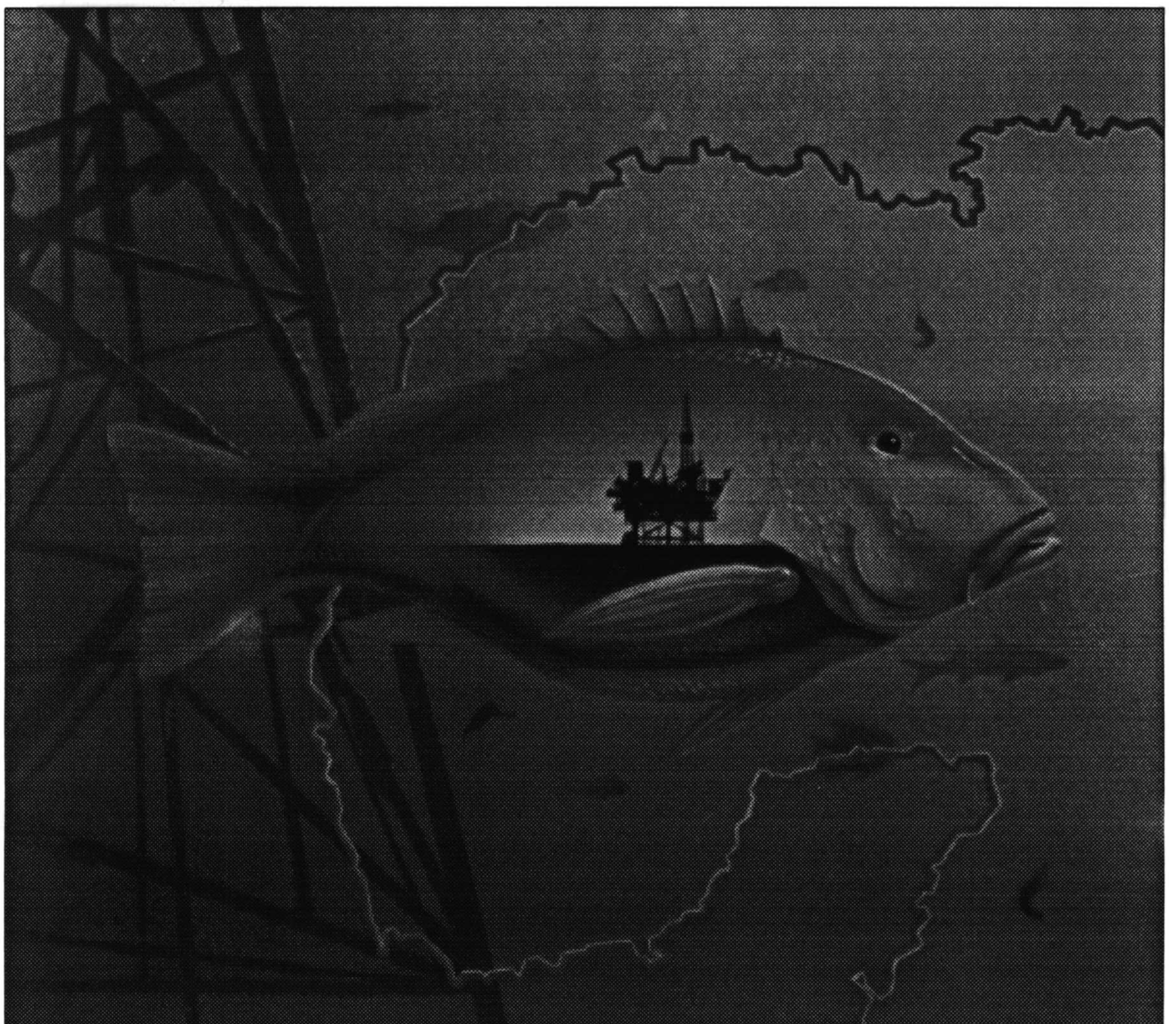
OCS Study
MMS 96-0050

Mariculture Associated with Oil and Gas Structures: A Compendium



MMS U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region

OCS Study
MMS 96-0050

Mariculture Associated with Oil and Gas Structures: A Compendium

**14th Information Transfer Meeting
Mariculture Sessions
New Orleans, Louisiana
November 17, 1994**

Compiled by

Villere C. Reggio, Jr.
Minerals Management Service
Gulf of Mexico OCS Region

Published by

**U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region**

**New Orleans
September 1996**

DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Minerals Management Service (MMS) unless so designated by other authorized documents.

The papers in this report were not subject to peer review, but were subjected to technical editing for publication by MMS and its contractor subsequent to the meeting.

REPORT AVAILABILITY

Copies of this report may be obtained from the Public Information Office (Mail Stop 5034) at the following address:

U.S. Department of the Interior
Minerals Management Service
Gulf of Mexico OCS Region
Public Information Office (MS 5034)
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123-2394
Telephone: (504) 736-2519 or
(800) 200-GULF

CITATION

Suggested citation:

Reggio, V.C., Jr., comp. 1996. Mariculture associated with oil and gas structures: a compendium. In: Proceedings: Fourteenth Information Transfer Meeting, November 17, 1994, New Orleans, La. OCS Study MMS 96-0050. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, La. 32 pp.

ABOUT THE COVER

Thanks are extended to Mr. Steve Kolian of Tulane University for providing the cover photo.

CONTENTS

PREFACE

Interest and inquiries regarding the use of offshore oil and gas platforms for mariculture purposes have increased significantly in the last five years. Hence, in response to our customers, Minerals Management Service (MMS) has begun informal investigations into the legal and technical aspects of using active or obsolete petroleum structures for open ocean fish culture. Although MMS has no current authority to lease or regulate OCS lands or waters for mariculture, it is apparent that petroleum structures already in the marine environment present unique opportunities for fisheries enhancement and development, as was the case for converting obsolete structures for the creation of artificial reefs (Rigs to Reefs).

MMS is committed to the wise use and conservation of all marine resources and hopes the information shared with us through our Information Transfer Meeting in 1994 will assist others interested in capitalizing on the potential compatibility of petroleum development and fisheries development. The following publications are suggested for additional information on the problems, opportunities, and existing regulations pertaining to aquaculture and mariculture:

Marine Law Institute. 1992. An assessment of the regulatory framework for finfish aquaculture in marine waters. University of Maine School of Law, Portland, Maine. Also available through the National Coastal Resources Research and Development Institute, Portland, Oregon (Publication No. NCRI-T-92-013).

National Research Council. 1992. Marine aquaculture: opportunities for growth. Washington, DC: National Academy Press.

Rubino, M.C. and C. Wilson. 1993. Issues in aquaculture regulation. Available from Bluewaters, Inc., Bethesda, Maryland.

U.S. Dept. of Agriculture. 1994. Resource guide to aquaculture information. National Agricultural Library, Beltsville, Maryland.

MARICULTURE ASSOCIATED WITH OIL AND GAS STRUCTURES

Mr. Villere C. Reggio, Jr.
Mr. Dave Moran
U.S. Minerals Management Service
Gulf of Mexico Region

INTRODUCTION

Increasing competition and regulation along with declining economic success of ocean capture fisheries portends increasing interest and opportunities for aquaculture and mariculture. Growing public demand for a consistent source of quality, healthful seafood has already stimulated offshore fish culture proposals in the quality, temperate offshore waters of the Central and Western Gulf. Notwithstanding the legal uncertainties of open ocean mariculture, researchers and entrepreneurs are keying on the potential availability of extant petroleum structures to test the feasibility and potential for fish husbandry in the Gulf of Mexico.

In the spirit of reinvention MMS organized a session designed to bring together regulators, researchers, and aspiring offshore fish culturist to evaluate the potential and problems of dedicating offshore petroleum structures to growing fish for market. Buoyed by the long-term success of Ecomar's harvest of marketable shellfish from OCS structures in the Santa Barbara Channel, representatives from MMS, the oil and gas industry, academia, the fishing industry, and the private sector offered visionary concepts, thoughtful opinions, and serious constraints to extended economic development of ocean resources tied to the multiple use potential of offshore petroleum structures. The documentation that follows should serve as a useful source of information to all who can see the wisdom of developing fuel and fish from a common base of operations.

Mr. Villere C. Reggio, Jr., is an Outdoor Recreation Planner with the Minerals Management Service, Gulf of Mexico OCS Region. His responsibilities include assessment, research, and reporting on the interrelationship of the OCS oil and gas program with the recreational elements of the marine and coastal environment throughout the Gulf region. For the past 20 years Mr. Reggio has had a special interest in evaluating the fisheries value and potential of oil and gas structures.

Mr. Dave Moran is a General Biologist under the Regional Supervisor for Leasing and Environment, Minerals Management Service, Gulf of Mexico OCS Region. Dave's primary responsibility encompasses environmental assessment of offshore oil and gas operations.

MARICULTURE FROM OFFSHORE OIL AND GAS LEASES

Mr. John Mirabella
U.S. Minerals Management Service Headquarters
Herndon, Virginia

Oil and gas operations have been occurring in offshore waters, bringing jobs to the area and oil and gas to the country. We have tended to ask the question, "Can we conduct oil and gas operations without interfering with other users of the offshore waters?" The parties involved have worked to solve most problems encountered, and, for the most part, the oil and gas companies have been good neighbors to the other offshore users. However, mariculture provides a new opportunity. We are now asking, "Can a functioning oil and gas facility provide an offshore platform for launching a new industry?" Rather than having oil and gas operations and mariculture activities just "not interfere" with each other, these two activities are looking to assist each other. If the expense of maintaining an offshore platform can be shared between two users—then maybe a mariculture enterprise that would otherwise be marginal can become profitable, and an oil and gas operation can continue production long after the field would have otherwise been abandoned.

From the start, MMS believed this to be a worthwhile and interesting project and assembled a workgroup to evaluate the potential project and determine what further information was needed. The MMS also facilitated communications with the National Marine Fisheries Service, the Department of Energy, the Corps of Engineers, the Environmental Protection

Agency, the oil and gas industry, and the Congress; all showed an interest.

Much progress has been made—but questions remain concerning extra stress on platforms, the effect on current and future production from the platform, liability for damage and end-of-lease obligations, and involvement of other government agencies at the federal, state, and local levels. Some of these issues are straightforward. For example, MMS regulates the design, construction, and installation of all platforms in the OCS. If a new platform is to be built, MMS is prepared to work with the Corps of Engineers or other agencies to help develop and implement appropriate regulations.

Once a platform is constructed, the lessee must perform periodic inspection and maintenance. With regard to some aspects of maintenance, annual costs are independent of the level of production. The MMS must ensure that if minimal production operations continue to prevent the lease from expiring, then maintenance and inspection also continue.

Other agencies will also need to add their experience to facilitate the establishment of mariculture projects. The Corps of Engineers has responsibility for prevention of obstructions to navigation, and the U.S. Coast Guard has responsibility for ensuring that platforms and artificial islands are marked so as not to be a hazard to navigation. Marking may be more complex if large nets are placed adjacent to platforms. The Corps of Engineers and the U.S. Coast Guard have extensive experience with their respective areas and problems are not anticipated.

Regulation of worker safety is less clear. The U.S. Coast Guard and the Occupational Safety and Health Administration have a Memorandum of Understanding covering the working conditions for oil and gas activities. What happens when mariculture activity takes place on the same platform? This is an area the two agencies would need to work out.

Consideration of end-of-lease obligations and bonding issues is important. In the event of a request for reassignment, MMS will evaluate the ability of the new company to satisfy all end-of-lease obligations. Just as with requests for assignment to oil and gas producing companies, MMS will cooperate with all parties to explore ways to protect the Government without undue burden on small companies.

Where do we go from here? Clearly a number of questions still exist. The MMS will need to work within its governing laws and regulations to search for solutions. One important key will be communication. The MMS will work with other government agencies and mariculture companies; oil and gas companies will need to work with each other and with the government agencies. The meetings that have already occurred and this session are good starting points.

OIL AND GAS VIEWS ON USE AND REUSE OF PETROLEUM STRUCTURES FOR MARICULTURE

Mr. David A. Dougall
Agip Petroleum Company

INTRODUCTION

Harvesting fish and shellfish has been a major source of food throughout the history of civilization. Recent over-harvest of our ocean resources has raised concern about the future of our fish stocks. In the United States, the authorities have evolved a system of allocating fisheries resources through a combination of seasonal closures, zone closures, and catch limits, administered by the National Marine Fisheries Service (NMFS).

Cultivating fish and shellfish has also been with us since long before Christ. Today, aquaculture is a major business. Farm raised trout, catfish, and crawfish are familiar to most of us. These commercial operations take place in ponds and raceways from the extremely large to the quite small. Within the last few years, considerations have been given to the use of oil and gas structures to aid in marine aquaculture—mariculture. This paper is provides an industry perspective on the opportunities and obstacles presented by the use of petroleum structures in mariculture operations.

PERSPECTIVE

This paper is prepared from the perspective of an offshore oil and gas operator. While the paper deals with fisheries issues, the author claims no fisheries expertise. Information presented herein is based upon limited literature review and discussion with other oil and gas operators. Views expressed in this paper are those of the author.

OIL & GAS PLATFORMS

There are nearly 4,000 oil and gas platforms in the Gulf of Mexico. These structures range in age from brand new to roughly 30 years old; in size from single well caissons to large, multi-pile; in water depths from a few feet to over 1,000, and in distance from shoreline to more than 130 miles. Platforms consist of a supporting structure (jacket or caisson) and a topside structure (deck), which supports production, processing and safety equipment, quarters (if any), and helideck (if any).

Platforms present some obvious opportunities for mariculture operations:

* They would provide a more or less permanent, solid platform from which to conduct operations. The decks would provide a stable place for storage, feed delivery equipment, and utilities (power, navigation aids, communications, and environmental monitoring). The structure would provide support for anchoring containment and winching systems. Further, the offshore oil service infrastructure (service boats, air transportation, and port facilities) offers an existing transportation system for personnel, supplies, and products.

* Platforms are well known as artificial reefs, providing healthy ecosystems which are major destinations for recreational fishing. This abundance of associated sea life suggests a healthy environment suitable for cultivation of fish and shellfish.

* The offshore location tends to moderate swings in water temperature, and water currents make the system essentially self-cleaning, providing new, oxygenated water and removing wastes from fish and feeding.

PROJECTS

A Santa Barbara, California firm, Ecomar, presents a real success story and an object lesson relevant to considering oil and gas structures for mariculture. Ecomar contracts with a number of oil and gas operators offshore of the California coast to remove what is considered biofouling by oil and gas operators from their platforms. The substantial buildup of sea life attached to the underwater support for the platforms causes enough wave and current drag to present structural concerns. To alleviate this problem, operators pay up to a few hundred thousand dollars every few years for divers to remove the growth.

One man's biofouling is another's gourmet dinner, and Ecomar has for about ten years been separating, cleaning, and marketing mussels removed from platforms to an increasing list of restaurants.

Two things to bear in mind about the Ecomar harvesting operation:

1. Operators view this as a very good way to conduct <u>essential</u> platform maintenance. Because Ecomar is able to market the product, the operators get a cost break on the removal operation. An additional benefit is showcasing the healthy environment that surrounds these platforms.

2. In spite of what should seem an obvious win-win proposal, it took Ecomar's owner, Bob Meek, the better part of ten years to sell the idea to the oil and gas operators and the regulatory authorities. Operators' reluctance can be summed up in two issues: liability and interference in operations.

A related success story is the Rigs-to-Reefs Program in Texas and Louisiana. At the end of a platform's useful life, oil and gas operators are required to plug and abandon all the wells, sever all structures below the mud line, and physically remove the structure from the lease. Simply stated, the Rigs-to-Reefs Program offers an operator the opportunity to move the structure to a designated reef site rather than hauling it all the way to shore for scrap.

From the oil and gas operators' point of view, the Rigs-to-Reefs Program is highly successful for two very good reasons:

1. Liability: The Rigs-to-Reefs Program presents the operator with an opportunity to fulfill his responsibilities in clearing the oil and gas lease in such a way that long term liability for the structure is transferred to another financially responsible entity (i.e., a government agency).

2. Economics: The cost to clear a platform from a lease can be anywhere from $½ to $15 million or more, depending on water depth, location, condition and configuration of the structure, and salvage value of parts. This cost can sometimes be dramatically reduced by participation in the Rigs-to-Reefs Program. One-half of the estimated savings goes to the agency to pay for long-term maintenance of the reef and for accepting liability.

Mariculture around oil and gas platforms in the Gulf of Mexico has been discussed and conceptualized for over 10 years. To date, only one mariculture project has been conducted in association with oil and gas platforms in the Gulf of Mexico. This project, funded by an oil company, in cooperation with Texas A&M, has been ongoing for several years. The project team has raised redfish, but not as a commercial success. The project began on a producing platform and is now based on one that is no longer active.

The operator of this project has indicated a number of obstacles, institutional as well as technical, which must be overcome before large-scale mariculture operations at offshore oil and gas platforms are likely to become a reality. The validity of these concerns was largely confirmed in discussions with other operators not presently involved in mariculture activities but with whom proponents would probably deal.

INSTITUTIONAL OBSTACLES

The following issues are of an institutional nature. Some should be addressed by the appropriate regulatory authorities; others should be considered by mariculture proponents when they are fashioning proposals.

LIABILITY

The greatest concern expressed by oil and gas operators is liability, liability for accidents and liability for lease abandonment. Whether mariculture operations are conducted on a producing or an inactive platform, the issue of liability for personal injury, property damage, and environmental damages must be resolved. Not only are authorized personnel working on and under the platform at risk, so are intruders, on and under the platform. Risk of injury, property and environmental damages from collision and natural disasters also must be resolved.

The longer term and probably more difficult issue is liability for lease clearance. If an inactive platform is to be used for mariculture operations, somehow the ultimate fate of the structure and eventual cost for dealing with it must be resolved.

In light of what most consider the "deep pockets" theory, the willingness of a somewhat tentatively financed entrepreneur to accept the liabilities associated with a platform-based mariculture operation is not likely to be adequate. Aquaculture in the United States has a history of failures. Companies that fail quite often file bankruptcy, in this case, possibly leaving the previous operator with the liabilities. Somehow, the oil and gas operator has to be relieved of liability as a previous owner.

Finally, there are requirements for maintaining a platform. Navigation aids, cathodic protection, and minimal repair and upkeep of the structure are expense items which must be factored into the economics of such an operation. Together, these costs can exceed $10,000 per year.

OPERATING PRIORITIES

Another major concern is interference with the operations of the platform. Operations on these facilities are entirely focused on production of oil and gas. Any activities which do not fall within that focus will be met with reluctance unless they can be shown to be: (1) valuable and (2) conducted in a manner that will not be "under foot."

PERMITTING

Oil and gas operators are accustomed to working within a tightly regulated environment. However, the agencies with which we work generally have well-defined and understood areas of authority. Reportedly, working through the regulatory framework to obtain all the necessary authorizations to conduct a mariculture operation from an oil and gas platform can be a major challenge. Conflicts include overlapping areas of authority and standards to be applied to the operations.

SPATIAL CONFLICTS

Oil and gas operators lease mineral rights from the U.S. or a state government and obtain authorization to temporarily place structures on those leases and produce the mineral resources. Conducting mariculture operations in association with oil and gas structures opens up new issues of private use of public resources. A new "user group" conflict may arise with commercial fishing operations and with recreational fishing and diving interests, all accustomed to benefitting from the presence of these structures.

FINANCING

Finally, there is an inclination on the part of proponents of projects relating in some way to oil and gas facilities to anticipate major investment, if not outright underwriting of the project, by the petroleum company involved. Oil companies, large and small, have been trimming budgets and focusing investments on core business. Project proponents should not make grand assumptions about financial participation on the part of the oil companies in these ventures. If companies do get involved, they will be likely to consider the platform infrastructure to be a major investment in itself.

TECHNICAL CONSIDERATIONS

Certainly, persons who have been engaged in research and applied aquaculture activities are the technical experts in this area. However, discussion with other operators suggested the following items in need of improvement.

Cage Construction

A number of approaches have been designed for containment of fish in cages. However, placement of cages in association with oil and gas platforms presents current forces far beyond those experienced in nearshore operations. Cage construction and anchoring/retrieval systems must be well-designed, adapted, and field tested for this environment.

Target Species

The high cost of marine farming in comparison with onshore aquaculture suggests that high dollar species must be cultivated to achieve the necessary profit margin. Successful spawning and stocking of high dollar species is reported to be a major problem.

SOLUTIONS/SUGGESTIONS

Ultimately, the obstacles enumerated above will be favorably resolved. From the perspective of an oil and gas operator, the following are some suggestions which, if implemented, would help move mariculture toward commercial reality.

Relief from Lease Responsibilities

Long term liabilities and lease clearance responsibilities are a major obstacle to mariculture on oil and gas platforms. Proponents are most likely to be entrepreneurs without the financial backing to adequately take on these responsibilities; at the same time, oil and gas operators will not be wiling to retain long term liabilities. A possibility to consider is a mechanism for site clearance to be funded up front and placed in an appointed trust and the oil and gas operator provided with a legally binding release from future liabilities.

Streamline Permitting Requirements

Some means of simplifying the permitting process is essential. Use a lead agency approach, and work between the agencies to clarify roles, eliminate overlap, and streamline the process.

Grant Lease Rights to the Mariculture Operations

Some means should be established to protect the mariculture operator from damages to his crop from other fishing and diving activities. Since a process exists to set zone and species closures, the NMFS should be able to create some sort of lease rights for the mariculture operation.

CONCLUSION

Oil and gas operators consider offshore platforms to be sort of an idyllic microcosm of sea life. We provide structure where one did not previously exist, and sea life is attracted and thrives. It makes a great deal of sense that these circumstances should somehow be capitalized upon. The Rigs-to-Reefs Program is a positive step. Commercial farming in association with these structures appears to be an additional opportunity. Over time, the obstacles, both institutional and technological, will probably be resolved, and mariculture could evolve into a major business and a major food source contributor.

Mr. David A. Dougall is Manager of Environmental Affairs & Safety for Agip Petroleum Company, with drilling and production operations in the Gulf of Mexico. Mr. Dougall's background includes consulting for Pilko & Associates, where he conducted environmental risk assessments, compliance audits and permitting activities. His background also includes corporate and field assignments for Phillips Petroleum Co., including several years coordinating Phillips' permitting and compliance efforts in California. He received his M.S. degree in Environmental Science and B.S. degree from the University of Oklahoma and is a registered professional engineer in Oklahoma and Arkansas.

MARICULTURE IN THE GULF OF MEXICO: SEA PRIDE INDUSTRIES' SEA TREK AND SEA STAR SYSTEMS

Dr. Edwin Cake, Jr., Chief Science Officer
Mr. John D. Ericsson, Chief Executive Officer
Sea Pride Industries, Inc.
Gulf Breeze, Florida

Sea Pride's innovative plans for mariculture in federal waters of the U.S. Outer Continental Shelf (OCS) include (1) installation and operation of the Sea Trek Ocean Farming System® for cage-culture of native finfishes in the open sea and (2) operation of the Sea Star Oyster Relaying System for cleansing and improving of oysters from inshore waters that may not meet federal water-quality criteria. Sea Pride has spent hundreds of thousands of dollars researching, designing, developing, and permitting these systems for use in the Gulf of Mexico.

The patented Sea Trek System (Figure 4B.1) will consist of a ballastable, concrete platform (similar to those already in use by the oil and gas industry on the Gulf of Mexico OCS) that rests on the sea floor and six ballastable, net-covered, barrel cages arrayed radially around the platform. The inner end of the cages will be chained to the platform and the outer end will be anchored to the sea floor. The barrel cages will be ballasted vertically and/or rotated horizontally to facilitate fish harvesting, net cleansing, biofouling reduction, and storm protection. Systems for feeding, aeration, and vacuum transfer of the fishes will link each cage with the platform via an umbilical connection.

The Sea Trek System will be located four miles southeast of the mouth of Mobile Bay, Alabama, in 50 feet of water on the south-western corner of Exxon Energy Company's OSC Lease Block 827. The five-acre U.S. Army Corps of Engineers-permitted mariculture site will be surrounded by a floating AquaFence® that encloses 13 acres and reduces floating hazards and user conflicts. The Sea Trek System has been designed to rear up to three million pounds per year of native finfishes including red drum, red snapper, hybrid striped bass, and mahimahi (dolphin fish) and will be supported by a land-based or platform-based hatchery facility. The Sea Trek platform will be manned 24 hours a day except during hurricane conditions when the cages will be ballasted to the sea floor and/or released on independent anchoring arrays for fish and cage protection.

Sea Pride received its U.S. Army Corps of Engineers (USACOE) permit (#AL93-01004-M) under Section 10 of the 1899 Rivers and Harbors Act in October 1993. Sea Pride received its U.S. Environmental Protection Agency (USEPA) Ocean Discharge Permit (#AL0067237) under Section 403 of the amended 1972 Federal Water Pollution Control Act on 20 September 1994. To our knowledge, these are the first permits issued for mariculture operations and related ocean discharges anywhere in U.S. Federal OCS waters.

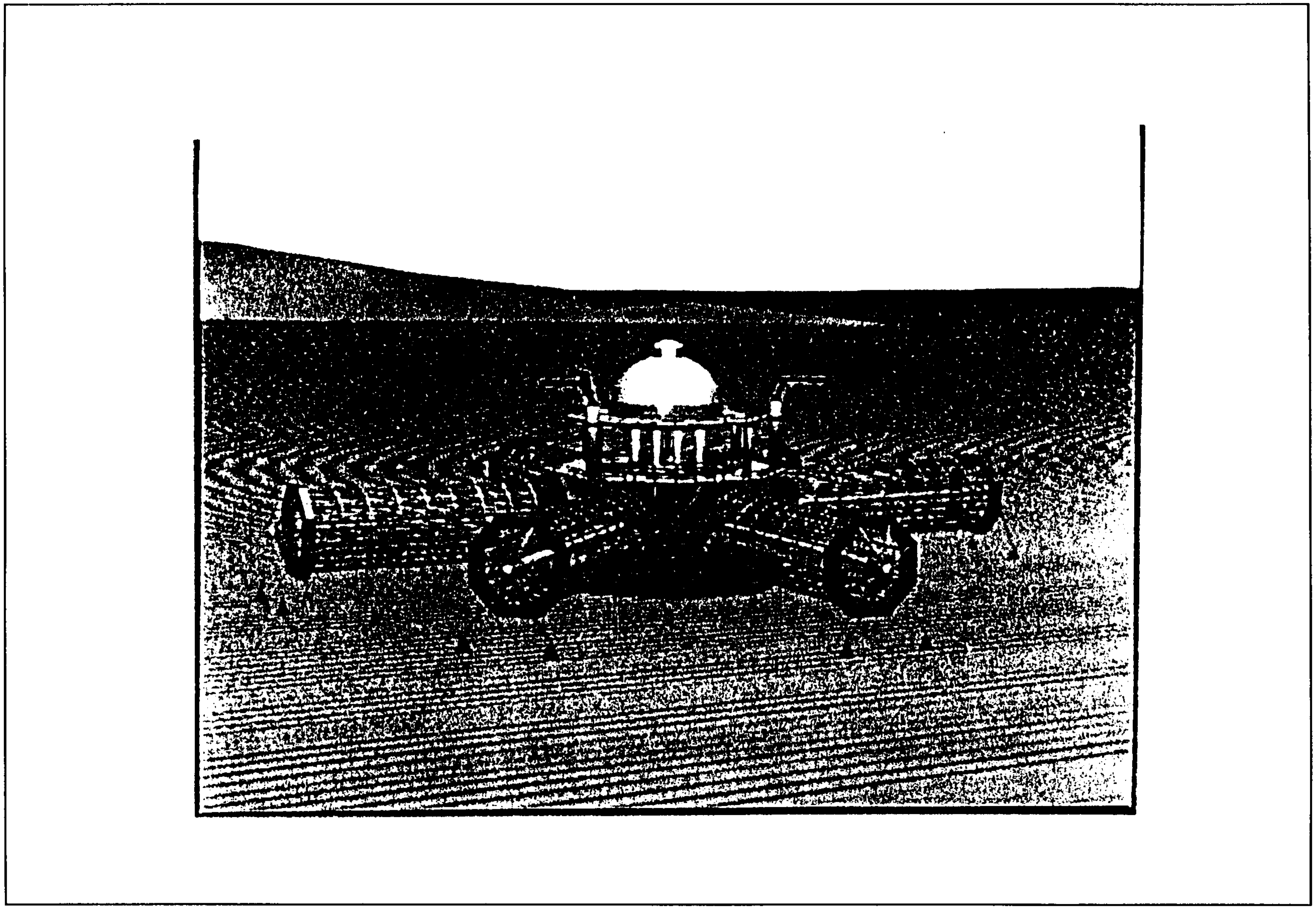


Figure 4B.1. Horizontal view of computer-assisted drawing of the Sea Trek Ocean Farming System® resting in 50 feet of water showing the central platform and the six semisubmerged barrel cages. The cages will be 170 feet in length and 40 feet in diameter. The octagonal platform will be 112 feet in diameter and will rise 125 feet from the sea bed.

The patent-pending, Sea Star Oyster Relaying System (Figure 4B.2) is a ballastable device for holding, deploying, cleansing, enhancing, and recovering oysters to be relaid from coastal waters that do not meet federal water-quality criteria for shellfish growing areas. Oysters that are relaid from contaminated coastal waters to "approved" waters of the open Gulf of Mexico will purge themselves of potentially-pathogenic bacteria and viruses during the required 14-day relaying periods. The oysters will also be enhanced by increasing their internal salt content (or "salty" flavor).

Each Sea Star unit will hold approximately 60,000 3-inch-plus oysters in 288 plastic trays. A fully-loaded unit will contain eight racks (two stacked racks per side x four sides), and each rack will contain 36 trays of 200+ oysters each. The Sea Star units will rest on the bottom near the Sea Trek site off Alabama and/or at an OCS site approximately 3 miles south of Ship Island, Mississippi. As many as 12 Sea Star units will be utilized at each site and will be deployed and recovered via jack-up vessels or other marine equipment. USACOE permits (Rivers & Harbors Act, Section 10) are pending for commercial oyster-relaying operations at the two OCS sites. Public notices were issued by the USACOE Mobile District on 6 February 1995, and the permits should be granted in March 1995 if no conflicts arise.

The Minerals Management Service (MMS) of the U.S. Department of the Interior facilitated Sea Pride's contacts with and ultimate "letter-of-agreement" from Exxon for the operation of the Sea Trek Ocean Farming System®. At present, the MMS has no specific regulatory authority or policies relative to mariculture activities or operations on the OCS in the Gulf of Mexico. Between now and the year 2000 hundreds of OCS platforms that will be abandoned in the nearshore waters of the Gulf of Mexico may be suitable for mariculture applications. The MMS will have an opportunity to facilitate additional mariculture ventures and may exert some regulatory authority over such ventures when the abandoned platforms are converted for mariculture rather than removed as required by current MMS regulations.

Sea Pride Industries chose its permitted Sea Trek/Sea Star site off-Alabama for many reasons, including excellent prevailing water-quality conditions (high salinity and dissolved oxygen, low nutrient loading, acceptable current flows, lack of pollution sources, etc.), geological bottom stability, and close proximity of ports, infrastructure, and seafood processing facilities. Other positive aspects of the nearshore Alabama site included the "accepted" presence of natural gas exploration and production platforms, reduced user-conflict issues, and the pro-mariculture philosophy of the Alabama Marine Resources Division which operates the Claude Peteet Mariculture Center at nearby Gulf Shores.

The acquisition of requisite USEPA and USACOE permits for Sea Pride's mariculture activities has been a long and cumbersome, yet successful process. At the outset, Sea Pride tried to anticipate the environmental information needs of the various federal and state regulatory agencies. Sea Pride prepared and submitted environmental assessments and monitoring proposals to the USEPA knowing that its Region-IV staff had never considered a permit for ocean discharges from a mariculture facility in federal waters. Sea Pride and the USEPA negotiated in good faith, and all permit issues were resolved satisfactorily.

Sea Pride has designed and will operate environmentally-sound systems in the Gulf of Mexico. Sea Pride cannot afford to adversely impact the area's water quality because to do so would adversely affect the finfish and shellfish stocks that will be cultured and/or cleansed.

The presence of the Sea Trek and Sea Star Systems will attract numerous commercially- and recreationally-important finfishes and shellfishes to the area. Those fishes will in turn attract sports fishermen and increase fish catches in the immediate vicinity of the platform. The aqueous finfish and shellfish wastes that will be diluted and disseminated by tidal currents will increase general primary production over adjacent areas of the OCS.

Sea Pride recognizes the worldwide and areawide reductions of finfish and shellfish landings and is attempting to solve some of the fish shortage via mariculture. It has plans to fabricate and deploy Sea Trek Ocean Farming Systems® in Micronesia and other international areas where native finfish populations are being depleted via overharvesting, or shellfish populations are being threatened by increasing human "pollution."

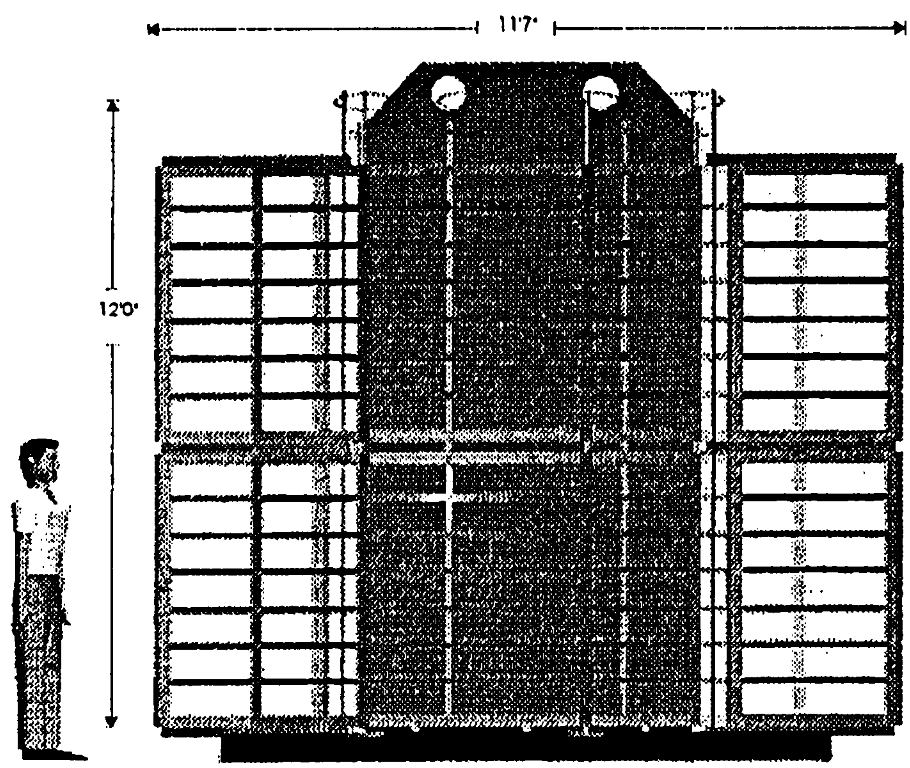


Figure 4B.2. Horizontal view of computer-assisted drawing of the Sea Star Oyster Relaying System showing eight oyster racks around the central ballast tank. The system size will approximate a 12-foot cube.

Finally, Sea Pride's believes that its Sea Trek and Sea Star operations in the Gulf of Mexico will start a new mariculture industry similar to the $75-million-a-year salmon-culture industry in the U.S. Pacific Northwest. A successful Gulf of Mexico mariculture industry would reduce U.S. dependence on imported fishery products, thereby reducing the Federal deficit; increase the availability of high-quality finfish and shellfish products; increase job opportunities for underemployed or out-of-work fishermen and newly-trained mariculturists; expand the market for regional grain products that will be needed for feed formulation; and develop new culture systems (platforms, cages, racks, etc.) that can be fabricated and serviced by existing industries along the Gulf coast, thereby boosting local economies.

THE ENGINEERING OF MARICULTURE PENS IN ASSOCIATION WITH OIL AND GAS STRUCTURES

Mr. Clifford A. Goudey
Massachusetts Institute of Technology
Sea Grant College Program

SUMMARY

Many oil and gas structures in the Gulf of Mexico are no longer producing energy and present attractive sites for offshore mariculture. By incorporating the existing structure into a fish pen system, its removal cost can be avoided and the overall system cost can be reduced. However, the exposed locations of candidate structures are unlike anything experienced by conventional, sheltered-water mariculture operations and present new challenges.

Techniques for the design and performance prediction of oil and gas structures are well established. The prediction of pen system behavior and the estimation of loads generated by waves, currents, and extreme events have only recently received attention. The flexible nature of most pen systems is essential to their survivability but it complicates their analysis since their geometry is variable. Of the many engineering issues confronting the mariculture system designer seeking to exploit an existing structure, predicting the loads imposed on the structure by the pen system is of prime importance.

This presentation describes the use of scale models and wave basins as a means of both predicting loads and understanding the behavior of complex pen systems under simulated environmental exposure.

MODEL TESTS OF MARICULTURE SYSTEMS

Many of the practices that have been developed for the model testing of ships and structures can be applied directly to mariculture systems. The scaling of geometry, weight, speed, wave heights, and frequencies all follow rules established by Froude. As with most conventional model tests, attention to model details can be important and the use of as large a model as possible is always important. In addition, the netting and tension-member portions of a pen system require the use of modeling practices which have been developed in trawl net testing programs. Netting geometric parameters must be accounted for as well as the elastic moduli of materials used in the netting and load-bearing lines.

Figure 4B.3 is an example of an experimental set-up in a circulating water channel aimed at predicting the resistance of a pen system in a current. It is important to note that the resistance determines the shape and the shape determines the resistance: these are highly non-linear systems. Such a test set-up is also useful in determining netting deformation, water flow, and feed pellet trajectories.

A proper test protocol will call for the introduction of netting of several different blockage ratios. In this way the effects of biofouling on netting can be determined with respect to increased loads and reduced water flow. The latter factor can be important in determining stocking densities.

The performance of a mariculture system in waves can be predicted through the use of a wave basin. Due to the dynamic nature of such tests, the contribution of all elements of the system must be included such as anchor lines. Figure 4B.4 is an example of a test setup in a wave basin of a pen designed for full ocean exposure. In such a test, load cells are places at a variety of locations within the system to determine wave-induced loads and help

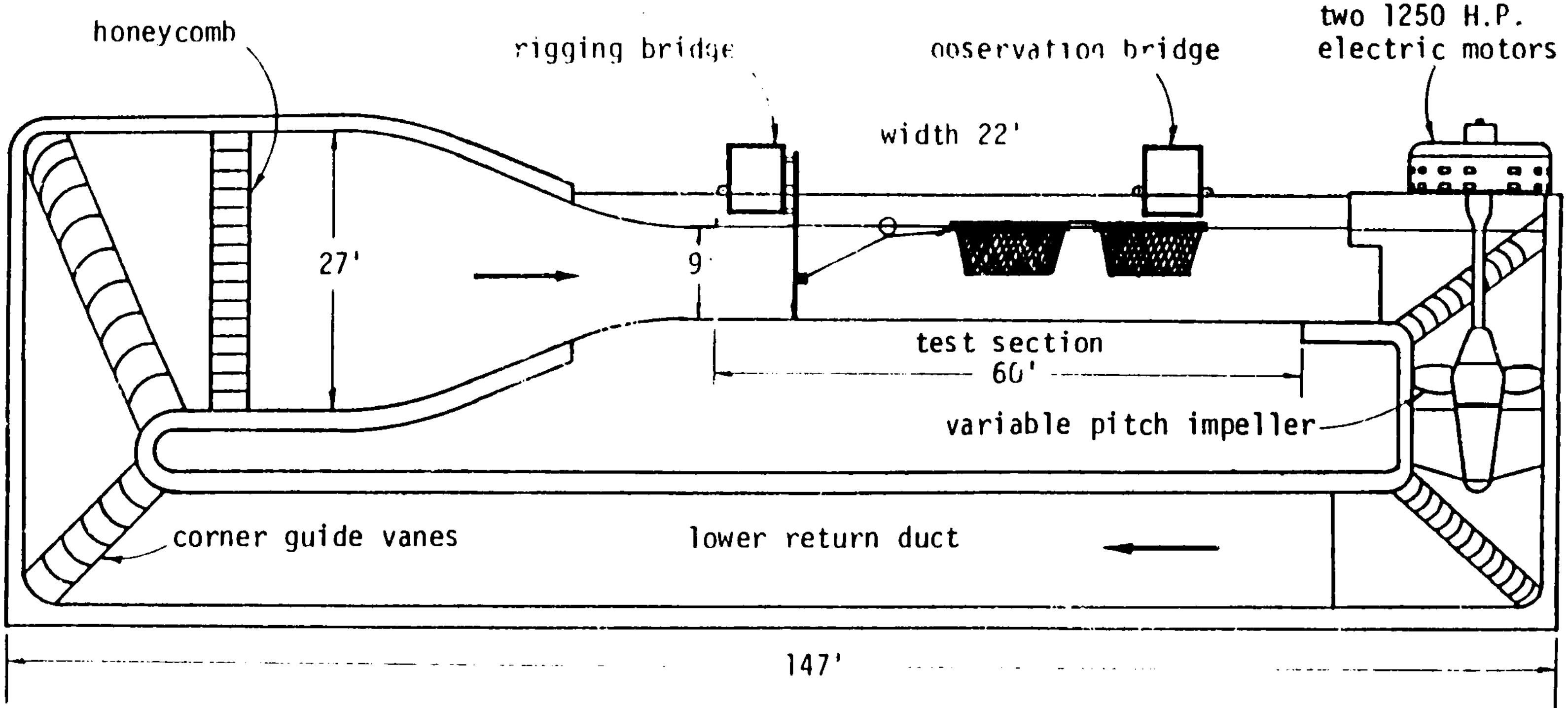


Figure 4B.3. Fish pen tests in the David Taylor Model Basin circulating water channel.

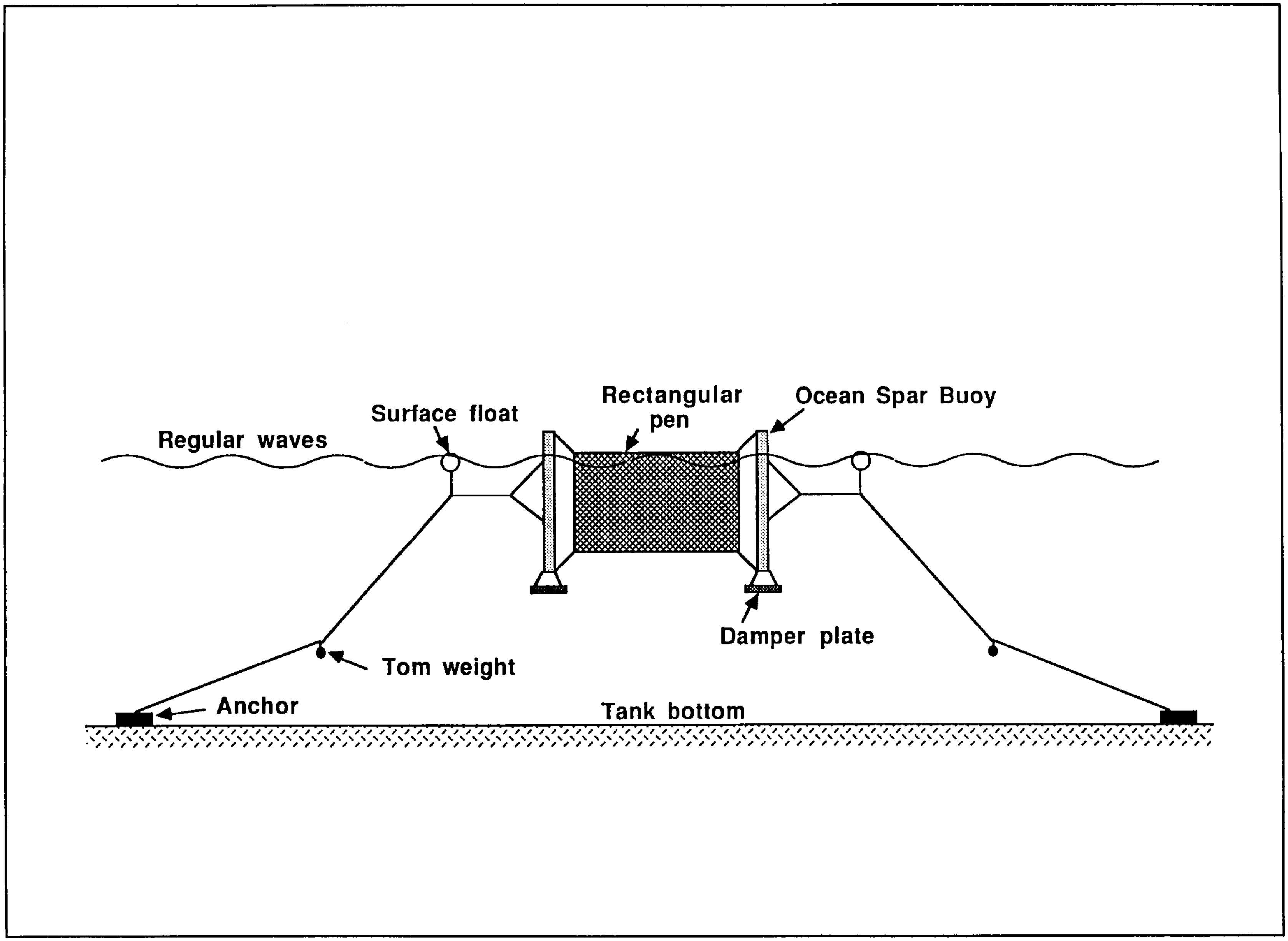


Figure 4B.4. Ocean Spar pen tests in the David Taylor Model Basin maneuvering and seakeeping basin.

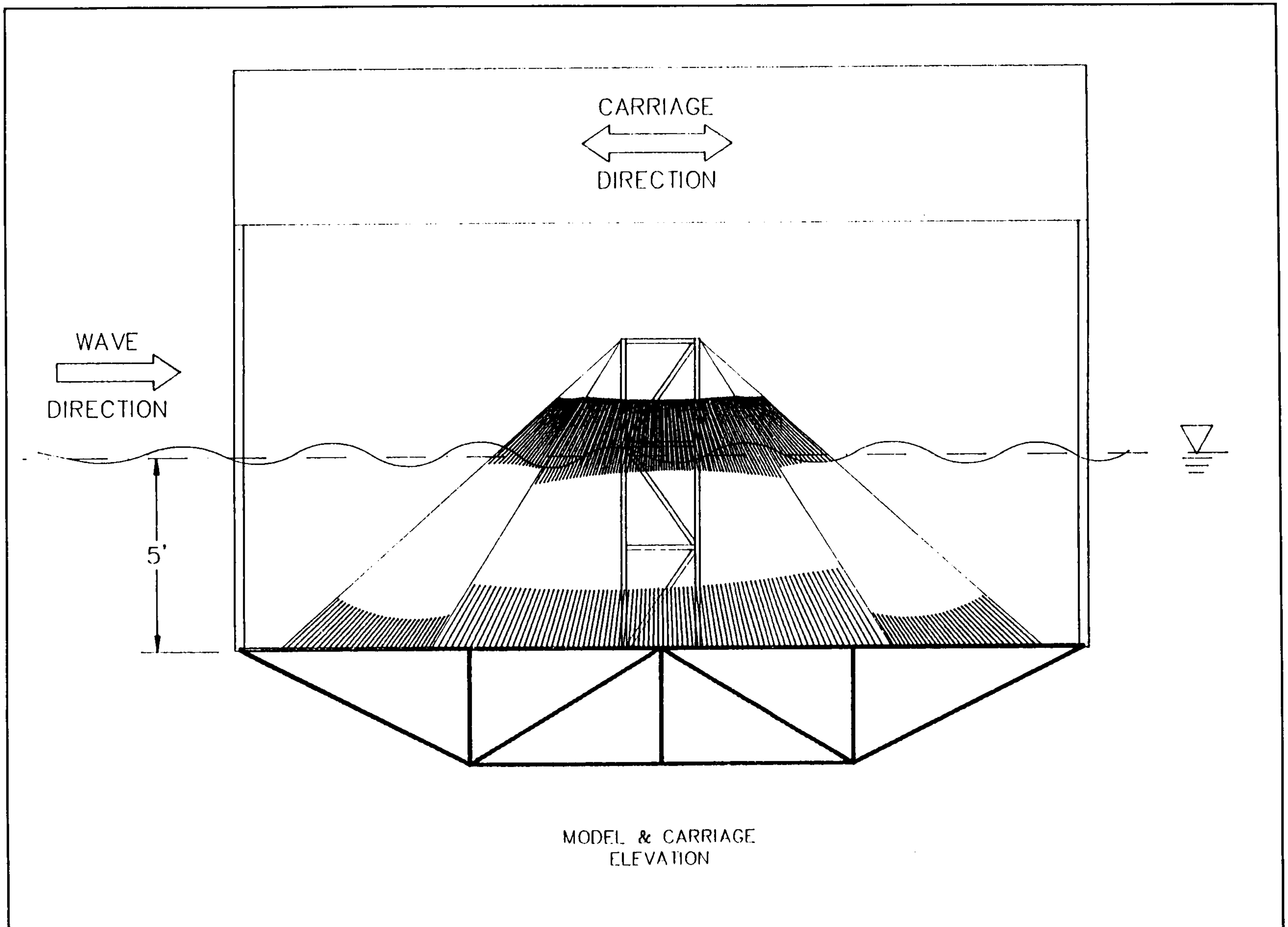


Figure 4B.5. Combined wave and current tests at trhe David Taylor Model Basin maneuvering and seakeeping basin.

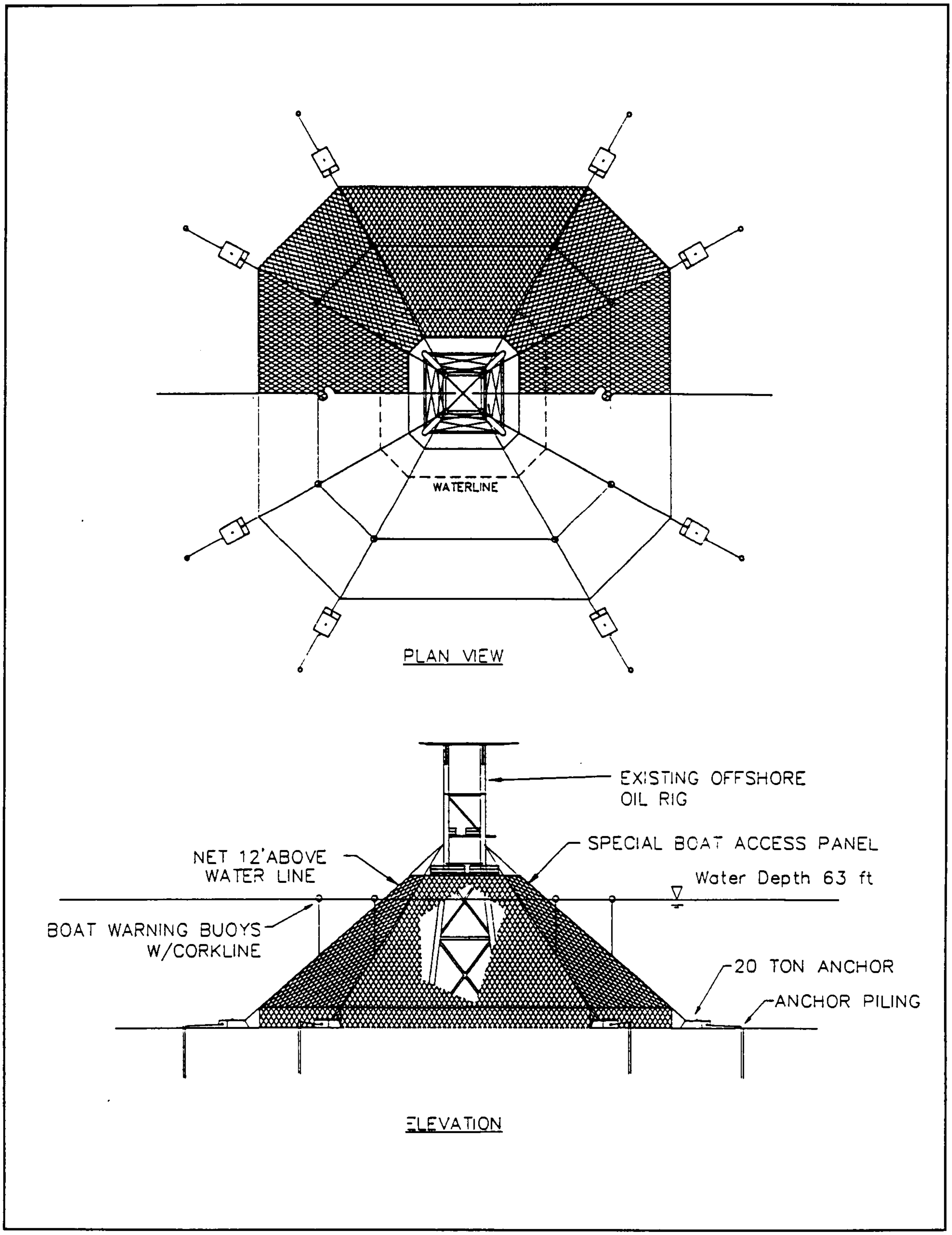


Figure 4B.6. The tent pen mariculture system.

identify areas where cyclic loading and snapping are potential problems. A test regimen of regular waves over a range of frequencies is useful in identifying resonant behaviors and associated peak loads. Breaking waves are useful in understanding the performance of the system under extreme conditions.

In a unique series of tests further described below, the combined effects of current and waves were found to be different than the simple summation of current and wave results determined separately. This is attributable to the non-linearity of these flexible systems and provides a strong argument for doing combined tests. Figure 4B.5 is the experimental set-up for a combined current/wave test where the entire model and a false bottom is suspended below the wave basin carriage to allow its movement through the water.

AN OIL STRUCTURE BASED MARICULTURE SYSTEM

In a collaborative effort by the author and NET Systems of Bainbridge Island, Washington, a mariculture system sited around an oil structure has been designed and evaluated at the model scale. This work, sponsored by an SBIR grant, explored a wide range of system geometries, finally focusing on a concept which offered unique economic appeal.

An important measure of a pen system's merit is the cost of the system versus the enclosed growing volume. A further measure is the amount of growing volume that is away from the air/water interface and the associated wave-induced stress. From a simple geometric perspective the concept of a tent-shaped pen was quickly identified as attractive. An important feature of this concept was the utilization of the structure as the central support for the tent pen. It was critical, therefore, to determine the loads that would be generated by such an installation since that would ultimately determine the size and economy of the approach.

A candidate design using a 45√ angle for the netting was used as the basis for model testing. A 1/10 scale model of such a tent pen system surrounding a structure in 50 feet of water was evaluated. Figure 4B.6 shows the model configuration. Model wave frequencies ranged from 0.3 to 0.7 Hz in 0.1 Hz intervals. Currents (carriage speeds) of 0.3, 0.5, 0.7, and 1.0 were used. These ranges correspond to ocean wave frequencies from 0.095 to 0.22 Hz. or wave periods from 10.5 to 4.5 seconds. The corresponding full-scale currents range from 0.95 to 3.16 knots.

Measurements of anchor loads and structure attachment loads were made at selected locations within the system. Load data was measured using small strain gage load cells and recorded on a PC-based data acquisition system. Angle measurements of structure attachment lines were made manually during each run. Data was analyzed and presented in terms of load verses speed or wave frequency. Wave data was normalized to a model wave height of one foot and presented in terms of both average values and amplitudes.

From the model data, full-scale load predictions can be made. Tension members of the systems can be determined and anchors and attachment padeyes sized. In addition, structural attachment loads and their angles can be combined to determine the resultant load on the structure and its foundation pilings. Through these techniques it was determined that, depending on the adequacy of the candidate structure, the tent pen concept was both economically attractive and feasible from an engineering standpoint.

The ultimate success of an offshore mariculture operation will depend on its ability to compete with existing sheltered-water operations and wild harvest fisheries. Offshore sites offer economies of scale but introduce challenges to the designer. Through the use of logical design, performance prediction through model tests, and the specification of components adequate for the task, a tent pen system has been introduced which will cost between $7 and $9 per cubic meter, including installation but exclusive of structure costs. This compared favorably with today's protected-water systems which are priced at $10 to $20 per cubic meter.

Industry partners are currently being sought for the further development of the tent pen design. Systems can be engineered for structures in water depths from 40 to 100 feet. Interested parties should contact the author or Gary Loverich at Net Systems.

MARICULTURE POTENTIAL, PROBLEMS & PERSPECTIVE NEARSHORE & OFFSHORE TEXAS AND THROUGHOUT THE GULF OF MEXICO

Mr. Tim Moore
Texas Aquaculture Association

Gulf of Mexico offshore aquaculture is defined as the rearing of marine organisms under controlled conditions in the Exclusive Economic Zone (EEZ) of the United States; that is, from the three mile territorial limit of the coastal states to 200 miles from shore. There currently is no federal policy with respect to regulating offshore aquaculture.

While marine aquaculture has focused on the production of fish, shellfish and algae in recent years, it is the raising of aquatic animals for food that has seen the truly explosive growth in the last twenty years, with most of that growth taking place in the last ten years.

Why this sudden interest in mariculture? The global catch of fish in 1990 was less than 100 million metric tons. This quantity is simply not adequate to meet the demand that exists today, let alone the demand that will exist in the future.

And regretfully, the oceans of the world will probably never produce more fish than that 100 million metric tons. If anything, a scenario of less and less appears likely. The Food and Agriculture Organization (FAO) has projected that the industrialized nations of the world will require an additional 22.5 million and the non-industrialized nations another 5.9 million metric tons of fish and seafood products by the year 2000. That's a total of 28.4 million metric tons or nearly 60 billion pounds. If the oceans of the world are not going to produce more seafood in the years immediately ahead, that 60 billion pounds must come from aquaculture worldwide.

As most of you are acutely aware, fish landings from the worlds' oceans have lagged far behind the population growth. So not only are we seeing the absolute demand of those in the market now pulling ahead of the supply but we're seeing an additional gap because population is growing much more rapidly than the industry is able to keep up with.

We can simply no longer catch enough fish or aquatic animals to meet the demand of these products. With the population growth and changing diets of health-conscious consumers, aquaculture facilities have begun to respond by expanding to help fill the gap.

Mariculture dwarfs the expectations for the future. Mariculture promises to become the dominant factor in the world seafood industry in the next twenty years but only if the capital necessary to ensure its growth becomes available.

With all of that as background let's look a little more closely at some of the things occurring in the mariculture world and how they may impact on investments in mariculture.

If current state and federal regulatory trends continue to dominate the environmental agendas, several trends are apparent. We are either going to grow marinefish on shore in systems that are environmentally correct, i.e., those that emphasize water reuse and conservation, minimal impingement and negligible effluent impacts, and build facilities that fully consider competing users of the available resources, or we will grow marinefish offshore in open waters where potential impacts are less controversial and environmental impact statements and routine monitoring are not required.

One thing is certain. World demand for seafood appears insatiable. We know that because what started in just a few countries is now truly worldwide and nearly every nation on earth, industrialized or third-world is not only participating in aquaculture but is increasing their annual production and their number of species produced.

Along with globalization, we are seeing a gradual sorting out and relocation by species of aquaculture production areas. More and more aquaculture activities are closing down in geographic areas which are inhospitable for cultural, climactic or economic reasons and are moving closer and closer to more hospitable sites. Aquaculture now is beginning to migrate to places where greater opportunity for ongoing profitability exists, places with warmer

climate, inexpensive land, abundant water, minimal effluent discharge problems, low labor cost.
The primary reasons for interest in offshore mariculture are

- Existing structures such as drilling platforms can be used during and beyond their capable years of extracting oil and gas from the seabed below as growout sites.

- Most pollution from sewage, pesticides, petroleum spills and industrial wastes that occur in coastal waters can generally be avoided in offshore sites.

- Nutrient loading from waste feed and fecal material can be avoided in offshore areas where water volumes and movements will rapidly disperse the waste products.

- Offshore water quality is traditionally more stable than inshore areas. These very enticing benefits are balanced and possibly overbalanced with serious constraints.

- Offshore facilities must endure the harshness of the Gulf. Structures must be engineered to routinely withstand high winds and wave actions that peak at 15-20 feet.

- Modeling structures for the Gulf of Mexico cannot be modeled in the David Taylor Wave Tank. Engineers that design projects for the Gulf cannot easily go from the toothpick model to a full scale ocean structure. Engineers have not been able to accurately predict the force of X height wave times the current when every ninth wave doubles or even quadruples in force. The base line data does not clearly indicate whether offshore structures like rigs should defy nature or work in some sort of unison with nature in the Gulf environment.

Conventional wisdom says:

- Eliminate anchors from the mooring system of any net pen design. They are expensive, unreliable and could interfere with shrimp trawling operations.

- A reliable automated water flush feed delivery system which can be used on either active, unmanned platforms or non-producing rigs has been developed and tested with success.

- Containment nets should in fact not be netting but rather panels of molded fiberglass with 1-2" square grids standardized for all pens and easily replaced by divers as the material becomes biofouled.

- Annual production for any cage system can be increased utilizing supplementing water circulation via a platform mounted pump during high DO demand (i.e., adult fish, mid-summer).

- Every project that I am aware of in the Gulf of Mexico incorporating mariculture concludes that all viable future facilities must be built as much as 20 feet below the surface in the Gulf of Mexico. Conventional wisdom is that "Hostile Environment" only moderately describes the challenges presented mariculturists in Gulf of Mexico.

If it is true that systems have had more success submerged, and thereby removed from the most extreme wave action, then the ability to raise and lower cages in the water for maintenance and harvest must become key components to any system. One of the most simplified versions utilized an exchange of air and water volume inside an octagon flotation collar attached to the pen.

Submerged structures require automation to surface and harvest, requiring additional cost in construction. It appears beneficial to build pens outside the platform legs to allow for expansion of cage volume to an economically viable size. This outside the leg location eliminates the need for anchors, which have been problematic in many systems. The rigidity of units appears to allow for more simplified and reliable feed delivery system.

Current U.S. and international law and offshore lease agreements require the complete removal within one year of offshore structures at the end of the intended useful life. In testimony to Congress, The Marine Board of the National Research Council projected that by the year 2000, two-thirds of the existing offshore structures will have become commercially unproductive and subject to removal and onshore disposal.

Let's be realistic and look at it from the oil and gas companies' perspective:

In consideration of this time-line utilization of offshore structures, oil & gas companies find it nearly impossible and downright unattractive to contribute surplus equipment to anyone but an authorized artificial reef program, such as Louisiana's. Of course the same liability concerns combined with engineering and operational issues dissuade oil and gas companies from considering mariculture agreements involving active production structures.

Other limitations to consider:

- Federal oil and gas leases for the OCS do not authorize the conduct of any sort of commercial activities. e.g., no casinos, no restaurants, no vendor warehousing and no mariculture.

- Mariculture is not related to the core business of oil and gas production. Most oil and gas companies continue to divest non- core, non-strategic assets and activities to cope with increasing compliance costs and foreign competition.

- Oil & gas companies are unwilling to increase their exposure to lawsuits stemming from ANY source.

- Safety concerns discourage oil and gas companies from considering mariculture on active structures, and they are legally bound to remove inactive ones.

- Oil and gas companies would never warrant the suitability or serviceability of offshore structures for uses other than their intended use.

- If oil and gas companies were in a position to accommodate mariculture activities on offshore structures they would require the operator to post performance bonds for both installation and removal of equipment, maintain sufficient insurance to cover all foreseeable damages, and ensure that no structural modification could interfere with either normal or emergency oil and gas operations, including evacuations.

These six major constraints must be overcome for ANY oil and gas company to participate in a mariculture project now or in the future.

Offshore production activities require vastly different approaches and technologies from those utilized in coastal or inland waters. Currents in excess of seven knots, wave actions exceeding 15 feet and seasonal hurricanes dictate utilization of materials and engineering approaches that are inherently more expensive than those in protected waters. Information on engineering requirements for such facilities is developing but have not as yet proven economically competitive.

Anti-fouling has not been comprehensively factored into design criteria materials. Fish biology and fish behavior in cage or net culture is only nominally understood.

High-value species must be economically feasible in offshore culture. Species most favored for offshore production include yellowtail snapper, ling and mahi mahi. These species have achieved complete life cycles in captivity, and larval rearing techniques as well as prepared diets continue to improve. By its very nature, offshore cage culture and its appropriate technologies make it a high-risk/high-cost production method. Marginally valued species simply are not cost effective. Some research indicates that until we in the United States adopt an Asian mindset that allows for an $8-9 dollar per pound average price, mariculture production models will fail to be sustainable and profitable.

With the best technologies available to the industry, we must remember that the agriculture policy in this country has always supported a cheap and affordable food policy.

The risk/reward ratios for platform culture have not been fairly assessed. If pricey fish products prove to be the only viable species, we still haven't determined market demand for these products.

As offshore cage culture commercial production of these high-priced fish increases, per unit cost will be driven downward. This forces us to produce more fish in the same systems to maintain profitability.

We know that dolphins (mahi mahi) experience rapid growth on a cut fish and shrimp diet, but there is no known feed ingredient mix of like nutrition currently developed for open sea culture. Mahi Mahi are symptomatic with schooling behavior and experience less than desirable growth conversion rates when the culture environment experiences rapid and fast current flows. Rapid flows force rapid swimming action in the culture species. This action always increases rapid oxygen intake and contributes to oxygen depletion.

We know that in warm water culture, dissolved oxygen levels can and do fluctuate greatly in the hot summer months. We do not know optimal dimensions for cage culture for each species and in what densities.

We do know that with maximum fish biomass there are many situations in the open seas where large fish in the middle of culture cages will demand supplemental aeration. Supplemental aeration requires additional pumps and energy and additional operational costs.

We know that 70% of all saltwater sportfishing trips made by coastal residents beyond three miles from shore made their trips to oil and gas structures. What does this mean for offshore mariculture? It probably means that fully automated, manned platforms will be required for security and economic reasons. Poaching and theft will demand unique and innovative solutions. The fact that these offshore structures lie in public U.S. waters makes them especially vulnerable and accessible. Video surveillance and utilization of alarm systems may be required as effective deterrents. Satellite communications to trigger patrols of the platforms will certainly be a necessary component of security.

We know that the Gulf waters nearshore structures are threatened by increased nitrogen and phosphorus levels and more unstable salinity. Better culture waters appear to be outside the three-mile barrier. Most of the available rigs lie in the waters beyond three miles anyway.

If the most desirable sites are beyond the three-mile boundary, then this culture methodology will develop on the most inaccessible, remote platforms that will require more costly maintenance from shore, more costly ingress and egress with personnel.

On the positive side however, the more remote locations also offer less risk of winterkill, which is greatly reduced further offshore as oceanic water is not subject to rapid temperature change.

We know that at an average cost of $10 to 15 million for existing construction and placement, industry cannot bear the cost of duplicating these structures for growout facilities. Existing structures must be utilized. A short window of opportunity exists for the development of offshore mariculture.

It is highly unlikely that there will ever be coordination of mariculture activities with oil and gas operations on active platforms. However if oil and gas personnel and mariculture activities can utilize boats, helitransport services, decompression chambers, diving activities and the like, favorable cost controls for mariculture activities will be better achieved. Availability of decompression chambers, need for 110' utility boats to ferry out personnel and to deliver the structures themselves, feed, harvest equipment, use of trained divers for structural repairs can exceed $2,000 per day. These technologies do not come without serious ongoing operational costs that cannot easily be borne by mariculture activities alone.

It will not be easy to make this culture concept viable, sustainable or profitable. High quality seafood demand will continue, regulatory pressure will continue to mount for land-based operations, platforms will continue to be chopped up and scrapped or donated to rig-to-reef programs. Mariculture has a short window of opportunity to make best use of these multi-million dollar structures. We need the fish they are capable of producing, we need the jobs they are capable of generating; therefore, we will meet the demand for technology that makes these platforms viable. Profitability may well be the single most limiting factor in the consideration of the ocean giants for mariculture production.

With roughly an eight-year window of opportunity, the most innovative and viable projects will compete for investment and venture capital dollars against other investment alternatives and possibly less risky ventures. Offshore projects will not enjoy a honeymoon with investor attitudes. This culture technique will not be capable of sustaining highly visible public losses and failures without an immediate erosion of investor confidence. We cannot afford to elephant hunt on the high seas. The most visible of projects in the next five years must show positive promising results. This means that collaborative government and private enterprise projects must pave the future. Platform culture will not attract small investors. These projects are for the stout-hearted and will be funded by big business. They will succeed if they are designed around economies of scale or as supplemental income streams to other offshore integrated oil and gas activities.

THE WATERMARK CORPORATION

Mr. Gregg Creppel
Watermark Corporation

Watermark is embarking upon a venture of attempting to couple offshore oil and gas production with operations designed to farm fish and shellfish in the offshore environment on deep water oil and gas platforms. Recognizing that natural resource management, energy production, and food availability will all become critical issues in the coming century, Watermark has developed a plant that will meet these needs (Figures 5B.1 and 5B.2). Oil and gas production and seafood farming are two industries that are viable for development in the Gulf of Mexico immediately and concurrently. Management believes that the success of combining these industries is built upon the premise that diversity in commercial operations will provide a shield from the risks associated with either operation by itself because of the "buffering" that one operation's revenue flow should offer to the other.

Watermark's primary focus is to establish a mariculture (sea farming) operation that will utilize offshore oil and gas production platforms located in the clear, oceanic-quality, deep waters of the Gulf of Mexico, beyond near-shore land runoff and related pollution. Watermark has researched the global state of affairs with regard to inadequate food supplies for future generations and has selected mariculture as a business venture that will contribute to the solving of these global societal problems. Furthermore, Watermark has chosen to conduct this business in a way that can turn the liabilities of off-shore oil and gas platforms into assets. The company will seek to acquire platforms which still have hydrocarbon production in order to receive the benefit of the revenues generated from further oil and gas production. This income can create a positive cash flow for the company during the time in which the mariculture operation is being established and can enhance the overall corporate profitability thereafter.

The demand for seafood significantly exceeds the ability for the countries of the world to supply seafood to consumers. Seafood shortages are related to the decline in natural fishery populations both from over-fishing and environmental degradation. With the anticipated continued decline in natural seafood supplies, mariculture is attracting wide interest from both the business community and governments around the world as a means to supplement dwindling natural fishery supplies and eventually could become a dominant source of seafood.

Mariculture, the farming of marine organisms in a controlled aquatic environment, is an infant science with significant, although untested, potential. Well planned, efficiently managed mariculture operations can achieve goals of environmental protection and natural fishery stock preservation. The farming of marine species can reduce pressures on natural stocks, which in some instances are approaching extinction, and can provide economic stability to fishing communities by providing significant profit-producing food harvests for growing populations world-wide. As mariculture technology continues to develop, including the use of better environments, such as deep ocean water regions, and the continued improvement of caging methods and feeding of culture species, there is no doubt that the proportion of seafood provided through mariculture versus natural fished stocks will continue to increase.

Watermark's goal is to supply a premium-priced species such as pompano to the seafood market. There are many economic advantages to cultivating a delicacy product such as pompano. This product can command a high price, eliminate the vagaries of commodity markets, and control market expansion by supply rather than demand. Presently, the pompano market (about one million pounds annually) is relatively small compared to other fishery products, due to a limited catch by fishermen. The market is also highly elastic and could be greatly expanded with little effect on its price. Pompano has an excellent name and reputation throughout the United States. No efforts have been made, however, to

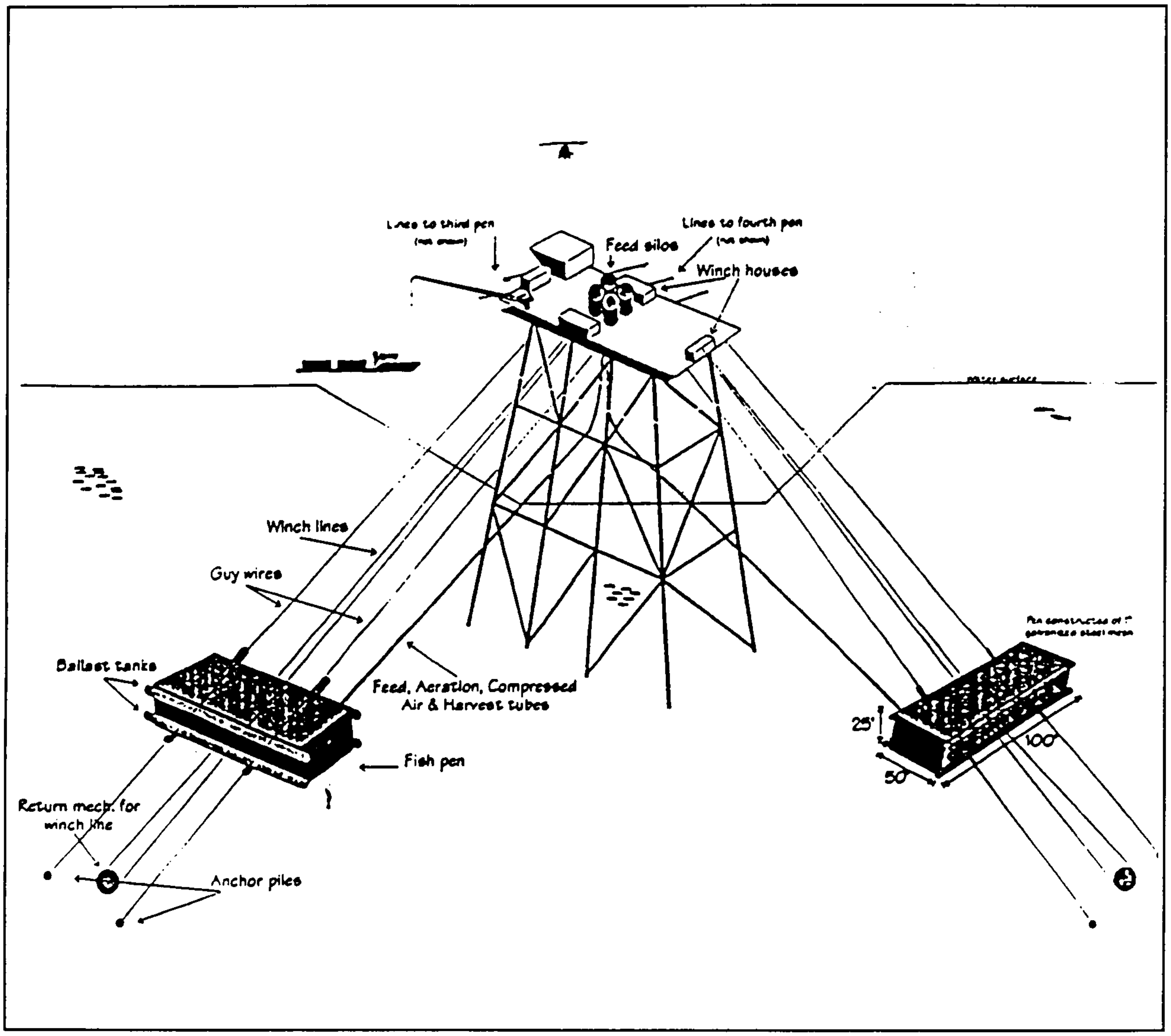


Figure 5B.1. Surface view rendition of oil and gas platform supporting mariculture facilities.

expand the pompano market because of its limited natural supply.

The concept of utilizing offshore oil and gas production platforms for mariculture purposes is not new. It is only now, however, that the environmental, economic, and biotechnological components are coming together to facilitate this industry. The development of this proposed relationship provides a catalyst for a critical evolution in the way natural and man-made resources are utilized, as even the most bountiful of resources are finite.

Watermark envisions rapid horizontal expansion to a number of platform facilities, followed by vertical integration of several of the component services and products involved in mariculture. With as many as 3,800 platforms in the Gulf of Mexico, there is the potential for the company to obtain a substantial number of producing platforms that will serve as mariculture facilities. As Watermark expands, it will also eventually be able to minimize the Company's dependence on commercial purveyors of feed products and processing facilities. This will result in enhanced profitability by incorporating value-added processing at all levels of production as well as through cost reduction.

Oil and gas platforms provide an excellent environment in which to grow enormous quantities of

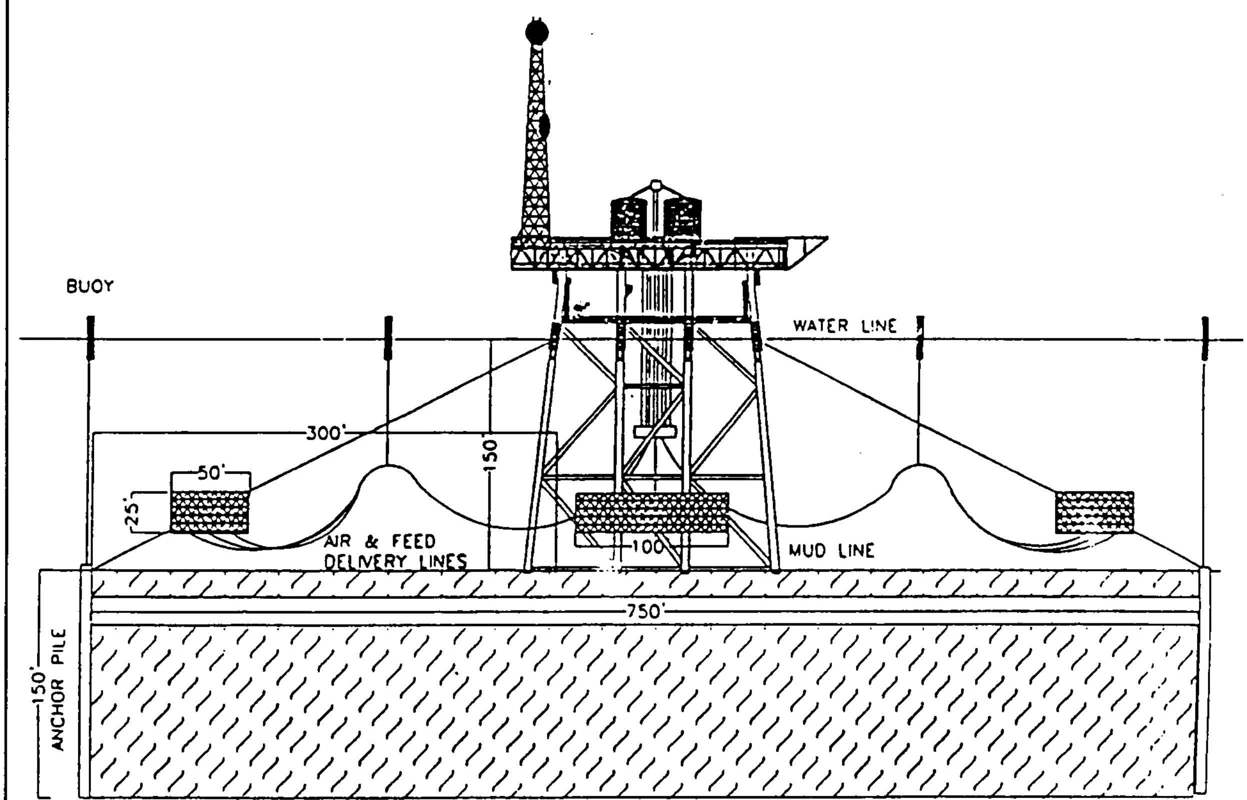


Figure 5B.2. Vertical cross-section rendition of oil and gas platform supporting mariculture facilities that shows the radial dimensions of the complex.

high-value fish and shellfish worth many millions of dollars. The possibilities for growth and profits for Watermark through combining the business of oil and gas production with the business of mariculture are extensive, and Watermark has assembled the right management team with the expertise to get the job done.

HIGH SEAS MARICULTURE

Mr. Michael C. Kacergis
Maryland Shrimp Company Inc.

To most people the word aquaculture is either a foreign term or it invokes images of cutting edge technology and exotic gadgetry for rearing shellfish and finfish. While many believe that aquaculture is a new industry, the reality is that aquaculture dates back to the ancient Romans in the West and the Chinese in the East. Today, worldwide efforts in aquaculture, especially mariculture or marine aquaculture, are expanding as traditional fishery stocks dwindle or collapse.

The U.S. fishing industry is experiencing difficult times, as indicated by these headlines that paint a picture of a recently-unfolding crisis:

Baltimore Sun: "Over Fishing Has Nearly Depleted World's Oceans"
Boston Globe: "Fish: Greed, Pollution, Development Take Toll"
Buffalo News: "The Worldwide Fishing Crisis"
National Fisherman: "Disaster Relief Funding Sought To Keep Northeast Fishermen Afloat"
The Economist: "The Tragedy Of The Oceans" (a possible allusion to G. Hardin's 1968 article, The Tragedy of the Common, Science 162:1243-1248.)

In reality the decline of ground fish populations has been seen over many years. Georges Banks has experienced one remarkable shift in species biomass. Traditionally cod, haddock, and yellow tail flounder dominated this rich fishing ground. Today dogfish (shark) and skate account for 75% of the catch by weight (U.S. Department of Commerce 1992).

In 1988, the United Nations Food and Agricultural Organization (FAO) reported that the world fish production accounted for approximately 98 million metric tons. This figure includes 14 million metric tons from aquacultural production (FAO 1991). According to dollar value statistics from the FAO, as of 1992 the United States ranked as the world's second largest importer of fishery products. Japan ranked first in fish imports. In 1993 U.S. imports of fishery products reached a record $10.6 billion while our exports of fishery products accounted for only $6.9 billion. This resulted in a trade deficit of $3.7 billion (U.S. Department of Commerce, 1994).

In general, the U.S. fishing industry appears plagued by catch reductions and closures due to diminished fish populations. Some examples include the west coast herring roe fishery now reduced from its historical significance to a season lasting all of 42 minutes. The Alaskan halibut fishery is shifting from last year's pair of 24-hour "derbies" to a system of Individual Transferable Quotas (ITQs). (For an overview of ITQs, see D. Shaw. 1994. Halibut: Understanding ITQs: When youy buy, what you'll pay. In Seafood Leader, Vol. 14, pp. 106-114.) For the second time in 28 years Alaska is closing the Bristol Bay king crab fishery. On the east coast the New England Fishery Commission is proposing sweeping closures on Georges Bank to allow haddock stocks to regain strength. And in Gulf of Mexico waters, Florida just passed a referendum that essentially bans nets larger than 500 square feet of mesh from state waters.

There are several measures that may ease fishing pressure and allow fish populations to regain strength. The implementation of bans and area closures represent the harshest restrictions to be endured by the fishing community. Individual transferable quotas, limited entry, area licensing, and sole ownership (Edwards *et al.* 1993) are additional measures that may aid in the recovery of fish populations. Mariculture, a truly renewable industry represents an alternative that would help mitigate heavy fishing pressures currently exerted on our living marine resources. By producing sufficient quantities of domesticated fish species, we would reduce our dependence on natural stocks, allowing them to regain historical levels.

Mariculture would also provide a means to reduce our dependence on imported fishery products. In 1988 seafood product imports accounted for more than 25% of the dollar value of all food and live animal imports combined. The imported seafood products total for 1988, $5.3 billion, was slightly greater than the total imports of meat products and live animals, $5.2 billion (National Research Council 1992). In light of our dependence on imported seafood, the 1994 $3.7 billion deficit, and declining fish populations, it would be prudent to explore the possibilities of large scale mariculture.

In the Gulf of Mexico there exists a unique opportunity to link the oil and gas industries with mariculture operations. The petroleum industry on the Outer Continental Shelf (OCS) began in 1947 when the first well was drilled beyond the sight of land (Emmer *et al.* 1992). Since then the industry has experienced many lucrative years but today it finds itself in an economic slump. A new trend has recently appeared in the OCS where the petroleum industry began removing more production platforms than they were installing. (See Figure 5B.3 for

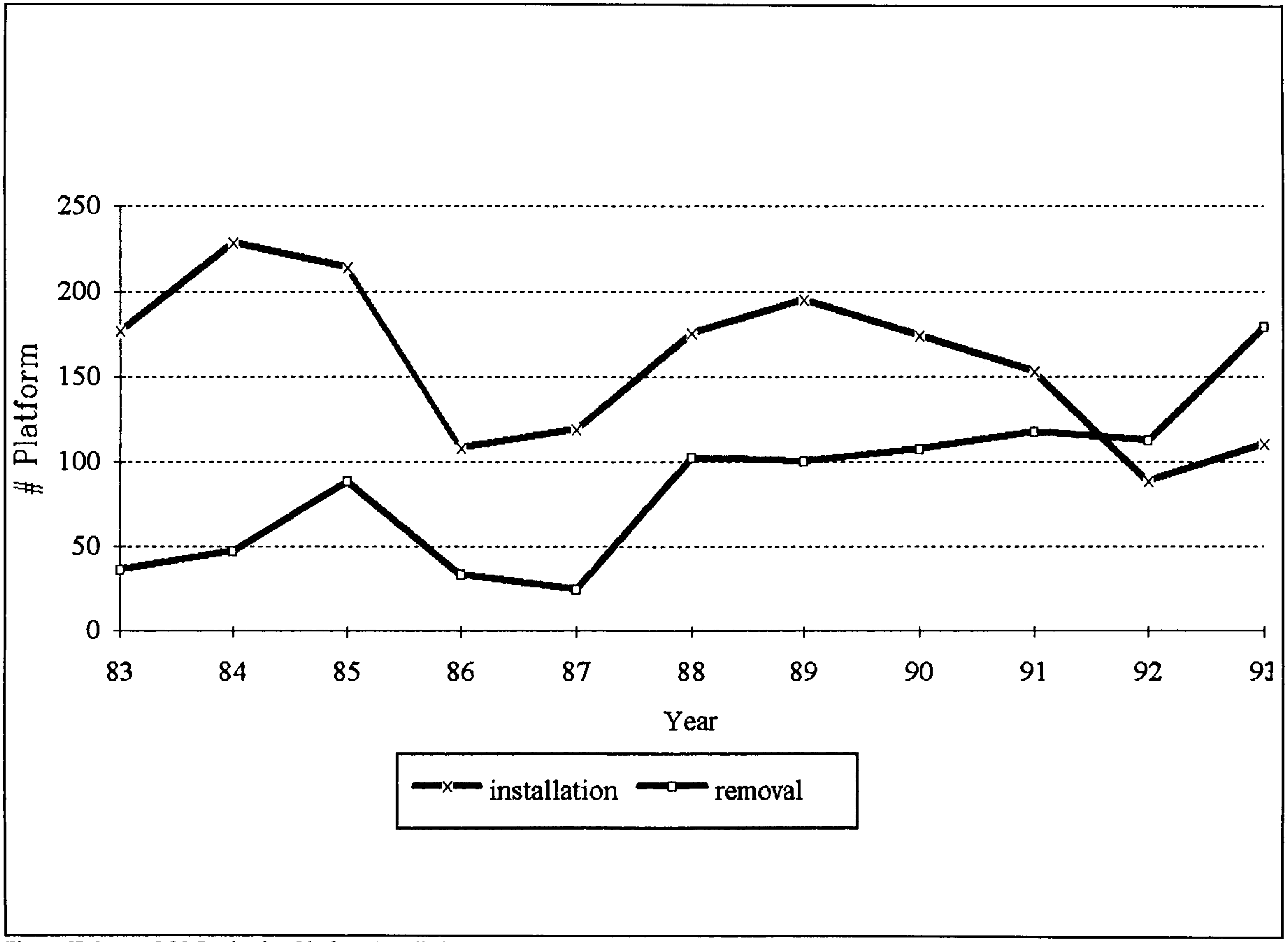


Figure 5B.3. OCS Production Platform Installation vs. Removal.

additional detail.) Since 1987 and 1993 the number of platforms being removed jumped from 24 to 179 respectively. This accounts for an 87% increase in platform removals over only six years (U.S. Department of the Interior 1994). These platforms, which have reached the end of their effective design life are viewed as a liability and not a valuable resource. The largest aspect of the liability is presumably the considerable cost of platform removal. One should note that many of these platforms are situated in waters highly suitable for raising a wide variety of marine finfish and shellfish. As each platform is removed, a potential opportunity to establish a mariculture site in the OCS is lost.

Maryland Shrimp Company (MSC) feels that mariculture can intervene in several ways, providing financial incentives for both platform owners and for the Minerals Management Service. Platform owners will benefit from the additional revenue stream generated by a percentage of the sales of fish. This new revenue stream, which could effectively cover the debt service on the platform could transform a marginally producing platform into a profitable platform. A non-producing platform scheduled for removal would remain on station. This would postpone the costly removal and greatly increase the design life of the platform. Under MSC's program the platform would now serve as a support structure for mariculture operations whereby one platform will be associated with one netpen. Platforms or "Offshore Mariculture Infrastructure Stations" can now serve as housing for netpen attendants, storage for feed, and a site for energy generation required for the daily operation of the netpen. MMS would benefit from a royalty based on a percentage of the fish sales. Maryland Shrimp Company views the role of MMS in OCS mariculture as that of lead agency in regulatory oversight. MMS already regulates gas and oil operations in the Gulf of Mexico and has in place the necessary infrastructure to fill the position of lead agency. This infrastructure includes support systems, transportation, and the generation of data for the Gulf of Mexico.

Netpens will not be attached directly to the platform for both engineering and safety considerations. The only direct connection between the netpen and the platform will be an umbilical that will provide power to both the winching system and surface lighting. In the event of catastrophic failure of the netpen the umbilical will have a breakaway connection, thus allowing the netpen to settle to the bottom and not affecting the structural integrity of the platform. The netpens are designed to allow remote adjustment of their height in the water column. This will permit netpen attendants on site to raise or lower the pen in varying weather conditions.

Maryland Shrimp Company plans to raise a range of economically important finfish species. These species include:

Tuna	(*Thunnus sp.*)
Mahi-mahi	(*Coryphaena sp.*)
Red drum	(*Sciaenops ocellatus*)
Snapper	(*Lutanus sp.*)
Grouper	(*Epinephelus sp., Mycteroperca sp.*)
Tilapia	(*Tilapia sp.*)

All species above were chosen for a variety of reasons. Economically, species appeal as a "white table cloth item" (a term used to describe high value, high priced items in the restaurant trade) implies high economic value on the retail market. This factor alone makes a species highly attractive for domestication. In the case of blue fin tuna, wholesale export prices can command as much as $35.00 per pound. Growth rates and ease in spawning are other important considerations in the choice of a fish species targeted for domestication. Mahi mahi demonstrate high fecundity (many eggs from a single spawn) and tremendous growth rates in captivity where a 1.3 kg fish can be raised from the egg stage in approximately 130 days (Hagwood *et al.* 1981; Kraul 1993).

Even though tilapia is a fine fish for human consumption, this species was chosen for several additional reasons. First, certain species of tilapia are filter feeders which means all their nutritional requirements can be derived from the surrounding water. This significantly reduces the quantity of food required to rear them. Full strength sea water is known to inhibit the spawning of tilapia. Even though there are reproducing populations of tilapia in the coastal brackish waters of Florida, Louisiana, and Texas, we are not aware of any reports of tilapia caught in deep waters of the OCS. In the event of escape, it is unlikely a tilapia would survive long. This species of fish is suited to the relatively shallow protected waters of rivers, ponds or estuaries. Their morphology allows the fish only short bursts of speed which will make them easy prey for the streamlined pelagic predators which roam the Gulf of Mexico. Tilapia will provide both a protein source as feed required by the species of higher economic value as well as high quality white fish fillets for human consumption.

There are several benefits the mariculture industry has to offer. One of the more obvious benefits is the creation of jobs in economically troubled regions. Many positions would be created including netpen attendants, fish processing, and transportation. Maryland Shrimp Company has a standing policy to set starting wages at $11 per hour. Unlike the traditional fisheries, mariculture is a truly renewable industry. Entire generations of fish are reared from larvae to adulthood supplied by eggs of captive brood stock. Another benefit is that fish farming offers relief from the heavy fishing pressures exerted on many fish populations. Markets can be supplied with farmed fish, thus reducing the dependence of wild stocks. Mariculture can also directly replenish depleted populations through a program of stock enhancement. Large quantities of larvae and juvenile fish can be released into specific areas where populations once flourished in the hope that a small percentage will survive to the age of reproduction. Last, unlike traditional fish harvest methods, there is no bycatch associated with mariculture. (Bycatch or incidental-catch is the taking of non-target species. Bycatch is usually discarded into the sea dead.) For a worst case scenario one need only examine the global shrimp industry's bycatch records to view discard rates as high as 1,100% (Warren 1994).

Mariculture in federal waters has its share of difficulties, the largest being regulatory ambiguity specific to ownership of fish within a netpen. For example, the Magnuson Fishery Conservation and Management Act, does not mention aquaculture or mariculture within its text. It does state however, ". . . the United States claims . . . sovereign rights and exclusive management authority over all fish, and all Continental Shelf fishery resources, within the exclusive economic zone." (For additional information, see Magnuson Fishery Conservation and Management Act, section 101.00-627(a).) This gives ownership of fish within a netpen to the Federal Government and eliminates private ownership. The Canadian Aquaculture Act (ascended to 8 December 1988) on the other hand states in section 16(5),

> "All aquacultural produce of the species and strains specified in the aquaculture license, while constrained within the boundaries of the aquaculture site, are the exclusive personal property of the licensee until sold, transferred, or otherwise disposed of by the licensee."

For mariculture to exist in the OCS there must be a legal provision that specifies private ownership to fish within the netpen. Without such a provision, there is little incentive for private industry to invest under such financially risky circumstances.

The oil and gas industry in the Gulf of Mexico's OCS is experiencing a dramatic shift toward increased production platform removals. These platforms should be considered a valuable asset rather than a financial liability. Mariculture offers a renewable industry and alternative revenue stream to the platform owner. By creating an industry in the OCS, mariculture will offer many jobs to communities burdened by high unemployment rates. Mariculture represents a viable alternative to the traditional methods of harvesting marine fish products. Finally, mariculture has the potential to satisfy many of the United States' seafood needs and offers relief to our increasing seafood import deficit.

REFERENCES

Edwards, F.H., A. J. Bejda, and A. Richards. 1993. Sole Ownership of Living Marine Resources. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Woods Hole, Massachusetts.

Emmer, R.E., A. Rheams, and F. Wagner. 1992. Offshore Petroleum Development and the Comprehensive Planning Process. Final report submitted to Minerals Management Service.

Food and Agricultural Organization (FAO). 1991. FAO Yearbook, Fisheries Statistics, Catches, and Landings. Vol. 68, 1989.

Hagwood, R.W., G.N. Rothwell, M. Swafford, and M. Tosaki. 1981. Preliminary report on the aquaculture development of the dolphin fish, *Coryphaena hippurus* (Linnaeus). Journal of the World Aquaculture Society 12(1):135-139.

Kraul, S. 1993. Larviculture of the mahi mahi, *Coryphaena hippurus* in Hawaii, USA. Journal of the World Aquaculture Society Vol. 24 , No. 3 pp. 410-421.

Hardin, G. 1968. The Tragedy of the Commons. Science 162:1243-1248.

National Research Council. 1992. Marine Aquaculture: Opportunities for Growth. Committee on Assessment of Technology and Opportunities for Marine Aquaculture in the United States. Washington D.C.: National Academy Press. p. 290.

U.S. Department of Commerce. 1992. Status of Fishery Resources off the Northeastern United States for 1992. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Woods Hole, Massachusetts.

U.S. Department of Commerce. 1994. Fisheries of the United States. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, D.C.

U.S. Department of the Interior. 1994. Current Facts and Figures, Minerals Management Service, Offshore Oil and Gas Operations, Gulf of Mexico OCS Region, August 1994.

Warren, B. 1994. Major report points to many incidental-catch problems worldwide, but few solutions. *In* National Fisherman, Vol. 75, No. 1, pp. 16-17.

OPEN OCEAN MARICULTURE AND THE SIGNIFICANCE OF PETROLEUM STRUCTURES TO FISHERIES

Mr. Steve Kolian
Tulane University

Discourse begins by introducing an open ocean mariculture concept and then moves on to address two case studies that examine the significance of petroleum structures to the regional fisheries. The mariculture idea, called Hydro Wheel (Figure 5B.4), is to submerge and organize several petroleum structures as artificial reefs inside a planning area. Then process fish above the reef configurations, sending the discards down to the reef fish.

For example, if a trawler came up and unloaded his catch at the processor, the usable portion of the harvest would be channeled to the market and the discards would be sent down to the reef fish. His by-catch would be reduced to 1%, everything would go to the market or be utilized to feed the reef fish below. Commercial and recreational hook and liners would catch fish above the reefs.

More importantly, the fishermen will be doing the work for the fish. Most of his catch will be diffused through a pipe system distributing about 2,000 lbs. of fish offal a day. His trawls, his haul, his diesel engine, will help find the next meal for the fish. Much as in agriculture, where yield can be related to the input of subsidiary energy, i.e. machine, fertilizers, irrigation. Hydro Wheel production will be relative to the amount of food and habitat invested. The proposed system can be a platform for a succession of fisheries management strategies, including crab culture, lobster farming, brooding and stocking, etc. Fishermen will be transferred from predator methods to agrarian methods, lifted from one groove to be set in another.

REEF HABITAT, RED SNAPPER, AND PETROLEUM STRUCTURES: CASE STUDY

The Louisiana continental shelf is home to over 3,000 oil and gas platforms. The base of a platform, called a jacket, forms a profile against ocean currents. Attaching organisms, including hermatypic coral and octocoral, colonize the substrate up and down the steel structures. The 3,000 oil and gas platforms peppered across the shelf constitute 90% of the reef habitat offshore of Louisiana (Scarborough-Bull 1987). Otherwise, there would be virtually no reef habitat. Sedimentation from the Mississippi and the Atchafalaya smothers any natural reef development until a thin archipelago of coral reefs, about 100 miles seaward from the coast (Figure 5B.5).

As the wells dry up, the structures are removed. Every year over 300 acres[3] of high-profile substrate disappears off the continental shelf (MMS platform

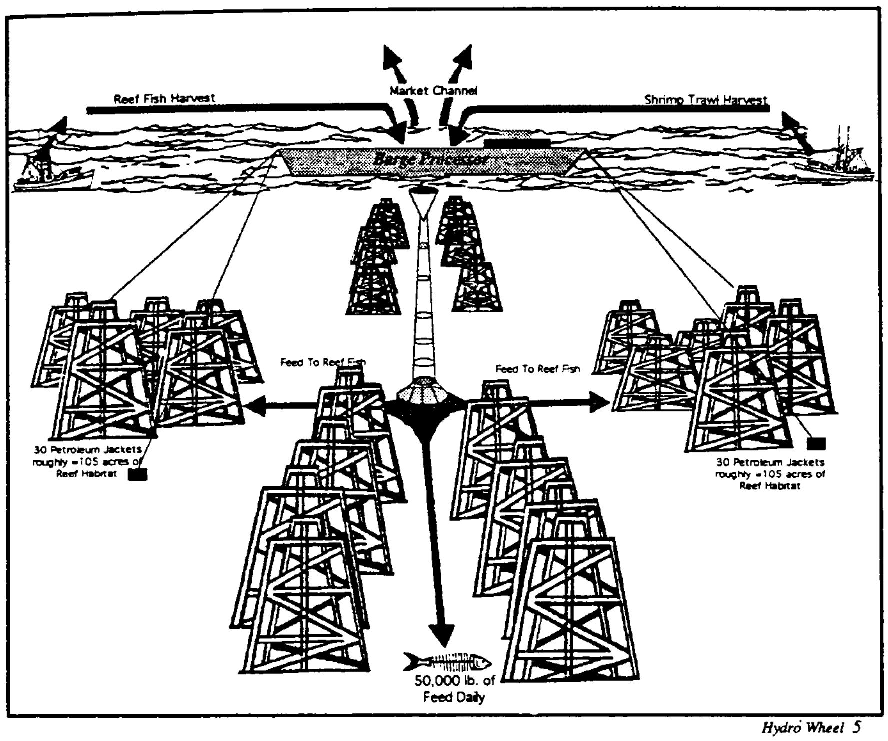


Figure 5B.4 Hydro Wheel concept.

removal schedule 1994). To reef fish such as red snapper, the ferrous profile of an oil and gas platform provides the same functions as the calcium profile of natural coral. They form grazing areas, respite from the current, nursery grounds, and protection from predators. They accommodate feeding mechanisms for numerous species at every trophic level.

Due to their hydraulic morphology, artificial reefs have a much higher (10-15 times) carrying capacity than natural reefs. So the removal of petroleum structures, estimated to be 90% of the reef habitat along the Louisiana continental shelf, may be more significant than the figure above suggest (Figure 5B.6)

Authorities are campaigning for the mandatory use of a Bycatch Reduction Device (BRDs) to protect red snapper from incidental catch by shrimp trawlers. Contrary to popular opinion, the BRDs are not being implemented to protect finfish in general; they will be required to protect red snapper. Ground fish are only being harvested at about 50% of their optimum yield (NMFS 1981).

Red snapper exhibit such a strong fidelity to structure, the developers of BRDs have encountered trouble designing a device that works. Red snapper have been observed to refuse to swim out of a net equipped with a cumbersome BRD (Atrand 1994). In another report, by-catch reduction devices where used on one side of a vessel and a normal net on the other. Researchers found that the nets without a BRD consistently had zero or very few snapper mortalities while the nets equipped with a BRD consistently contained larger snapper mortalities (Lirette 1994). This suggests that snapper are structure oriented.

Most of the red snapper habitat ranges west of the Mississippi right where oil and gas structures compose the majority of reef habitat. If the bulk of the reef habitat disappears, the red snapper populations will decrease proportionally. There are approximately 18,000 licensed commercial shrimp operators in Louisiana alone (LDWF 1989). The BRDs will be enforced upon all the shrimpers in the Gulf of Mexico. Thousands of fishery jobs are in jeopardy due to the declining populations of red snapper.

JAPANESE ARTIFICIAL REEFS AND PETROLEUM JACKETS

Japan has experienced amazing success with their artificial reef program. They have invested $7 billion in their coastal program so far and continue to reinvest year after year (Nagahata 1991). Their aim is self reliance, to transform a national fleet that once pursued fish in distant seas to one that harvests fish in Japanese coastal waters.

Their materials are usually reinforced cement blocks, and they are only about 2 by 2 meters, though some modules reach 10 meters in height (Sonue and Grove 1985). Although they sometimes try other configurations, generally they drop cement blocks and pile them on top of each other (Figure 5B.7). So the end result is not, by any means, as highly developed an engineering design as petroleum structures.

The cost of Japanese installations vary from $60,000 to $16,300,000 (Nagahata 1991). An eight-tier petroleum jacket from a 120-foot depth composes

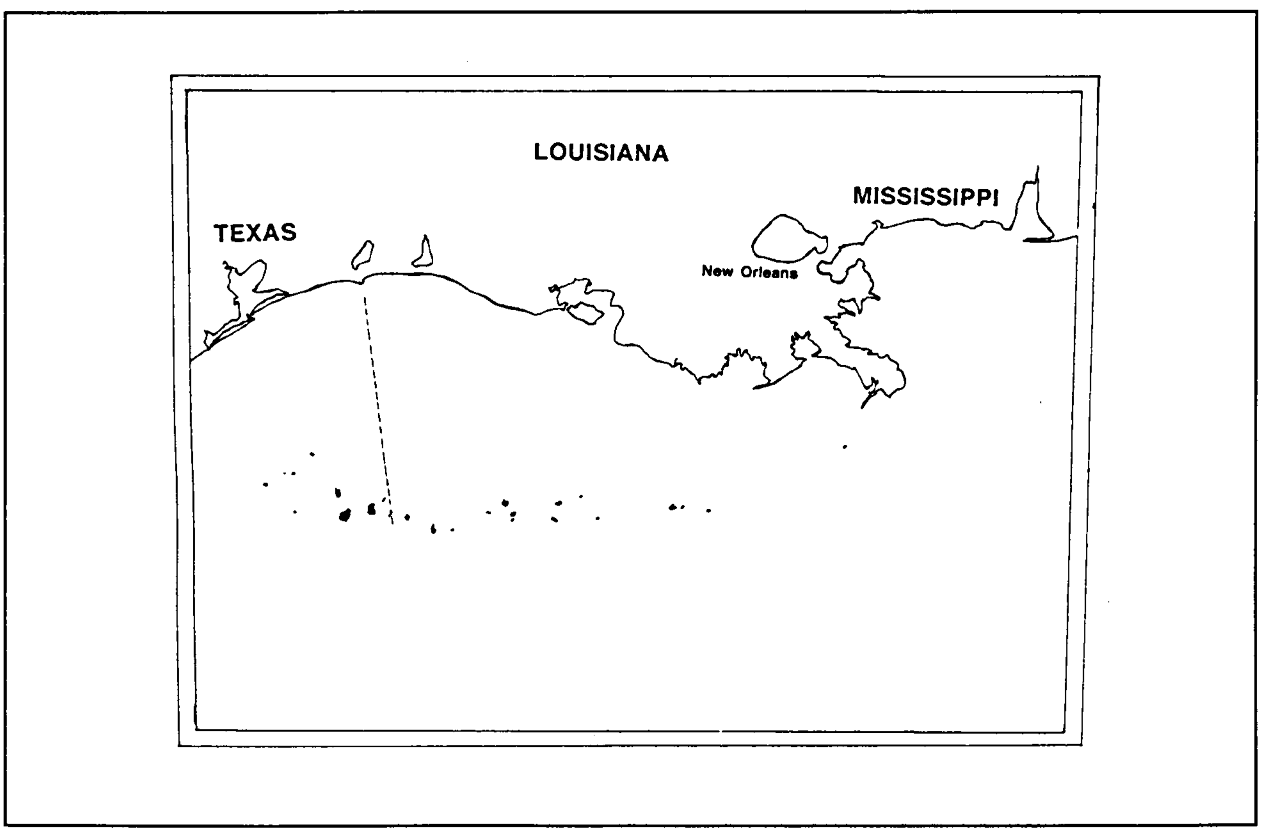


Figure 5B.5. Tributary sedimentation prevents any natural reef development until a thin archipelago of reefs.

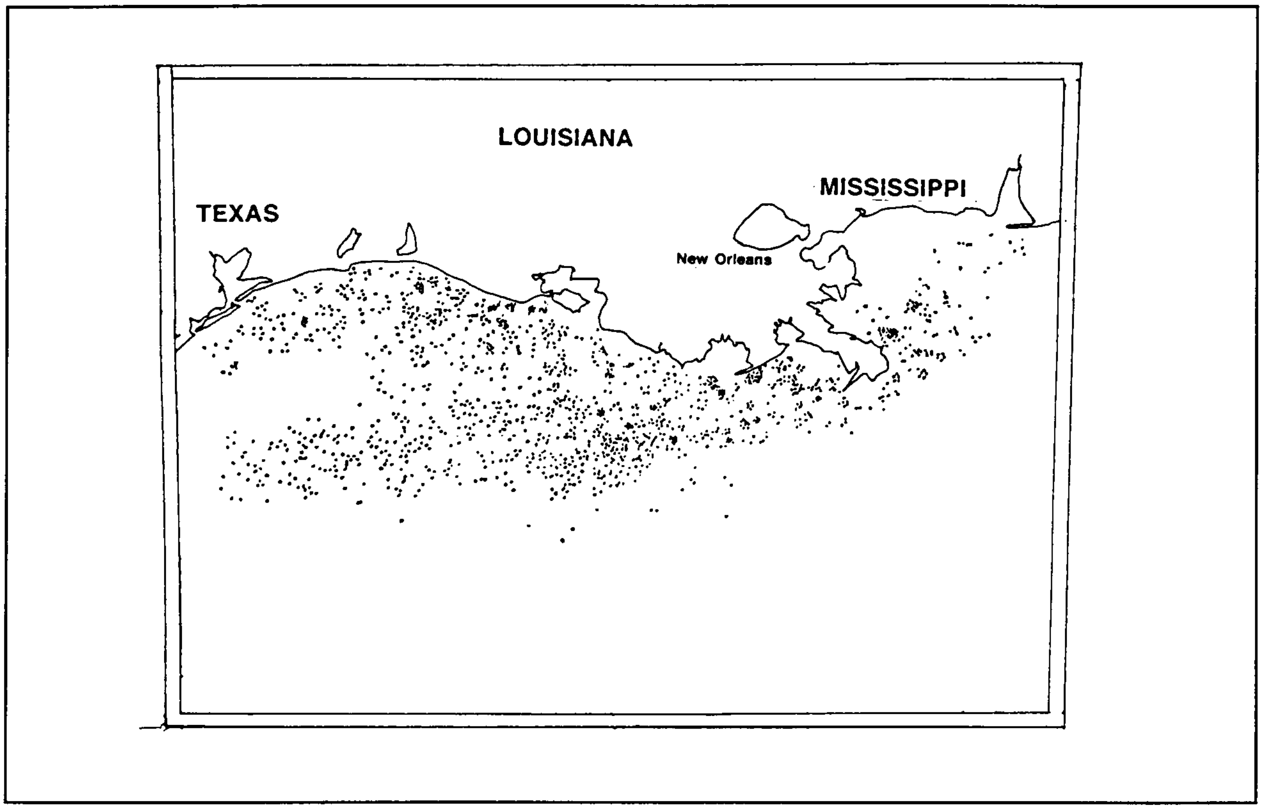


Figure 5B.6. Petroleum structures constitute 90% of the reef habitat along the Louisiana continental shelf.

93,000 m^3 of volume with a footprint of 3,900 $meters^2$ encompassing 3.5 $acres^3$ of substrate surface (Quigel and Thorton 1987) (Figure 5B.8). A comparable Japanese cement reef of that size would cost $10,000,000 to build and install.

Bonsack and Sutherland (1985) showed that Japanese artificial reefs offset their investment dollar in one year. If they spent $10 million to build and install 93,000 m3 of reef habitat, the fishermen would catch $10 million worth of fish over the reef every year. They would spend about $45 billion on cement modules to build the equivalent amount of reef habitat presently available in our petroleum jackets.

CONCLUSION

Man and marine life would mutually benefit by leaving the oil and gas structures in the water, particularly when you consider Japan has spent $7 billion installing artificial reefs and our oil and gas companies will spend over $7 billion to remove them all (Reggio 1989). The obsolete oil and gas platforms could help develop a new fishery approach that eliminates waste and transforms fishermen from predator methods to agrarian methods. It is crucial that parallels be drawn between snapper populations and petroleum structures as well as natural reef habitats and the ferrous profiles supporting the platforms. They constitute 90% of the reef habitat along the Louisiana continental shelf. Over three hundred $acres^3$ are being destroyed every year.

REFERENCES

Atrand, S. 1994. Mr. Atrand is a representative of Gulf of Mexico Fishery Management Council. Information obtained by interview.

Bonsack, J.A. and Sutherland, D.L. 1985. Artificial reef research: a review with recommendations for future priorities. Bulletin of Marine Science, Vol. 37.

Lirette, D.J. 1994. Mr. Lirette is a Fishery representative for the Terrebonne Fisherman's organization. Information obtained by interview.

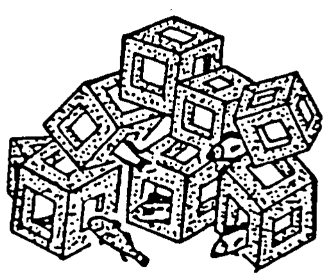


Figure 5B.7. Japanese artificial reefs.

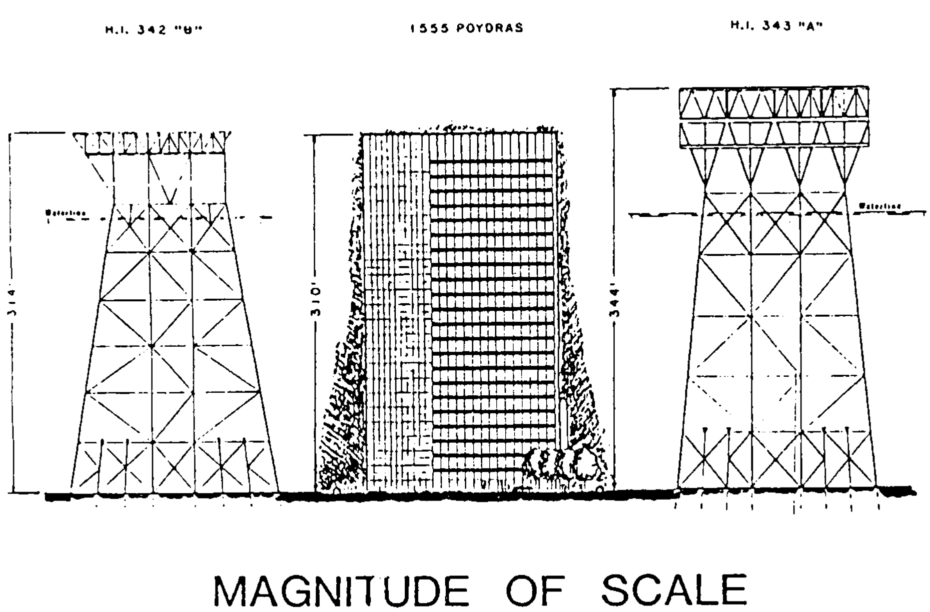


Figure 5B.8. Petroleum platform.

Louisiana Wildlife and Fisheries. 1989. Number of Commercial Trawling Licenses issued in 1989.

Nagahata, Daishiro (ed.). 1994. Recent advances in aquatic habitat technology. Proceedings of the Japan-U.S. Symposium on Artificial Habitats for Fisheries, June 11-13, 1991, Nihon University Conference Hall, Tokyo, Japan. Rosemead: Southern California Edison Company.

NMFS. 1981. Draft Fishery Management Plan, Environmental Impact Statement and Regulatory Analysis for Groundfish in the Gulf of Mexico. National Marine Fisheries Service.

Quigel J.C., and Thorton W.L. 1987. Rigs to reefs—a case history. *In* Petroleum Structures as Artificial Reefs: A Compendium. Fourth International Conference on Artificial Habitats for Fisheries, Rigs-to-Reefs Special Session, 4 November 1987, Miami, FL OCS Study/MMS 89-0021. 176 pp.

Reggio, V.C., Jr. (compiler) 1989. Petroleum Structures as Artificial Reefs: A Compendium. Fourth International Conference on Artificial Habitats for Fisheries, Rigs-to-Reefs Special Session, 4 November 1987, Miami, Fla. OCS Study/MMS 89-0021. 176 pp.

Scarborough-Bull, A. 1987. Some Comparisons Between Communities Beneath Petroleum Platforms Off California and in the Gulf of Mexico.

Sonue C. J. and Grove R.S. 1985. Typical Japanese Reef Modules. Bulletin of Marine Science, Vol. 37.

Mr. Steve Kolian grew up commercial fishing in the Gulf of Mexico from Brownsville to the Dry Tortugas with several years' experience in both the trawling and reef fishery. Mr. Kolian also worked on the railroad on lines across the Canadian Provinces and the U.S. Rockies as a gandy dancer and as part of a section gang. He received his B.A. from Augsburg College and MSPH in Environmental Water Quality at Tulane University.

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 **Royalty Management Program** 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.