are unknown. These two factors may, in the long run, result in disastrous management of the environment if we continue to make decisions based only on the obvious short-term effects of multiple-use programs on ecosystems.

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