Artificial Reefs of the Gulf of Mexico:

A Review of Gulf State Programs & Key Considerations

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Reef Pyramids being deployed into a Florida Bay
Photo Courtesy of Florida Fish & Wildlife Conservation Commission

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BACKGROUND

All five Gulf States have artificial reef programs, and over the past few decades the states have built artificial reefs both inshore and offshore across the Gulf Coast. Additional reefs are being proposed, particularly with the various funding sources related to the Deepwater Horizon disaster. This paper provides a review of existing artificial reef programs, provides baseline information on natural reefs on the northern Gulf of Mexico, and provides for a better understanding of the economic and environmental considerations that should be accounted when developing new artificial reefs.

OVERVIEW

There are many different types of natural-occurring reefs within the Gulf of Mexico, but the natural bottom of the Northern Gulf of Mexico is predominately flat sand. Outside of a few, ecologically-important coral reefs off the Florida coast and the Texas/Louisiana border, the Gulf's natural nearshore reefs are primarily shallow carbonate banks of scattered boulders rather than discrete reef complexes.

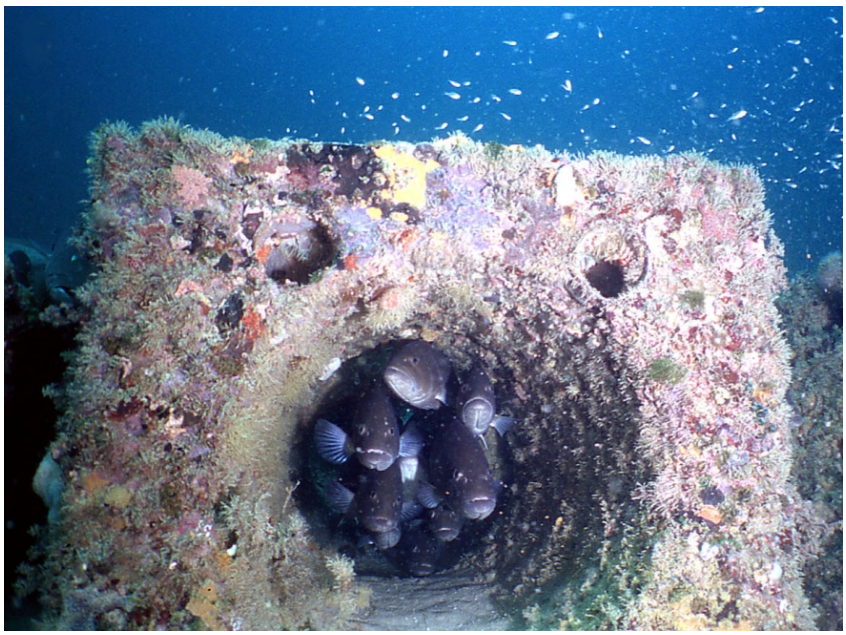
The Gulf's estuaries are also home to reef complexes, primarily oyster reefs which provide nursery habitat for fish and other wildlife, protection from predators, water filtration, and reduced erosion. In addition, oyster reefs have significant economic impacts, including commercial fishing and indirect contributions to Gulf Coast tourism. The Gulf of Mexico accounts for approximately 67% of the nation's total oyster harvest.

Unfortunately, the estuaries of the Northern Gulf of Mexico are believed to have lost well over half of their historic oyster reefs, primarily a result of overharvesting by means of destructive dredging practices and habitat degradation, including reductions in water quality and quantity.

Additional types of natural reefs found in Gulf estuaries are serpulid (calcareous) reefs in Texas and fragmented coral reefs in bays of Florida leading to the Florida Keys coral archipelago. Serpulid reefs were formed from the calcareous tubes of serpulid worms in hypersaline bays such as Baffin Bay in Texas. Formation of the reefs began about 3,000 years ago and ended about 300 years ago, so degradation of these reefs contributes to the loss of hard substrate in the system. Florida reefs face threats from coral bleaching events and outbreaks of various coral diseases.

All five Gulf States have implemented artificial reef programs that aim to supplement the Gulf's natural reef habitats. According to William Seaman, Jr. (2000) an artificial reef is defined as ***"one or more objects of natural or human origin deployed purposefully on the sea floor to influence physical, biological, or socioeconomic processes related to living marine resources."***

Nearshore artificial reefs can be created that will develop communities of encrusting organisms and bait fish over time. As various encrusting organisms such as corals and sponges cover the artificial reef material, small animals take up residence. As these small animals become abundant larger animals are attracted and feed upon these, and so on until a reef food web is created. Energy is able to then provide biological growth potential that provides additional protective habitat, as well as sustenance for fish species. Some experts believe that artificial reefs can function comparably to natural reef communities. Others argue that artificial reefs merely attract existing fish from the adjacent open water habitat, forming more dense fish aggregations.



Grouper Utilize Artificial Reef Structures off of the Dixie County Coast in Florida
Photo Courtesy of University of Florida

STATE ARTIFICIAL REEF PROGRAMS

Alabama

Alabama has one of the largest artificial reef programs in the United States. Alabama's Artificial Reef Program is the product of a cooperative agreement between the U. S. Army Corps of Engineers and the Marine Resources Division of the Alabama Department of Conservation and Natural Resources. The program is the culmination of many meetings, letters, reports and workshops between various user groups within the coastal area. It is intended to be dynamic with changes occurring as technology develops on artificial reef construction.

Artificial nearshore oyster reef at Helen Wood Park near Mobile, Alabama
Photo Courtesy of Cesar Harada

<u>Offshore Reefs:</u>

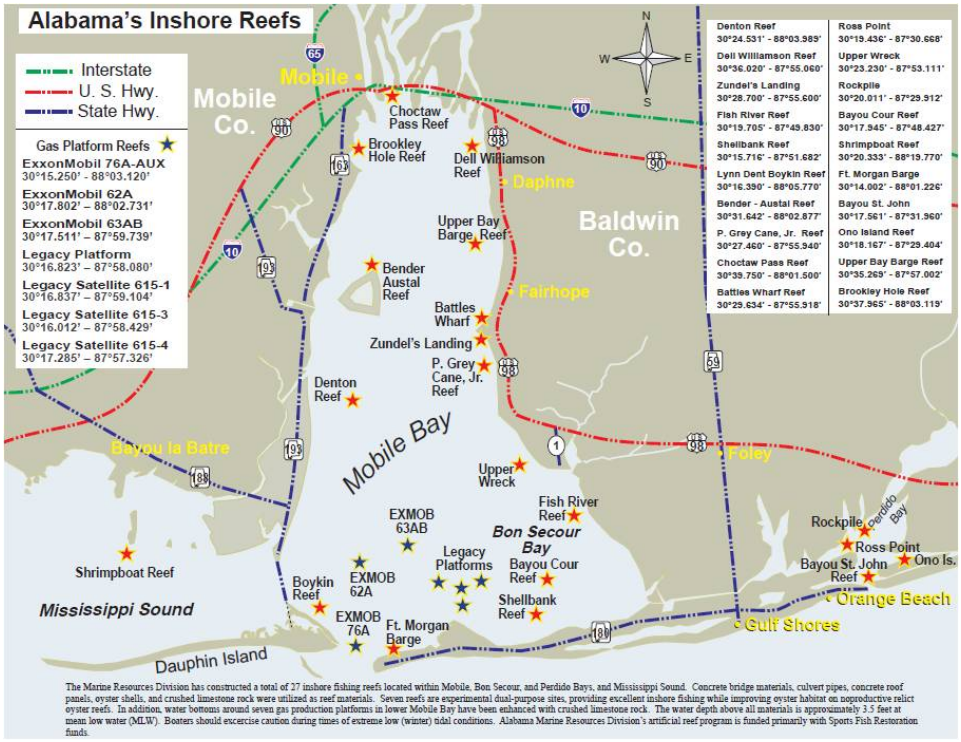
Alabama's artificial reef building program started in 1953 when the Orange Beach Charter Boat Association asked for the authority to place 250 car bodies off Baldwin County, Alabama. This proved to be very successful in attracting reef fish, and in the years since many different types of materials have been placed offshore of Alabama. These have included, but are not limited to, additional car bodies, culvert fragments, bridge rubble, barges, boats and planes. In 1974 – 75,

in an excellent example of State/Federal cooperation, several "ghost-fleeted" liberty ships were sunk in five locations off Mobile and Baldwin Counties in 80 - 93 feet of water.

In 1987, a general permit was issued by the U. S. Army Corps of Engineers creating specific areas offshore of Alabama for the creation of artificial reefs. These were designated areas for these structures in order to coordinate with other users of the offshore area (spatial planning). By 1987 the areas encompassed almost 800 square miles.

Inshore Reefs:

Beginning in 1996 the Marine Resources Division determined there was a need for artificial reefs within Alabama's inshore waters to provide fishing opportunities for fishermen who preferred to fish these areas. Therefore, when bridge rubble from the replacement of several coastal river bridges became available as reef material, Division personnel began to examine possible sites. Plans were to complete these reef complexes by placing cultch material inside the rings to promote the creation of natural oyster reef communities.



Map of Alabama's Inshore Fishing Reefs, courtesy of the State of Alabama

In 1998, a similar reef was constructed on the western side of Mobile Bay on the remnants of Whitehouse oyster reef. Oyster cultch material was placed within the interior of this reef in August of 1998, completing the largest inshore artificial reef to date in Alabama's inshore waters with an area of approximately 75 acres and a mile in circumference.

Plans are to continue to expand this program of inshore artificial fishing reefs. The Division was recently offered concrete culvert fragments as artificial reef material. Working with local conservation groups, commercial shrimp fishermen, and Mobile County, the division plans to create ten additional inshore reefs over in the near future.

For more information, please visit Alabama Department of Conservation & Natural Resources' artificial reef webpage

Florida

The Florida Artificial Reef Program was legislatively created in 1982 and as of 1999 has been administered by the Florida Fish and Wildlife Conservation Commission (FWC), Division of Marine Fisheries Management. The program was developed to obtain a mechanistic and predictive understanding of how artificial reefs function ecologically and physically across spatial and temporal scales in order to use artificial reefs as a component of fisheries management. The primary objectives of the program are to provide financial and technical assistance to coastal local governments, nonprofit corporations and state universities to develop, monitor, and evaluate new artificial reefs. Under the program, near shore and offshore reefs (in Florida most offshore reefs are classified as having depths of more than six meters) have been constructed with one or more of the following intended objectives:

1. Enhance private recreational and charter fishing and diving opportunities;
2. Provide a socio-economic benefit to local coastal communities;
3. Increase reef fish habitat;
4. Reduce user conflicts;
5. Facilitate reef related research; and,
6. While accomplishing objectives 1-5, do no harm to fishery resources, Essential Fish Habitat (EFH) or human health.

Today, approximately 70-100 public artificial reefs are constructed annually off of Florida using a combination of federal, state and local government and private funds. Approximately 40-75% of the money used annually from all sources for artificial reef development in Florida is administered through the FWC Artificial Reef Program. Funds administered by FWC are grants-in-aid pass through funding derived from U.S. Fish and Wildlife Service federal aid in Sport Fish Restoration Program and state salt water fishing license revenues. The money is used to reimburse local government and nonprofit participants for funding transportation and deployment of reef material, construction of modular reef units, reef monitoring, pre-deployment site assessments and special projects, such as planning (socio-economic studies)

and research. Although it varies year-to-year, approximately 70-80% of grant project funding goes to artificial reef construction with the remainder used for monitoring, research or other reef planning projects.

Other reef building activities undertaken in Florida, beyond the scope of the FWC artificial reef program, include mitigation for or restoration of natural hard bottom reef habitat lost through such activities as beach re-nourishment, repair of reef system damage caused by vessel groundings, providing substrate for the regeneration of oyster reefs, and protection of re-planted vegetated shorelines vulnerable to erosion from wave activity.

Protected Marsh Habitat Adjacent to Nearshore Artificial Reefs in Pensacola, FL
Photo Courtesy of Ted Reese

Florida has one of the most active artificial reef programs among the 14 Gulf and Atlantic coastal states involved in artificial reef development. The Florida Artificial Reef Program is the only state program that is not exclusively run at a state agency level where the state holds all the reef area permits. Instead, because of the extent of coastline and statewide involvement in reef activities, the FWC program continues a cooperative partnership with local coastal county governments. Coastal cities, universities and qualified nonprofit corporations also work directly with the FWC in artificial reef development and monitoring activities.

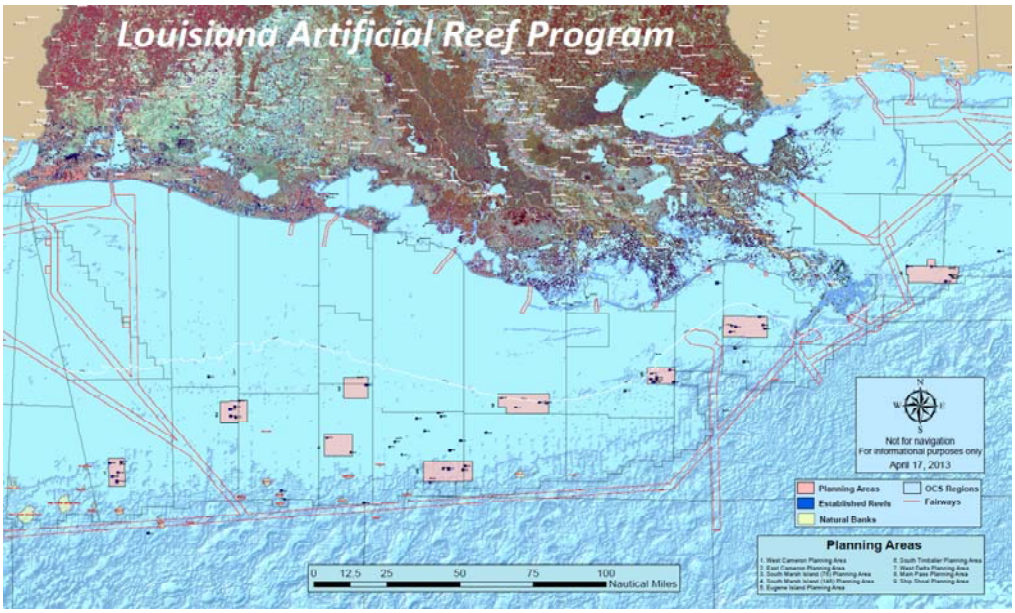
Thirty-four of Florida's 35 coastal counties spread along 8,426 miles of tidal coastline (1,200 miles fronting the Gulf of Mexico and Atlantic Ocean) are, or have been, involved in artificial reef development. Starting in the 1940's through August 2012, more than 2,700 planned public

artificial reefs have been placed in state and federal waters. Most artificial reef development has taken place since the inception of the Florida Artificial Reef Program in 1982. Local coastal governments hold all of the more than 300 active artificial reef permits off both Florida coasts. About half of these sites are in federal waters. Fishing clubs, nonprofit corporations and interested private individuals work through their local governments as the approved permit holders to provide input into public reef building activities.

For more information, please visit Florida Fish & Wildlife Conservation Commission's artificial reef webpage

Louisiana

The Louisiana Artificial Reef Program was established in 1986 to take advantage of obsolete oil and gas platforms which were recognized as providing habitat important to many of Louisiana's coastal fishes. Federal law and international treaty require these platforms to be removed one year after production ceases. The removal of these platforms was seen as a loss of reef habitat. Since the program's inception in 1986, more than 70 oil and gas related companies have participated in the program and donated primarily the jackets of oil and gas structures. In addition to material, companies also donate one half their realized savings over a traditional onshore removal into Louisiana's Artificial Reef Trust Fund.



Map of Artificial Reefs in Louisiana, courtesy of the State of Louisiana

In 1999, the Louisiana Program created the world's largest artificial reef from the Freeport sulfur mine off Grand Isle Louisiana. The sulfur mine, with over 1.5 miles of bridgework, is composed of more than 29 structures. The reef is in 42-50 feet of water and has 27 feet of

clearance. For safety of navigation it is marked by 5 lighted buoys. Forty (40) Armored Personnel Carriers (APC's) and one offshore tug are also deployed within two offshore artificial reefs.

The reef program has also developed 30 inshore reefs in Louisiana's state waters, primarily low profile reefs composed of shell or limestone. Eight inshore artificial reefs have been constructed using reef balls. Recycled concrete from the decommissioning of the old I-10 Twin Span bridges and other concrete sources have been used to develop new inshore reefs. Seven inshore reefs were constructed by Louisiana Department of Wildlife and Fisheries (LDWF) and twenty-three others were constructed in partnership with public conservation, private groups and other governmental entities.

Artificial Reef Tag Placed on a Reef Ball in Lake Pontchartrain
Photo Courtesy of Louisiana Sea Grant College

For more information, please visit Louisiana Department of Wildlife & Fisheries' Artificial Reef Webpage

Mississippi

The Mississippi Department of Marine Resources (MDMR) is responsible for managing marine waters of Mississippi. In 1999 the Mississippi Artificial Reef Plan was put into place to guide artificial reef development in Mississippi's marine waters and adjacent federal waters.

First known efforts at artificial reef construction off the Mississippi coast took place in the 1960's with the deployment of automobile bodies in offshore waters near the barrier islands. In 1972, a unified effort between state and federal agencies began to construct artificial reefs in

Mississippi. World War II Liberty Ships were made available from the National Defense Reserve Fleet for the creation of artificial reefs in coastal environments.

The state of Mississippi received five of these derelict vessels. Through a coordinated effort between the Mississippi Marine Conservation Commission and the Mississippi Gulf Fishing Banks, Inc. (MGFB), a local non-profit fishermen's organization, these vessels were cleaned, stripped, and the hulls sunk on two permitted sites south of Horn Island. After the hulls were sunk, the permits were transferred to MGFB. Additionally, funds acquired from scrapping these hulls were transferred to MGFB for future reef development. The MDMR Artificial Reef Program is continuing to work closely with MGFB to promote conserve and develop reef habitat for Mississippi fishermen. These reefs are located offshore and range in size from 8 acres to 10,000 acres. Along with the Offshore Reefs the MDMR has numerous Inshore Reef sites accessible by small boats, piers, and wade fishermen.

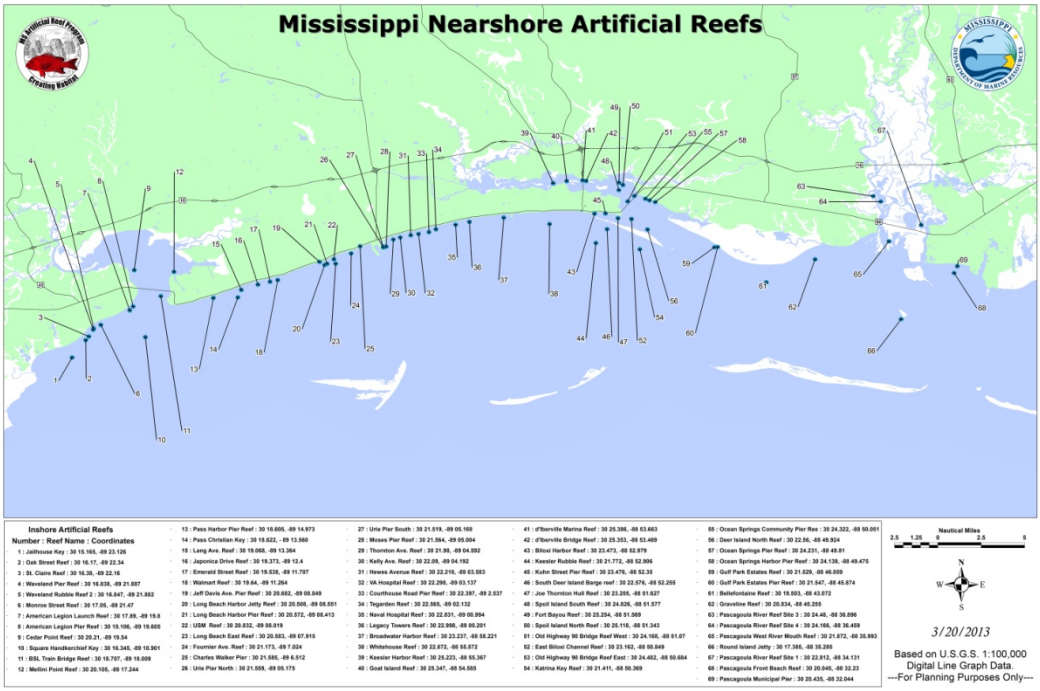
MDMR, Mineral Management Service (MMS), and petroleum companies are also working together to use decommissioned oil and gas platforms for offshore artificial reef development. This program is commonly known as "Rigs to Reef." Building on Title II of the National Fishing Enhancement Act of 1984, the National Marine Fisheries Service published a National Artificial Reef Plan which opened the door for Federal support for offshore artificial reef projects. Artificial reefs in Mississippi and adjacent marine waters are located and built to support and enhance recreational fishing. Properly located, constructed and managed reef sites can meet a variety of uses. All of these uses share the common purpose of enhancing marine habitat for associated important sport fishes and other organisms.

Nearshore Reefs:

Mississippi's nearshore artificial reefs are comprised of several different types of material including crushed concrete, limestone, and oyster shell. Development of these reefs has diversified habitat and increased high quality fishing sites which has proven to support a great ecosystem for Mississippi's nearshore waters. These artificial reefs provide the preponderance of both vertical relief and hard substrate for a variety of fish and invertebrate species.

In the spring of 2007, the MDMR received funds from the Emergency Disaster Recovery Program (EDRP) which was intended to help speed up recovery from the damage Hurricane Katrina caused to marine resources. It is anticipated that this 5-year program will continue to enhance and replenish what was lost to the storm. This project began with deployments around accessible fishing piers for Mississippi's shore fishermen, who were left with very few fishing options. In addition to artificial reefs around piers, the 2007 deployments also included low profile fishing reefs accessible to both wade fishermen and small boat owners.

In 2007, all three coastal counties were included with preference for reefs which sustained the most damage. As Mississippi's public piers and shore access points are rebuilt and reopened, MDMR's artificial reef program, in conjunction with Mississippi Gulf Fishing Banks will continue to enhance and replenish its inshore reefs.

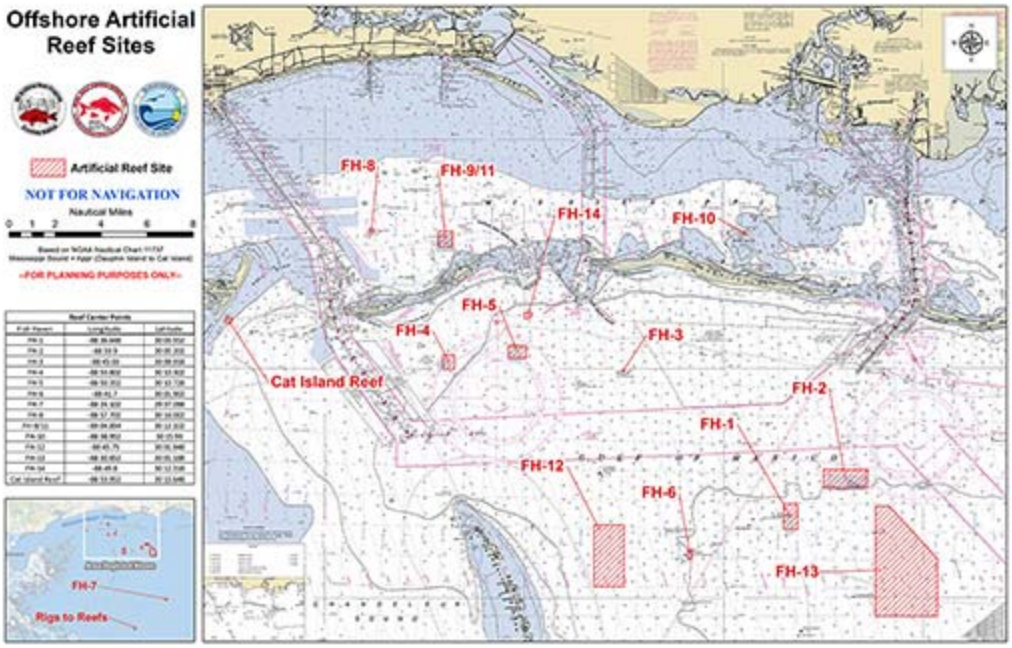


Map of Mississippi Nearshore Artificial Reefs, courtesy of the State of Mississippi

<u>Offshore Reefs:</u>

MDMR, in conjunction with MGFB, has 15 permitted offshore reef sites. These sites combined cover approximately 16,000 acres, with sites ranging from 3 to 10,000 acres. The sites located north of the barrier islands consist of concrete rubble while the sites located south of the barrier islands consist of concrete culverts, steel hull vessels, and artificial limestone reef pyramids. Limestone, primarily used for road construction, is thought to attract animals that wouldn't necessarily be attracted to the typical concrete reef structure. Small animals such as worms are attracted to the limestone which in return attracts larger species such as fish.

In 2007, MDMR used funds from the Emergency Disaster Recovery Program to implement a 5 year restoration project for both inshore & offshore artificial reef sites intended to speed up the recovery process from damage caused be Hurricane Katrina to Mississippi's artificial reef habitat.



Map of Mississippi Offshore Artificial Reefs, courtesy of the State of Mississippi

For more information, please visit Mississippi Department of Marine Resources artificial reef webpage

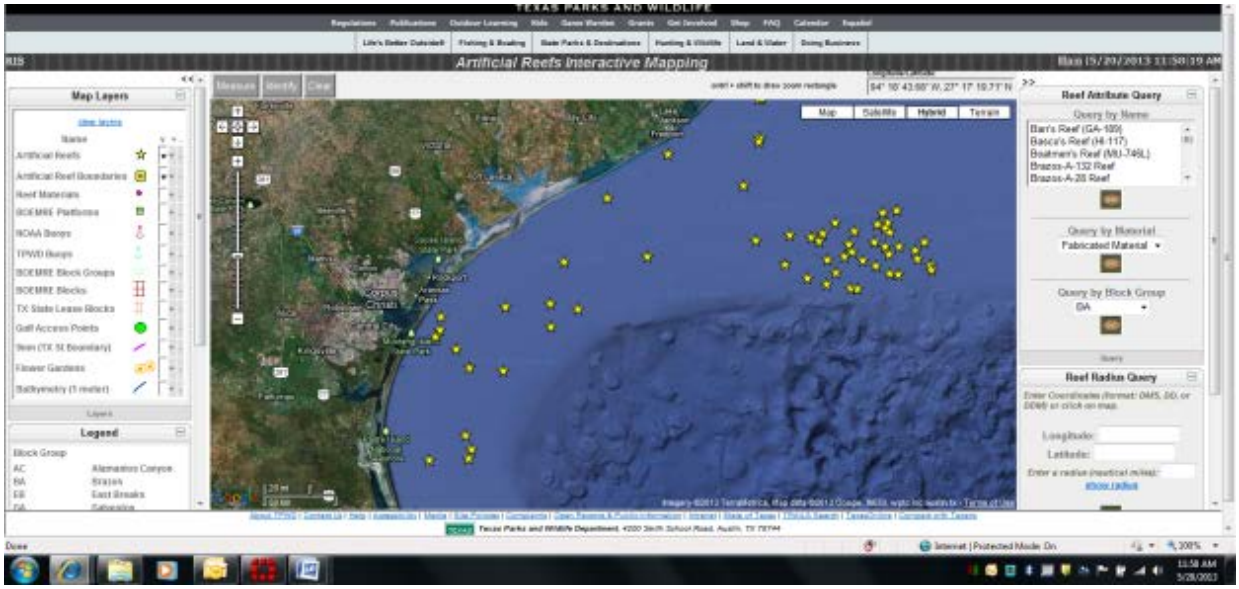
Texas

Texas has been involved in artificial reef development for nearly 50 years. Tires, automobiles and construction rubble have all been used in reef building, but these materials had little long-term success because they were easily broken up and moved by storms. The first highly successful artificial reef development occurred during the mid-1970s when 12 obsolete World War II Liberty Ships were sunk at five different sites in the Gulf. These sites are still productive and are being enhanced with additional durable and stable materials.

Oil rig workers and saltwater anglers have long noticed that petroleum platforms on the continental shelf act as unintentional artificial reefs, creating thousands of square miles of marine habitat Gulf-wide, as various species attach themselves to rigs below the waterline. The Texas Artificial Reef Program takes advantage of this insight partnering with conservation organizations, corporations, communities, and sportsmen to create and maintain more than 4,000 acres of artificial reef structures within Texas Gulf waters.

The slow-down in oil and gas activity in the Gulf in the 1980's resulted in an increase in the number of rigs being scrapped. Recognition that valuable habitat provided by these de facto

reefs should be preserved led to creation of comprehensive planning guides for artificial reef development. The Artificial Reef Act of 1989 directed the Texas Parks and Wildlife Department (TPWD) to promote and enhance the artificial reef potential in Texas. To fulfill this purpose, TPWD developed the Texas Artificial Reef Plan which was adopted in 1990. The Artificial Reef Program is guided by that Plan as well as recommendations from a citizen-based Artificial Reef Advisory Committee. The Program is constantly acquiring new reef material in various forms such as tugboats, barges, concrete reef balls, and petroleum rigs.



Snapshot of Texas Artificial Reefs Interactive Mapping tool, courtesy of the State of Texas

In recent years, numerous rigs have been donated by cooperating oil and gas companies. These companies have also donated to the Texas Artificial Reef Fund half of their realized savings from not having to remove the rigs to shore. These dedicated funds are used to finance research, administration, maintenance, liability coverage and construction of new artificial reefs. The Texas Artificial Reef Program is self-sufficient, with no funds from public sources or agency revenue.

The Artificial Reef Program focuses its efforts on three types of materials:

1. Decommissioned drilling rigs in the Rigs-to-Reefs Program.
2. Highway bridge materials and other sources of concrete and heavy-gauge steel in the Nearshore Reefing Program.
3. Large marine vessels in the Ships-to-Reefs Program.

All materials must meet federal and state guidelines for environmental safety and be free of contaminants.

For more information, please visit Texas Parks & Wildlife Department's artificial reef webpage

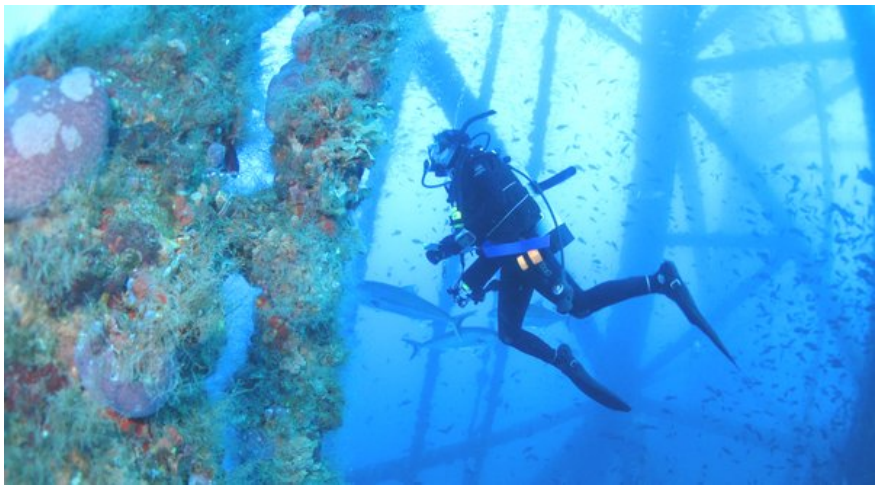
Other Programs

Rigs to Reefs (National):

The National Artificial Reef Plan (1985) provided the foundation on which the Minerals Management Service established the "Rigs to Reef" program. This program presented owners of offshore oil/gas production platforms an option to complete removal to shore once the installation ceased to be an active oil/gas production site. Platform jackets, once cleaned and deemed environmentally safe, could be donated to one of the Gulf States as artificial reef material.

In many instances donation to an artificial reef program saves the owner money, as it is less costly than complete removal. Studies have shown that the ecology of the Gulf of Mexico is enhanced by using platform jackets as artificial reefs. This means that new habitat is created, allowing for recruitment of flora and fauna onto and surrounding the artificial substrate (i.e., increased occurrence and diversity). From a fisheries perspective, recreational and commercial fisheries are enhanced with establishment and management of a robust artificial reef program. This means fish landings have been shown to increase on and around these structures; however, scientists have not been able to link the occurrence of these structures to overall health and productivity of fish stocks as a whole.

In the Gulf of Mexico, at the peak of oil/gas production on the continental shelf, there were approximately 4,000 oil/gas production structures on site. After nearly 70 years of activity, oil/gas production on the continental shelf of the Gulf of Mexico is declining, and subsequently, the rate of removal of production structures is increasing. Damage to idle platform structures by Hurricane Katrina in 2005 caused increased concern within the primary regulatory agency, the Bureau of Safety and Environmental Enforcement (BSEE), and platform owners. Storms toppled some platforms before environmental safety actions had been completed. Once toppled in this condition the possibility of environmental contamination increases and the cost of removal is significantly greater. Also, the time to complete the federal permitting process to donate a structure to an artificial reef program increased from generally six months pre-Hurricane Katrina to 12 months after Hurricane Katrina, increasing the owner's exposure to unforeseen events, nature and human caused. Subsequently, platform owners have elected to forgo the reefing option in favor of total removal.



A Diver Explores a Rig Platform in the Gulf
Photo Courtesy of Gulf of Mexico Foundation, Inc.

REEF-EX (National):

REEF - EX is the program name associated with the concept of deploying obsolete military combat tanks in the Gulf of Mexico and the Atlantic Ocean as artificial reefs. This program began on June 1, 1994 with the initial deployment of six tanks. With successful completion of this deployment, mechanisms were in place for deployment of hundreds of tanks in the future.

BEST MANAGEMENT PRACTICES

The following best management practices were excerpted from the *Multi-Species Recovery Plan for South Florida*, Nearshore Reefs chapter (US Department of the Interior, FWS; Living Document):

> **In recent years, research into artificial reef design effects on community structure has greatly increased our ability to optimize habitat value of designed reefs**. Study on the effects of module spacing (Frazier and Lindberg 1994, Lindberg *et al.* 1990), reef size (Bohnsack *et al.* 1994), reef height (Bortone *et al.* 1994), reef shape (Dade County 1995, Kim *et al.* 1994), hole size (Eklund 1996, 1997) and number of chambers (Sheehy 1976) have been accomplished as of this writing.
>
> As knowledge about the effects of design modifications on reef communities increases, it may become possible to design reefs to benefit **key species or age classes**. The evidence that natural nearshore reefs, not offshore reefs, provide nursery and juvenile staging habitat for many reef fish species (Lindeman 1997) suggests that **constructing artificial reefs closer to shore may supplement natural nearshore reefs by providing additional nursery and juvenile staging habitat for many reef fish species**. Ecklund (1996) has confirmed the intuitive sense that small hole sizes benefit small fishes. These findings lead to the conclusion that nearshore artificial **reefs with numerous small scale features would increase benefits for**

juvenile fishes. Further refinements in our knowledge of the effects of such design features are inevitable and sorely needed.

Restore areas to suitable habitat (Florida) – Restoration of reef habitat which has been buried by beach fill is probably unfeasible. Nearshore ocean bottom areas which once had reefs which were buried by beach fill can be enhanced by deployment of artificial reefs. Most beach projects have not been constructed with the benefit of before and after aerial photographs to assist in assessing actual acreage of reef burial. To attempt to restore an area which may have sustained such impacts, a list of the locations of past nourishments and re-nourishments of those areas would have to be made and historical aerials obtained in the hope that any historical reef bottom would be visible in those aerials. Alternatively, deployment of nearshore artificial reefs could be made at **appropriate nearshore sites around the southern half of the State to achieve ecosystem-wide enhancement**. The reefs should mimic natural reefs in form and function. Restoration of some mid-shelf habitat values has been accomplished in Miami-Dade County. Artificial reefs were constructed to replace values lost due to the dredge denuding reef during construction of the Sunny Isles project. Palm Beach County has restored some reef habitat values by constructing four mitigation reefs and one enhancement reef in the nearshore area, and approximately 35 enhancement reefs in the midshelf zone.

KEY CONSIDERATIONS

The following recommendations were taken from the *National Artificial Reef Plan (as Amended): Guidelines for Sitting, Construction, Development, and Assessment of Artificial Reefs* (US Department of Commerce, NOAA; February 2007):

Economic Considerations:

It is likely that the majority of artificial reefs will continue to be **built to support fishing and diving activities**, and **artificial reefs constructed for recreational use normally will be near major population centers**. Occasional reef construction in less populated areas may be **appropriate to stimulate local economies and alleviate fishing pressure on more congested sites.** Reef builders can use census reports, together with fishing license, boat registration, and landings data to delineate recreational fishing demand centers. For commercial fishing reefs, demand centers may be more sparsely populated, but should be recognized fishing communities with the appropriate infrastructure. Artificial reefs built for divers should focus on population centers with dive charter availability or potential. Artificial reefs built for research, reserves, culture of aquatic organisms, and other less user-oriented purposes will require siting criteria more specific to those uses. Further, it may be appropriate to avoid population centers for these types of reefs for best results.

Within each of the user demand centers identified, land and water access systems should be evaluated. Reefs should be planned in areas with adequate public access facilities and infrastructure support. Recreational reefs should be located for safe access by prudent anglers and divers, and in locations easily supported and maintained by reef managers. Studies of recreational use patterns can be particularly useful in this endeavor. Reefs for commercial fishing can be sited farther from harbors and inlets, but energy conservation should remain an important consideration. **Reefs installed as reserves, nursery**

areas, or spawning habitats should be located or managed to minimize fishing pressure, yet allow for adequate enforcement.

Before beginning the site selection process, reef planners should determine existing fishing patterns and conditions offshore of each identified demand center in question. Such information should include:

1. an estimate of reef use;
2. preferred target species and life history stage;
3. distances from nearest navigable inlet or harbor;
4. traditional fishing areas and methods; and
5. existing or future fishery management issues which may affect the reef site or users (e.g., stock status problems, user conflicts, closures, etc.).

Environmental Considerations:

When the intended artificial reef construction purpose is clearly established, the following should be established and addressed:

1. evaluation of social and economic siting concerns;
2. definition of a general reef construction target area;
3. delineation of known exclusion areas; and
4. assessment of proposed site geology, hydrology, water quality and fishery resources.

The **bottom composition** and character at an artificial reef site affects reef stability and longevity and should be carefully evaluated in the site selection process. In most cases, soft sediments such as clays, silts, and loosely packed sands should be avoided. Over time, reef materials may sink into these sediments or become partially covered. Benthic geology may also give a clue about siting and possible benefits from artificial reefs. Areas depauperate of cover such as rocks, aquatic plant or mud/sand bottoms may already have insufficient habitat to support an aquatic community, therefore reef developers may avoid lengthy surveys and ecosystems analysis of such areas.

Principal **hydrographic factors** to be considered in selecting sites for artificial reef construction include water depth, potential wave height, currents and tides. Water depth is significant as a criterion for sitting, for several reasons. First, reefs should be built in water sufficiently deep to avoid creating a hazard to navigation. Second, water depth has implications for reef users. In many coastal areas, water depth is a function of the distance offshore. This relationship should be considered when making tradeoffs between reef stability, clearance requirements, target species, and reef accessibility to various user groups (e.g., small versus large boat fishermen, commercial versus recreational fishermen, fishermen versus divers). Third, water depth affects the composition of species at the reef, including all sessile and motile invertebrates associated with the reef as well as plant life and fish assemblages. Reef materials placed in clear or shallow water with good light penetration generally will provide the best results in meeting the typical biological objectives of most artificial reef projects. Water depth is a key factor in determining the likely presence of desired life history stages of target fish species. Also, water depth at the reef site may critically affect reef material stability and long-term structural integrity. In this case, average wave energy in large, open bodies of water as a function of water depth is the major concern.

Wave interaction with a reef can be destructive, but its magnitude is difficult to predict. It is primarily dependent on wave height, wave speed, depth of the reef, and density and shape of the reef material. This force can resuspend bottom sediments causing sedimentation on the reef or destabilization of reef materials that are capable of moving short distances or entirely off the site. Reef materials and designs should be properly matched to water depths and predicted wave conditions to ensure their stability. Planning for worst-case storms may need to be considered on sites where movement of materials would be detrimental or hazardous.

Predicted currents (tidal or wave-generated) for a possible reef site can greatly influence reef effectiveness and can necessitate inclusion of certain critical design parameters in the selection of reef materials. Reefs should be designed to resist breakup, movement or burial that might result from the effects of currents. Detailed engineering studies may be required in some cases to ensure reef success in some areas.

Currents also influence the number of boats that can fish a reef at one time. Fishing reefs constructed across prevailing currents will allow the maximum flow of nutrient/food-laden, well-oxygenated water through the reef and the increased availability of food for reef organisms may improve hatching success of adhesive egg masses. This design orientation also helps create nutrient upwelling over the reef which, if large enough, attracts and concentrates baitfish and their predators, which are often targeted by fishermen. In spite of the possible advantages of orienting reefs perpendicular to general current directions, there are cases (exceptionally strong currents or predictable storm surge) where restrictions to water flow should be minimized. In these cases, structures might function better if oriented parallel to or at shallow angles to the predominant current flow.

General **water quality** is another important consideration. Water turbidity, salinity (in estuarine and coastal areas), dissolved oxygen, biological oxygen demand, water temperature, nutrient loads, pollution levels, and other water quality factors affect both the biological productivity and use value of artificial reefs. For example, benthic reefs built in areas with low dissolved oxygen levels (generally below 3 mg/l) or where anoxic (oxygen-depleted) conditions periodically occur will not achieve desired biological productivity levels and will probably not achieve management goals (Lenihan and Peterson 1998; Lenihan 1999). Similarly, reefs built in highly turbid water would have limited value to the diving community due to decreased visibility, but may be valuable as fish habitat. Polluted areas and areas affected by treated sewage effluent should be avoided to minimize resource exposure and possible human health risk.

<u>Biological Considerations:</u>

Artificial reef effectiveness is largely determined by the biological processes that enhance habitat for associated invertebrate and fish species, or the ability of the reef to improve recreational or commercial fishing. This discussion focuses on general procedure that should be used in isolating and accommodating key biological siting factors.

State and federal fishery management agencies, and other knowledgeable parties, have the capability to determine the nature of fishery resources and fishing activities in the geographical areas targeted for reef construction. **Objectives of the proposed reef should be compatible with fisheries conservation and management programs of the pertinent fishery management entities**. Clear objectives for the proposed reef should be based on an **assessment of public need, existing shore-based infrastructure, and the best**

available science. The scientific information that is used in decision-making should be relevant, inclusive, objective, transparent, timely, and peer reviewed. In addition, **reef builders should select the target species or species groups, and consider life stages that they wish to enhance or rebuild**. **Critical habitat and environmental requirements of those species also should be identified.** If selected target species are particularly sensitive to water temperature, salinity, dissolved oxygen levels, water turbidity, and contaminants, or if they have stringent habitat or food requirements, these parameters should be used as artificial reef site selection and design criteria. **For example, in building reefs for snapper, grouper, black seabass, rockfish, and other marine demersal species, low and medium profile reefs should be constructed from different sized materials, which will create numerous holes and crevices of varying sizes, providing shelter for juveniles and adults** (Anderson et al. 1989; Gorham et al. 1989; Lindberg 1991; Bortone 1994; Bortone et al. 1997; Ecklund 1996; Ecklund 1997; Strelcheck et al. 2005; Lindberg et al. 2006).

Prospective reef builders should be aware of existing and proposed fishery management plans and regulations for the species that may be significantly affected. **They should site or construct artificial reefs that would complement fishery management goals. Consideration should be given to the impact on the target species.**

Additional Considerations:

Some artificial reefs are thought to allow for mitigation, repair, and/or restoration of natural reefs. **Artificial reefs that that mimic natural reefs may serve to enhance adjacent oyster reefs, and it is thought that by combining these reefs enhances survivability of natural reefs by reducing predators.** More research is needed in order to fully understand the linkages between artificial and natural reefs in Gulf ecosystems.

Recent storm events, such as Hurricane Sandy in the Northeast, have raised new issues of concern regarding artificial reef stability. Sandy caused pieces of the old Cleveland Municipal Stadium, which had been deposited into Lake Erie to create three artificial reefs, to be thrown on to the shore during the storm.

The **vertical profile** of a reef structure may be important in determining overall fish species composition and biomass of a given reef. Low profile reefs may be more suitable habitat for demersal species, while high profile reefs may be more suitable for many pelagic fishes. A combination of high and low profile construction materials can often be used within one permitted location target a potentially more diverse fish assemblage.

The quantity and type of **interstitial spaces in reef structures are important in determining the degree and complexity of the biological community developing on and around the reef**. Numerous holes, crevices, walls and overhangs in a reef structure allow for a much more diverse community in general than would develop on reef material with less structural

complexity. Adequate interstitial spaces are necessary to establish a rich diversity of motile invertebrates as well as numerous cryptic fish species. It is thought by some that interstitial spaces may also be a factor in enhancing desired behavior such as increased reproduction, molting, or predator avoidance.

In addition to interstitial spaces, biomass may also be directly related to the **quantity and quality of surface area available**. This is particularly true of low profile benthic reefs in which the fouling community of sessile marine organisms achieved on the reef may be important to subsequent development of the demersal fish community. Many invertebrates are important food items for many fish species inhabiting the reefs. The greater the surface area available to these organisms, the more significant the food source available to other levels of the reef community.

Reef materials should allow adequate water circulation. This should prevent the stagnation of water in some parts of the reef, which could diminish productivity of the overall reef. Sufficient water circulation surrounding the reef also allows for better use of all surfaces of structures for the establishment of sessile invertebrates, as well as potential for improved access to fish and motile invertebrates (e.g., crabs).

Performance monitoring should document the degree of success as well as all impacts of a given artificial reef or reef system. Performance monitoring involves evaluation of an artificial reef to determine whether or not the reef is accomplishing the purpose(s) for which it was established. Monitoring can also detect whether the reef is having any unexpected negative consequences, as well as provide a great deal of insight into the need for future modifications to construction techniques, identifying research priorities and documenting the need for alternative management strategies or new regulations.

Ecosystem service valuation methods have recently been used to communicate potential localized impacts to coastal communities. Some estimates go as far to say that for every $1 spent on artificial reefs (Florida study) that the overall economic benefit of the artificial reef system, over its average functioning life span (timeframe not given) is $138. Further research is needed to understand ecological functioning and importance of artificial reef habitat in order to better make these assessments.

REGULATORY REQUIREMENTS

It is important to note that there are multiple regulatory requirements that must be met when considering best management practices and considerations listed above. While this document is not intended to provide an overview of these requirements or processes, a list of relevant entities and laws are provided here:

- US Army Corps of Engineers
    - Section 404 of Clean Water Act
- US Coast Guard
    - Private Aids to Navigation
- US EPA
    - Section 404 of Clean Water Act
- National Marine Fisheries Service (NOAA)
    - Magnuson-Stevens Fishery Conservation & Management Act)
    - Endangered Species Act
    - Fish & Wildlife Coordination Act
    - Marine Mammal Protection Act
    - Other Pertinent Laws
- National Ocean Service (NOAA)
    - National Marine Sanctuaries Act
    - Coastal Zone Management Act
- Bureau of Ocean Energy Management
- State & Local Governments
    - Varies by state resource management authority