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Keynote Address

Coastal Fish Management in Fluid Circumstances

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There is little room for argument that we meet together at this symposium on artificial reefs in the fluid circumstances of truly revolutionary times. The revolution of which I speak is not one of guns and bombs; rather, it is one of ideas and social and economic change. This is fully as true of coastal fish management as it is of our many human institutions. Indeed, it is the many changes in our human institutions that affect the coastal fisheries so profoundly. I need only mention encroaching development in the coastal zone or the current near-panic over the energy squeeze or the approaching law-of-the sea conference (LOSC) to bring this fact into fairly clear focus.

The welfare of coastal fish stocks is an increasing function of the unfortunate fact that the estuarine portions of the coastal zone have special attractions to great numbers of people. There are many well-known reasons for this phenomenon, but the net result of coastal zone development to accommodate them is to reduce the natural productivity through dredging, filling and pollution. Nearly two-thirds of the fish harvested on the Continental Shelf of North America are said to find their origin in, or are critically dependent at some life stage upon, the peculiar conditions found only in estuaries. Fortunately, a growing number of citizens in the coastal states are becoming aware of the biological significance of estuaries. As a result, a number of states (Massachusetts, Connecticut, Delaware, New Jersey, Florida, California, Washington) have passed legislation that either slows estuarine development or stops it altogether pending improved planning.

Suddenly, the Alaska pipeline has received Congressional approval in circumstances reflective of unreasoned haste -- at potential loss of important environmental gains of the immediate past. This is unfortunate if major spills occur, as is widely feared, at many river crossings as well as at the southern Alaska sea terminus. It turned out in tests at the University of Alaska, that Prudoe Bay crude oil is highly toxic (relatively low concentrations) to fingerling salmonids. Perhaps of greater immediate concern vis-a-vis coastal fisheries would be the very extensive development, certain to come soon, of the large deposits of petroleum under the Continental Shelf. Add to this the escalated shipment of crude oil expected soon from foreign lands, and the problem of potential oil spills in the Coastal Zone becomes serious indeed.

An estimated 2.1 million metric tons of oil (0.1% of world production) already are being introduced into the oceans annually through man-caused spills of all kinds.[1] This quantity does not include the fallout of air-borne hydrocarbons on the sea surface, estimated to be about five-fold the volume of the direct influx.[2] Unfortunately, most of the direct oil spills are concentrated well within the coastal zone. It is precisely here where the more soluble and more toxic fractions can adversely affect the finfish eggs, larvae and juveniles that are found seasonally concentrated near the surface. Shellfish are especially vulnerable, not to mention the devastation of oceanic and shore birds caught in oil slicks.

Thus, in the supertanker, it would appear that well-protected tanker docking facilities located well offshore may well create fewer environmental hazards than would conventional shore facilities. This view is predicated on the adoption of a number of specific safety precautions to preclude ship groundings, collisions, leakage, etc., and the development of adequate contingency plans to cope with accidents. At the same time, maximum stress should be placed on taking full advantage of possibilities for incorporation of features for enhancement of both oil drilling and production platforms and rigs and offshore port facilities in order to favor fisheries development and recreational use. In this respect, much that will be discussed at this conference should have significant application.

Plans for location and construction of floating nuclear power plants anchored up to three miles offshore, enclosed within massively-engineered protective breakwaters or placed on specially-designed artificial islands, are no longer speculative. At least one offshore ocean site already has been selected a few miles northeast of Atlantic City, New Jersey, with electrical generation expected to begin sometime in 1980. Engineering design for this floating nuclear power plant is sufficient to withstand tornado-force wind speeds, maximum hurricane-induced wave action and collision by the largest ships able to navigate site depth.[3]

The advantages of ocean siting are manifold. The disadvantages appear relatively small, at least when compared to land-based locations. The major ecological problem for marine life involves the heating and continuous discharge of vast quantities of water required to be passed around the reactor for cooling purposes. Careful ocean siting should effectively minimize possible adverse effects on fish populations. Massive discharges of heated cooling water (without costly artificial cooling before discharge) could be highly destructive in the confinement of estuaries, rivers or lakes.

Marine recreational fishing has grown by leaps and bounds in recent years, and the demand it reflects may be expected to increase rapidly far into the future. Habitual saltwater anglers were estimated to number about 4.5 million in 1955, about 6.3 million in 1960, about 8.3 million in 1965 and about 9.5 million in 1970. Thus, they more than doubled their numbers over the 15-year period of 1955 through 1970 (6.1% annual incremental rate versus 1.7% for general population).

Ownership of the fisheries resources of inland waters of the emergent American land mass has long been established as a public trust, with custody and responsibility for their beneficial management exercised by the state governments on behalf of their citizens. Evidently, there is little legal question that similar state custody and responsibility over living marine resources also extends into the waters above the submerged Continental Shelf, at least as far as the outer boundary of the territorial seas. Consequently, it should be recognized that the principal responsibility for management rests with the state governments rather than with the federal government.

Coastal jurisdiction over fisheries resources within the territorial seas (out to three miles) by states is not seriously questioned by the federal government. The latter, however, asserts control (while lacking adequate implementing authority) over fisheries from 3 to 12 miles offshore. President Truman in 1945 proclaimed the right of any coastal nation to exercise control over the fisheries resources adjacent to its shores and to set up conservation zones for fisheries protection in the contiguous high seas. The General Assembly of the United Nations in late 1972 overwhelmingly recognized the sovereignty of coastal nations over the living resources of the oceans lying above their adjacent Continental Shelf areas.

The National Marine Fisheries Service has identified clearly by its research that uncontrolled foreign fishing pressure on our Continental Shelf areas is the principal factor in the depletion of many species. It is, therefore, evident that successful management of the coastal marine fisheries, including the important recreational fisheries, is dependent substantially upon adequate control over foreign fishing pressure.

Fish management efforts must be expanded greatly if acceptable catch standards are to prevail as marine anglers increase. The needed management cannot be provided, however, without a solid foundation of factual knowledge derived from a substantial program of research on the biology of a great many of the common coastal zone fishes that are of such great significance to the recreational fisheries. Two items of urgent need in this connection, are (1) to differentiate functionally among research efforts in order to identify mission-oriented types of research and discipline-oriented types of research, and (2) to differentiate between the appropriate respective roles of the state and federal governments in the research area so as to identify priorities.

As I see it, the federal government principally should conduct the longer-term, more discipline-oriented kinds of research that will furnish the stockpile of biological and statistical data and methodology needed by the states in formulating their fisheries management programs. The federal program should feature studies that are beyond the scope of state capabilities and will be useful on a nationwide or regional basis, and avoid undertaking studies of a localized nature that lack broad interstate implications.

Short-term problem-solving studies (trouble-shooting), and routine evaluations of the effects of management projects (management investigations) should be left to the states. Management of international and high-seas fisheries or of interstate coastal fisheries (in cooperation with state governments) is a legitimate area of federal activity. Typical studies for which there is a great need in the coastal marine fisheries generally will fall within the broad areas of life history, ecology, behavior and population dynamics.

OPTIMUM VERSUS MAXIMUM SUSTAINED YIELDS

Research and management programs designed to serve the recreational fisheries interests must reflect a basic fish management philosophy that differs materially from that which has traditionally underlain the commercial fisheries programs. The latter has long featured the concept of maximum-sustained yield, which looks toward a maximum yield of protein. The former features the somewhat different concept of optimum-sustained yield -- in effect, maximum economic yield.

The concept of maximum-sustained yield is tied closely to the principle of full utilization. Again, this is interpreted traditionally in a narrow context of protein production for human consumption, on the assumption of waste otherwise. To be applicable for broader use in connection with the needs of the recreational fisheries it must become recognized that use in ways other than human food may represent full utilization of fisheries resources.

Such other uses include sustenance as prey for predator species that have great socio-economic value in the recreational fisheries and direct use as objects of recreational enjoyment. Generally overlooked by traditional MSY/full utilization-advocates, moreover, is the fact that virtually all of the substantial catch in the recreational fisheries enters the national diet. Such fish are estimated to account for at least one-third of the annual per capita national consumption of fish.

The concept of optimum yield (cited, incidentally, in the 1958 Geneva Oceans Convention) best accommodates the elusive but highly important element of "quality" in sport fishing. Though not universally defined or quantified, the concept of "quality" obviously includes considerations of variety in angling experiences. The species caught, the sizes of the fish involved, the situations in which they are found, and the method by which they are sought or harvested, are some such considerations. It seems evident that a conservation concept that seeks merely to produce a maximum yield of protein for direct or indirect nourishment of the physical human body alone will not accommodate adequately the purposes of the important recreational fisheries.

The need for increased fisheries research efforts has become urgent in the superjacent waters of the Continental Shelf. Only in the past 20 years has technology become so sophisticated as to threaten clearly the myth of inexhaustibility of the fisheries of the seas. Experience since the midpoint of this century has shown that depletion of fish stocks has become commonplace. Well-known examples along the northwest Atlantic coast include haddock, menhaden and river herring, to mention but a prominent few.

World fisheries experts expect that only small annual increments in world fish harvest are possible above the present level, approximating 70 million or so tons. Further increases will be dependent largely on utilization of presently unappealing marine forms, discovery of limited new stocks of desired species, and expanded cultivation at the edge of the sea. Increased efforts to harvest presently exploited fish stocks may be expected to result in greater depletion of the fisheries and dramatic reductions in total harvest.

Since the recent mid-sixties, wide-spread concern has been generated by a rapid escalation in the massive fishing effort being exerted on U.S. coastal fisheries by the great distant-water fishing fleets of some 19 foreign nations including the U.S.S.R., Poland, Japan, Korea, East Germany, Norway, Canada, Cuba, etc. The effect has been noticeable dwindling in those waters of the supplies of many common marine species that are important to recreational fishing as well as to the domestic commercial fisheries. Looking to the forthcoming (June 20 - August 29, 1974) Law of the Sea Conference (LOSC) at Caracas, Venezuela, the Ocean Affairs Staff of the U.S. State Department has developed a complicated proposal for national and international jurisdiction over the various marine fisheries resources.

The official U.S. Government fisheries proposal -- the so-called "species approach" -- advocates (1) that preferential rights be granted to coastal nations to harvest as much as they can of fish stocks found along and off their coastlines (with other nations free to take what is left), and (2) that coastal nations should have regulatory control over coastal fish stocks for as far offshore as the latter may swim, to the limits of their oceanic range, however near or far from shore that may prove to be in each instance. An obvious drawback is that enforcement would be difficult in the extreme and perhaps impossible from a practical point of view. This follows from the widely varying and intermingling species ranges and general inability to fish selectively in the commercial fisheries for individual species.

Contrary to the government's LOSC posture, many elements of the American domestic commercial fishing industry strongly favor a 200-mile seaward extension of U.S. national marine fisheries jurisdiction. This concept is much favored in principle by the recreational fisheries interests also. In fact, both these large interest groups are urging interim unilateral enactment of national legislation to bring it about now. The principal American interests opposed are the wealthy tuna fishing interests, the Department of Defense and the Department of State.

It is clearly evident from the proceedings of several LOSC preparatory conferences that much of the world fails to understand the U.S. fisheries proposal for regulation by individual species. Or, understanding it, the world either fails to support it or is strongly opposed to it. Meanwhile, the evidence is that the U.S. is refusing to recognize the signs. Worse, it is failing to think out its "fallback" strategy in sufficient detail and depth to preclude a reasonably predictable eleventh-hour crisis of decision-making when its own proposal fails. In contrast, proposals for an alternative U.S. position, based on some form of greatly extended fisheries jurisdiction outside the territorial sea, are rapidly proliferating. They find growing support in sport fisheries circles, domestic commercial fisheries circles, conservation circles, scientific circles and in the general public.

Extending fisheries jurisdiction to the outer edge of the Continental Shelf (depth of 200 meters) or to 200 miles offshore has much to recommend it as a constructive alternative to the ill-fated "species approach." This is especially so for protection of the immensely valuable domestic fisheries (both recreational and commercial). Leading zonal advocates envision that other nations would be permitted to harvest any true surpluses of desired species that might remain after the needs of the domestic fisheries are satisfied. Any foreign-flag harvest permitted inside the zone would, however, be governed by the constraints of rational optimum-yield management plans imposed and enforced unilaterally by the U.S. throughout the zone.

As with the "species approach" package, the highly migratory pelagic species would be subject to regulation by an appropriate international body. As with the "species approach" package, again, anadromous fishes would belong to the nations-of-origin in whose estuaries and rivers they spawned. No harvest of anadromous species by any nation would be permitted normally in ocean waters outside the zone of national fisheries jurisdiction. However, under an extended jurisdictional fisheries regime, compliance failures could be severely penalized by withdrawal of access to historic or underutilized fisheries within the zone.

Although the federal administration is failing to heed clear public opinion in the matter, the U.S. Congress is by no means deaf to it. By early 1974, at least a dozen extended fisheries jurisdiction bills had been introduced in the Congress. The most important of these is commonly referred to as the Magnuson-Studds Bill (S. 1988 in the Senate, sponsored by Senator Warren G. Magnuson of Washington; H.R. 8665 in the House of Representatives, sponsored by Congressman Gerry E. Studds of Massachusetts). This particular measure has the very important provision that such extension shall apply as an interim measure. If and when general agreement on fisheries is reached in international LOS negotiations, and upon entrance into force of an effective international fisheries regulatory regime, the interim Act would terminate.

The Magnuson-Studds measure has the great virtue of seeking to accommodate some of the special needs of the anadromous fisheries. It has been suggested that a 200-mile limit by itself -- lacking special arrangements for salmon fishing abstention by other nations in international waters beyond 200 miles -- would fail to protect the important U.S. stocks of Pacific salmon and steelhead trout from Japanese fishing during their extensive oceanic migrations. This simplistic view overlooks the very significant fact that the Japanese presently harvest vast quantities of other fish in "American" coastal waters that could easily be denied them if they refused to cooperate. An outstanding example is their catch last year of 1.2 million tons of pollock from areas in the Bering Sea that would fall well inside a 200-mile line drawn off Alaska. Thus, a 200-mile limit would, in fact, provide substantial new leverage (now entirely lacking) to the

Artificial Reefs Around the World

SESSION CHAIRMAN: WILLIS H. CLARK, Center for Marine Resources,
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Artificial Reefs in France

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The French experience in the field of artificial reefs is young and limited. It has been known for a long time that old ships, junk cars, scrap tires and other waste materials, properly deposited in the ocean, will soon provide food and shelter for fish. However, it was only in the late 1960's and under the influence of Japanese and American experiments that France developed an interest in artificial reefs.

The construction of artificial reefs seemed to be a practical way of restoring fish populations in certain areas and, at the same time, getting rid of derelict cars; consequently, a number of experimental reefs were set up along the coast of France. The first reef was constructed in 1968 and by the end of 1973 four or five experiments were underway.

In order to give you an idea of French efforts in this field, I will describe briefly three experiments concerning artificial reefs.

THE PALAVAS LES FLOTS EXPERIMENT (MEDITERRANEAN COAST)

The construction of an artifical reef in Palavas was decided on by a private firm, the Compagnie Generale Transatlantique (known in the United States as the French Line, the company which operates the liner "France") in cooperation with the local government and with the help of CNEXO (the French National Center for Ocean Exploitation, a government agency).

The local fishermen agreed to the construction of a reef in an area of no interest to them. This reef was made of approximately 150 derelict cars as well as concrete blocks, pipes and old tires. The first materials were sunk in 1968, two miles off the Mediterranean Coast at a depth of about 60 feet. The oil was drained from the cars, but they were neither burned nor specially treated before being immersed. The construction of this first reef took place under somewhat bad conditions, as the ship that was used could not carry more than two cars at a time. This resulted in some of the cars being scattered on the sea floor. Furthermore, for financial reasons, scientists were not able to follow up on the experiment to any great extent. I would add that there was no inventory of the site before immersion and only a few dives were made thereafter.

However, the results of this first reef experiment were nonetheless encouraging.

- After the first year, 80 percent of the reef was covered and a greater number of fish and crustaceans were observed.

- After the second year, the reef was entirely covered and a greater number of fish and crustaceans was observed.

Apparently the junk cars provided the best results. Their productivity was estimated at 10 to 14 pounds of fish per car including 8 to 10 pounds of conger eels, 2 to 4 pounds of other fish and 2 pounds of crustaceans. The Compagnie Generale Transatlantique was at one time planning to increase productivity of the reef by putting lobster postlarvae produced by its hatchery in Brittany in the cars. Unfortunately, for technical reasons, this experiment never took place.

The reef of Palavas is now abandoned, but C.G.T. is planning to build a giant reef in approximately the same area by immersing 4,500 cars a year. The reef could be located so as to prevent trawling in spawning areas. This project is still in the planning stage.

THE CONCARNEAU EXPERIMENT (ATLANTIC COAST - BRITTANY)

The artificial reef of Concarneau was designed by a biologist at the Concarneau fisheries lab and constructed by the local fisheries committee, scientists and industry people in a cooperative effort. The reef was originally to be built in 1969, but the construction actually took place in June of 1970. The reef was made of 99 concrete blocks, 1 m^3 each, distributed in three horizontal rows and two vertical layers. The upper blocks were specially designed for fish and the lower ones for crustaceans. The reef was 120 feet long, 14 feet wide and 6 feet high, and cost about $20,000 to assemble.

A year after immersion, the evolution of the reef was studied by scientists. The results were satisfactory and the reef did attract some fauna and flora. However, this particular experiment has been discontinued because of the high costs involved. In order to reduce expenses, the promoters turned to cheaper and easier-to-handle materials such as old tires.

In 1973, 35 units made up of old tires were sunk 25 to 30 feet deep. The tires were placed in stacks of six, fastened together with rods and weighted with concrete. If the results of this reef are satisfactory, 200 new units will be immersed this fall or next year.

THE ARCACHON EXPERIMENT (ATLANTIC COAST)

This experiment was performed in order to study the possibility of restoring marine fauna and flora to the bottom of the Arcachon basin, which has been overfished for decades. It is a pilot project aimed at studying encrustation of fauna and flora, sedimentation and corrosion of the reef and the best possible structure of a reef. In fact, the Arcachon experiment is the best scientifically designed so far. A preliminary inventory of the Arcachon basin including physical and chemical surveys, as well as studies on flora, fauna and currents has been done.

This experiment started in August 1972 when 25 cars were sunk at a depth of 45 feet. The cars had a lozenge shape. Its surface was approximately 200 m^2 and it was located less than 100 yards from the shore in order to be reached more easily. All materials used to build this reef were donated and transported to the site by private firms without charge

The first results seem very encouraging. The reef is covered with organisms and attracts fish and crustaceans, but counting them is very difficult because of very bad visibility. In 1973 additional cars were sunk and if the results of this small reef are promising, several larger reefs could be constructed along the Aquitine shore.

To conclude, I would like to make a few remarks that could explain why the development of artificial reefs has been limited in France even though oceanography is one of our priorities.

- Scientists agree that artificial reefs can attract and concentrate marine fauna and flora in certain areas. However, from the results already obtained, scientists believe that natural marine production does not increase because of reefs and they think that aquaculture is a better way to supplement marine production.

- Fishermen have nothing against artificial reefs as long as their construction does not interfere with traditional fishing zones. On the other hand, they think that artificial reefs do not really help professional fishing because their productivity is too low.

However, it is generally considered in France that construction of artificial reefs is probably the best way of improving the marine sport fishery and conserving game fish resources. These probably will be the reasons for further construction of artificial reefs in the near future.

Some Problems That May Be Faced in the Construction of an Artificial Reef

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POLITICAL FACTORS

A proposal for construction of an artificial reef is often the result of the "suggestion" of a governmental administrator who views it as a way to dispose of several kinds of solid waste. Usually, no research or analyses of costs or other factors has been attempted. However, considerable popular support and momentum may be attached to the proposal by the time it filters down to the "builder."

Organizations of commercial and/or sport fishermen may likewise initiate a campaign for the construction of a reef. Again, this is frequently, if not usually, done without any real understanding of the various factors involved. Finally, academic institutions or research organizations may initiate a proposal purely for research reasons. Such proposals may be well planned insofar as techniques and financial arrangements are concerned but may ignore the role that could be played by one or the other, or both, sorts of fishermen. It should be realized that in most cases benefit to fisheries is the ultimate objective of reef construction.

FINANCES

The financial considerations of building a reef are perhaps the most poorly understood and underestimated factors involved. Virtually all methods and materials commonly available require many man-hours and/or the use of heavy equipment, including both shore-based and marine machines that range from front end loaders, cranes, forklifts and electromagnets, to tugs, barges and helicopters. When construction materials are of such a nature as to dispense with the use of heavy equipment and large boats, the substitution of many human hands and smaller boats is required. All these methods cost money and under state-sponsored projects it may be very difficult to determine actual figures in terms of new dollars required if the state intends to do the work rather than contract.

ADMINISTRATION

The administrator or "builder" eventually is charged with the resolution of budgets, conflicting interests, sources of labor, material and equipment, and perhaps even the scientific and engineering design of the reef itself.

If various state agencies are asked to build the reef without supplementary budgets, the task of coordinating effort, equipment and personnel can be formidable even when each agency has a vested interest in completing the reef. If federal permits and funding are involved, these require vast amounts of time to prepare, submit and receive the necessary funds or permits, and this effort must be coordinated with the effort at the local level.

CASE HISTORY

Several years ago the government of the Virgin Islands decided that a good way to dispose of the rapidly increasing supply of junk automobiles on these small islands would be to build an artificial reef with them. The Caribbean Research Institute of the College of the Virgin Islands decided that if such a project were undertaken, scientific studies of the placing of the reefs and their growth and maturation should be undertaken. Consequently, the sites were chosen so as to afford convenience to the scientists, and the necessary applications for submerged lands permits were prepared and submitted to the U.S. Department of the Interior and the Army Corps of Engineers.

The permits were issued on February 23, 1973. In the interim, some re-organization and re-assignments within the governmental structure had placed authority and responsibility for construction and administration of the reefs in the Bureau of Fish and Wildlife of the Virgin Islands Department of Conservation and Cultural Affairs. Because of the inherent interests of the new administration, as well as budgetary considerations and the fact that the only source of additional funds was the federal Bureau of Sport Fisheries and Wildlife, it was decided that the chosen sites were not the ones most advantageous to the fishermen of all three islands.

Amendment applications were then submitted to the Department of the Interior in order to change the sites to locations that were not only geologically and biologically suitable, but also protected from severe weather so small boats could utilize them on a less restricted basis. This submission occurred on May 9, 1973.

After much correspondence, many telephone calls and some personal negotiations, it was discovered that the Department of the Interior had lost the amendment applications. Additional copies were provided but, as of this date, which is some two years after the decision was made to construct two reefs, we are still unable to apply to the U.S. Coast Guard for permits for the marking buoys. In addition, the federal contracts regarding funding have to be amended annually because of the delays.

Historical Review of Artificial Reef Activities in Japan

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In Japan, artificial fish reefs are called "tsukiiso" (literally, construction of reef) and it is almost common-sense knowledge among fishermen that fish are attracted to tsukiiso and that a good catch of fish can be had in the area. However, the exact date when a tsukiiso came to be used in Japan is still unknown. There are several written records suggesting that they were already in use during the Kansei era (1789-1801). A further study would reveal, in all probability, that the first practical application of tsukiiso dates further back.

In the sixth year of the Kansei era (1795), a fisherman called Shinzo Nishida of the Manzai Village, Tsuna County, the Province of Awaji (Awaji Island, south of Kobe), while fishing with the use of a gochi-ami (a semi-surrounding seine net for catching breams), fished by chance by a sunken ship and caught several thousand koshodai, (yellow spotted grunt, Plectorhynchus cinctus, (T. & S.)). When the sunken ship deteriorated in seven or eight years and fish stopped thronging around it, fishermen of the Manzai Village and the neighboring Toshi Village made large wooden frames mounted with sandbags and bamboo and wooden sticks and sank them on the sea bed in waters approximately 20 fathoms deep. This was in the first year of the Bunka era, 1804. About 100 days later during the summer in the neighborhood of the new artificial fish shelters, the fishermen netted a far greater number of fish than they used to catch around the sunken ship. In the 10-year period that followed, they sank several hundred such shelters.

There is a reef called Yoshida-iso on the southeast beach of a small island off the coast of Uoshima Village, Ochi County, Ehime Prefecture. Approximately 175 feet below sea level at full-tide, the Yoshida-iso rocks offered an ideal natural dwelling shelter for breams. The following story is written on a stone monument in the village. -- During the Kansei era, a large junk called Awayoshidamaru with the capacity for 1,000 koku (4,962 bushels) of rice struck the sunken rocks while the vessel was enroute to Osaka with a full load of unpolished rice. In the spring of the following year during the bream fishing season, fishermen of the village caught an extraordinarily large amount of breams. -- Several decades later in the ninth year of the Meiji era (1876), the village chief Chojiro Arinaga took a hint from the story written on the stone monument; he sank straw bags filled with parched rice bran and clay among the rocks of Yoshida-iso hoping that breams would be attracted to the rocks. The attempt was rewarded by a good fish catch before long when a net was cast.

In Kagawa Prefecture, facing the Inland Sea of Japan, where baits have long been used to attract fishes, there are some early examples of practical utilization of artificial shelters together with bait attraction. In the waterfront of the Hakoura Fishermen's Association in Kagawa Prefecture, even before establishment of the Association, the fishermen had started using baits to attract gray mullet. In the hottest season of every year, they placed ground-bait -- small balls of red clay and rice bran weighing about 750 to 1,000 grams apiece -- at proper sites. In the summer of 1906 (37th year of Meiji era), they sank three or four of these balls per location at five different locations where sand bags were used as anchors for towing nets.

In the autumn of the same year, they had an extraordinary good catch of tanago, surf perch (Ditrema temminckii Bleeker) in the neighborhood of these sand bags. Realizing the effects of artificial shelters, that winter the fishermen sank 200 koku (2,000 cubic feet) of cracked stones loaded on two ships with the capacity for 100 koku (1,000 cubic feet) each, and in the summer of the following year they sank another 200 koku of pebbles the size of chestnuts at the same places. An enormous number of tanago, as well as mebaru, rock fish (Sebastes inermis Cuvier) were said to have thronged around the shelter for four or five years, starting in the autumn of the 40th year of Meiji era (1907).

Also what is interesting is that at about this time, fishermen at different areas started exchanging knowledge about methods for attracting fishes. And, of course, stories about successful application of artificial fish shelters in some areas had spread to other areas.

For example, Kikujiro Mori, director of the Hakoura Fishermen's Association mentioned above, heard by chance, from Fukuyuki Nagao and other fishermen from a fishermen's association, on a survey tour to study bream nets, that fishermen in Aichi Prefecture found old anchors and scrap iron very effective in attracting bream into their drag-nets. It is reported that Mori was so inspired by the story that he sank about 60 or 70 scrap iron structures (mostly old buckets from dredging ships) off the coast of Misaki before the spring fishing season in 1911 (44th year of Meiji era). When the fishing season opened, as the story goes, each and every haul of gochi-ami (a net for bream) brought in a tremendous catch. Endowed with a progressive spirit, Mori also experimented with the use of various baits to attract fish, putting into practice what he learned from Arinaga, the village chief of Uoshima.

In Sennan County of Osaka, on the other hand, introduction of artificial fish shelters is said to date back to 1904-1905 (37th or 38th year of the Meiji era). At first, fish shelters were not installed collectively, but by individual fishermen who tried to increase their catch. There is even today a collection of sunken rocks on the beach of the village called "Saemon no sono" (Garden of Saemon) in memory of one such enterprising fisherman who installed a tsukiiso there. It was from around 1907 (40th year of Meiji era) that the village's fishermen started installing artifical fish shelters on a collective rather than individual basis. Each year since then they have been sinking a small ship loaded with stones.

In Miyazaki Prefecture, on the other hand, in localities where beach seines are used, special fish shelters were constructed. When they were first introduced, these shelters were made of concrete and wood branches, but thanks to various improvements made in subsequent years they are now constructing straw bags and baskets made in a special way to allow smooth landing of nets.

Judging from their origin, as we have seen so far, we may say that tsukiiso are supplementary fishing facilities primarily designed to attract fish. At present, fishing with pole and line is the most typical way of catching fish thronging around artificial fish shelters, through in some areas the use of gill nets, gochi-ami and other similar nets is permitted and in other areas the use of long line and gill nets is allowed in addition to fishing with pole and line.

Reef construction using such materials has become popular, influenced largely by tradition and the experience of fishermen in various prefectures. Since 1916, even scrapped naval ships (destroyers, target ships, etc.) have been used in some districts.

Since 1930, as part of its policy to promote the recovery of the depressed coastal fisheries, the Ministry of Agriculture and Forestry granted subsidies for public activities such as installing fish nests or artificial fish shelters to increase the catch of fin fish, lobster, sea cucumber, etc.

In 1952, under a five-year plan, the Ministry adopted a new national policy to assist in the construction of reefs made of concrete blocks. Until 1954 all artificial reefs were called tsukiiso, but after 1954 an official terminology was established dividing them into two categories -- artificial reefs mainly for attracting fin fish, and tsukiiso for attracting other organisms such as abalone, spiny lobster, algae, etc. From 1958, construction of a new type of reef, the so-called "large scale reef", each 25,000 m^3 in size, has been promoted. The amount of national expenditure provided by the government for the improvement of coastal fishing grounds during the period from 1952 to 1961 and from 1962 to 1970 is shown in Table 1. The amount of subsidy since 1952 was initially one third of the total construction cost. This rate was later increased to 50 percent for ordinary artificial reefs and to 60 percent for large-scale reefs.

By 1966, the number of ordinary artificial reefs totaled 721,065 (each reef being equal to 1 m^3 blocks) and of the larger reefs 328,217 (each reef being equal to 1.5 m^3 blocks). Between 1962 and 1970 the equivalent of 920,000 m^3 of ordinary reef blocks were installed in 3,427 localities and 1,320,000 m^3 of large scale blocks were placed in 439 localities.

Table 1
Governmental Expenditure for Improvement of Coastal Fishing Grounds in Japan

Name of Project	1952-1961	1962-1970
Tsukiiso (Placing stones, construction of concrete surface etc.)	573,191000 yen	1,766,248000 yen
Improvement of culture grounds	52,382	--
Artificial reef (after 1954)	441,984	2,176,742
Large scale reef (after 1958)	197,890	4,232,685
Expansion of Nori (laver) farms (after 1957)	54,497	348,138
Facility for collecting Nori (laver) spore (after 1955)	49,323	216,366
Collection of scallop spat	85,752	--
Investigation and supervision for these projects (after 1959)	33,680	212,170
Total	1,488,699	8,952,349

At the prefectural or fishermen's cooperative association level, many other materials such as concrete pipes, concrete boxes, steel meshes, steel pipes, earthen pipes, moulded waste plastic, plastic films, used drums, used car tires, old bus bodies, old railway wagons, scrapped street cars, etc., are utilized.

Installation of artificial fish reefs is recognized in many districts as a very important project for the development of coastal fisheries. Areas where artificial reefs have been installed are offering good grounds for hook and line fishing or purse seining and, since they constitute barriers, they play an important role in preventing overfishing by modern effective methods like trawling. At the same time, they are recognized as providing not only a nursery area for various species of young fish, but also a habitat for various benthonic organisms such as abalone, topshell, lobster, seaweed, etc.

The Fisheries Agency, under a special committee composed of scientists, experts and administrators is now reviewing these activities to make them more efficient. The committee is expected to publish a report shortly based on its study regarding such matters as reasons that induce fish to inhabit reefs, materials and structure of reefs and planning and arrangement of reefs on the sea bottom.

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A Brief History of Artificial Reef Activities in the United States

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The first reference I could find to artificial reef construction in the United States occurs in Ichthyology of South Carolina by John Holbrook, published in Charleston, S. C. in 1860. The author quotes from a publication by the Hon. William Elliott of Beaufort, S. C., entitled "Carolina Sports, by Land and Water." The quote, which follows, is in a section discussing fishing for sheepshead (Archosargus probatocephalus):

> "They were formerly taken in considerable numbers among our various inlets, into which large trees had fallen to which the barnacles soon became attached; but as the lands have been cleared for the cultivation of sea-island cotton, the trees have disappeared, and with them the fish; and it has been found necessary to renew their feeding grounds by artificial means. Logs of oak or pine are formed into a sort of hut without a roof, five or six feet high; it is floored, and then floated to the place desired, and sunk in eight feet of water, by casting stones or live oak timber within; as soon as the barnacles are formed, which will happen in a few weeks, the fish will begin to resort to the ground."

The next recorded reef construction effort occurred about 1916 and was well organized by the Boatmen's Association of Great South Bay, New York. Many of these individuals made their living by taking out recreational fishermen. These early boats lacked sophisticated sounding devices and the speed that a captain would need to take his clients to offshore fishing grounds, so they built fishing grounds within Great South Bay. The Association constructed a series of reefs near Fire Island Inlet made of butter tubs half filled with cement with a four-inch diameter stake from two to three feet long sticking up from the center of the tub. These reefs provided productive fishing for about 30 years and were rebuilt during 1946 and 1947 by the Bay Shore Tuna Club.

The Continental Shelf of the United States, particularly off the Atlantic and Gulf coasts, has extensive areas of sand or mud with little hard, irregular substrate. As recreational fishing grew, fishermen quickly learned to avoid these relatively barren areas and concentrate their bottom fishing effort on rocks, ledges, coral reefs, wrecks and other areas of irregular bottom. However, off many of the coastal states the rough bottom, fishing grounds nearshore were scarce and anglers had to go 20 to 40 miles offshore to find extensive areas of outcroppings and the associated concentrations of fishes.

Offshore artificial reef construction began in earnest in 1935 with the sinking of four vessels and tons of other material on the Cape May-Wildwood, New Jersy Fishing Preserve by the Cape May-Wildwood Party Boat Association. The reef was located about 10 miles southeast of Cape May Inlet in 65 feet of water. The Pennsylvania-Reading Railroad offered a "fisherman's special" a one-day round trip fare from Philadelphia to Cape May of only $1.25. In their brochure "Good Fishing," they described the reef as follows:

> "When completed the preserve will resemble a vast underwater forest of trees and pilings standing on end as though growing and completely covered with marine growth, worms, mussels and other forms of sea life. Interspersed will be the ghostly hulls

of sunken ships and barges, proving an ideal feeding and resting place for millions of fish."

The initial success and publicity that the Cape May Preserve received prompted the Atlantic City Chamber of Commerce to build an artificial reef 10 miles southeast of Atlantic City during the spring of 1936 and the Brielle, New Jersey Chamber of Commerce to start a reef off Manasquan Inlet in 1937.

There was little reef construction during the 1940's, other than the rebuilding of the Great South Bay reefs by the Bay Shore Tuna Club. Not only did the Bay Shore Tuna Club do an excellent job in rebuilding six reefs, they also kept records of the numbers and species of fishes caught for one fishing season before construction and the fishing season following the completion of the work. The following is a segment of a letter from the conservation chairman of the Bay Shore Tuna Club to the superintendent, New York Bureau of Marine Fisheries:

> "Within two months from the laying of the habitats, fishing territories previously known as good became excellent. Poor areas which had been abandoned by bass, blackfish or weakfish, showed signs of amazing improvements. After steady fishing of these emplacements, statistics show that the number of fish specimens caught during 1947 season, as compared with 1946 available results, increased as follows: sea bass -- 25 times; blackfish --2½ times; and weakfish --double."

Offshore reef building efforts, dormant for over 10 years, began again in 1950 with construction of McAllister Grounds off Long Beach, New York with debris from Manhattan building demolition. This was followed in 1953 by the Schaefer "Beer Case Reef," Fire Island Inlet, N.Y., built of 14,000 concrete-filled Schaefer beer cases.

An ambitious program, the first reef building effort recorded for the Gulf of Mexico, was initiated by the Alabama Department of Conservation and cooperating sportsmen's groups in 1954. Their objective was development of a series of artificial snapper banks along the 10 fathom contour. Anglers began catching red snapper, grouper, shark, spadefish and sea bass within six months after their first drop of 250 automobile bodies. The Texas Parks and Wildlife Department soon followed Alabama by developing both estuarine and ocean artificial reefs to help develop and improve sport fishing in Texas.

From the mid-1950's into the 1960's, as successful reef building efforts were publicized, numerous fishing clubs tried building small reefs to improve fishing conditions in their areas. Many of these efforts, attempted without technical assistance from state or federal agencies, were poorly organized and, because of their depencence on volunteer labor and donations, often ended abruptly.

Growing demands on sport fish resources, the interest in using artificial reefs to improve sport fishing and a lack of knowledge of how these reefs should be constructed for maximum benefit to both fishermen and the resource prompted state and federal agencies to begin research on artificial reefs. The Division of Fish and Game of the Hawaii Department of Land and Natural Resources initiated scientific studies on artificial reefs in 1957 to determine the effect of these man-made reefs on the standing crop of fishes. A 16-fold increase by weight of fishes occupying one site after the addition of concrete shelters encouraged Hawaiian biologists to begin constructing a series of artificial reefs using primarily car bodies and damaged concrete pipe (Kanayama and Onizuka, 1973). They also continued their studies of fish densities at these sites.

The California Department of Fish and Game began their evaluation of artificial reefs in 1958 (Carlisle, Turner and Ebert, 1964). Their research, which is continuing, has provided useful information on the practicality of man-made reefs in California waters, the effectiveness and cost of reef materials and the benefit to fishermen (Turner, Ebert and Given, 1969).

Randall (1963) built and began studying a concrete block reef at Lameshur Bay, Saint Johns, Virgin Islands, in 1960. Twenty-eight months later he found the standing crop of fishes on the artificial reef was 11 times greater than on an adjacent natural reef. Based on these findings, he recommended artificial reefs for enhancement of sport and commercial fishing around the Virgin Islands (Unger, 1966).

Although a number of other states and territories began reef evaluation studies soon after these initial efforts, there was little scientific information available for the Atlantic coast when we began our research on artificial reefs in 1966.

Our objectives were to establish a series of research reefs along the Atlantic Coast and to determine how these reefs could best be used to help develop and conserve recreational fishery resources. Specifically we wanted to answer as many of the questions as possible that state agencies and other reef building organizations would have when they started to build reefs, such as what types of material could be used, how much would it cost to build a reef, what type of reef would be most effective and how could these reefs be used to manage the resource?

We built ten reefs and provided technical assistance to states and other groups on many more. However, we have concentrated most of our research efforts on two reefs. One is a cooperative effort with the South Carolina Wildlife Resources Department on a reef off Murrells Inlet, S. C. and the other is a cooperative study with the National Park Service comparing a small tire reef in Biscayne National Monument with a similar size, adjacent patch reef.

We conducted pre-construction surveys to determine the species and numbers of fishes living on the reef sites before building our research reefs. Once the reefs were constructed, we continued our surveys and also used trapping and tagging to gather information on species composition, relative abundance and movement of fishes on and between reefs.

Within days after our reefs were installed, fishes began to appear. Adult fishes were first to arrive on some reefs, while juveniles were first at other sites, depending on the time of year and geographic location. Initially, these fishes are attracted to the shelter reef material provides. Some fishes, such as grunts, feed on grass beds and sand bottom at night but use reefs for shelter during the day. Reef materials also provide sheltered areas of calm water or favorable currents by damping or deflecting currents. Fishes use these areas to conserve energy. We have observed this repeatedly on the artificial reef off Singer Island, Florida where the strong current of the Gulf Stream is over the reef much of the time. Many fishes are crowded inside the shelter when the current is strong, but scattered around or above the material when the current is weak (Stone, Buchanan and Steimle, 1974).

Many fishes feed on algae or encrusting and motile invertebrates associated with the reef as well as using the shelter reefs provide. Reefs also may be used as landmarks or visual reference points for fishes. These landmarks provide a spatial reference for fishes in a rather featureless environment (Klima and Wickham, 1971).

We evaluated a number of different non-toxic scrap materials on our research reefs including car bodies, building rubble, concrete culverts, ships and barges and tires. We used car bodies on our first research reef since they were an obvious solid waste that was not being used at that time. Car bodies initially provide good habitat since they rapidly become covered with encrusting organisms and provide numerous crevices for shelter. However, we do not recommend car bodies since they are expensive to prepare and handle and last only three to six years on most open ocean reef sites. (Stone, 1972)

Building rubble and concrete culvert reefs will last indefinitely. However, this material also is difficult to handle. The rubble tends to settle and provide less effective substrate than the culvert.

Ships and barges can be used as the high profile nucleus of a new reef or as effective additions to existing reefs. Several states now are in the process of acquiring and installing surplus Liberty Ships available to states through public law 92-402. Most of the Liberty Ships available through this law now have been requested (Parker, et al. in press).

Based on our findings and those of other researchers, we define artificial reefs as man-made or natural objects intentionally placed in selected areas of the marine environment to duplicate those conditions that cause concentrations of fishes and invertebrates on natural reefs and rough bottom areas. By increasing the amount of reef habitat, artificial reefs provide the potential for increasing the stock sizes of fishes. We believe artificial reefs can be an effective management tool that states or other management agencies can use to develop fisheries which benefit both anglers and the economy of coastal communities (Buchanan, 1974) and conserve the resource by increasing habitat.

In the last 10 years, many state agencies have developed effective reef construction programs. North Carolina, South Carolina and Georgia have excellent state programs while Alabama, Texas, California and Hawaii are continuing their effective efforts. New York hopes to renew their reef building efforts this year. There are over 200 artificial reefs off the coasts of the United States, many of which were built by private organizations, but most with state or federal guidance.

Although we have gained much knowledge about artificial reefs in the last 15 years, there is still more information that is needed to enable us to realize the full potential of artificial reefs in the management of our fishery resources. We at the federal level hope to work with the states to answer questions such as: How large should an artificial reef be to sustain a certain amount of fishing pressure? We are prepared to provide whatever assistance we can to agencies interested in reef construction or research.

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The Scientific View

SESSION CHAIRMAN: JOHN E. RANDALL, Bernice P. Bishop Museum, Honolulu, Hawaii

Geological Considerations for Artificial Reef Site Locations

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Artificial reefs are man-made structures which may be composed of a number of different kinds of materials and placed on the seabed to enhance the biological potential of the reef site. Primary benefits from artificial reefs may include increased sport fishing, recreational diving and research on reef ecology.

In March 1973, a workshop was held in Corpus Christi, Texas to outline the benefits and problems associated with an artificial reef program for Texas. The workshop concerned itself primarily with offshore artificial reefs which may be constructed from World War II surplus Liberty Ships. Participants discussed the requirements for siting these reefs. Certain areas along the Texas coast were to be selected and, later, specific reef sites chosen within the areas. Criteria for selecting areas are outlined in publications by the Texas Coastal and Marine Council. This paper focuses on the issue of site selection and, specifically, the geological criteria which must be considered.

GEOLOGIC FACTORS IN SITE SELECTION

The Texas Coastal and Marine Council has chosen four primary areas as potential locations for artificial reefs. Specific reef sites still await selection.

Each reef site within an area should be considered for the following important geological attributes:

- Substrate character
- Pre-existing bottom obstructions
- Sub-bottom characteristics
- Average water turbidity
- Oil and gas seeps

Substrate Character

Substrate character may be the most important factor in site location because the substrate (seabed) is the foundation upon which the artificial reef will be constructed. Moreover, the geologic character of the substrate is highly sensitive to the oceanic environment in which the sediments are deposited. A muddy substrate, for example, may reflect an environment in which winnowing of the sediments by currents is negligible or one in which ambient turbidity is very high. In either case, reef organisms would not flourish.

In general, a soft, muddy seabed is unacceptable as a reef site because (1) the reef would sink into the mud, (2) sedentary reef organisms and reef fish do not like muddy water and (3) the benefits of underwater study and scuba diving would be lost in a turbid environment.

The areas selected by the Marine Council are, depending on the seabed map one uses, in generally suitable geological regions. According to Curray (1960), Areas S-1 and S-2 are in muddy sand or muddy shell zones; S-3 is on the fringe of a muddy area but still has sandy and shelly parts; area S-4 is in a muddy zone. This muddy zone may or may not be soft and incompetent. Muds become hard and compact with time. The Pleistocene Beaumont Clay, for example, is quite stiff and would make a suitable foundation for a Liberty Ship reef. In contrast, the modern muds of the major river deltas in the Gulf of Mexico are soft and unsuitable for reef sites because they have not had time to become compacted and de-watered.

The map by John Grady (1970) shows that areas S-3 and S-4 are in muddy zones, area S-1 is in a sandy zone and S-2 is in a mixed sand-silt-clay zone. The 1969-70 Whico Oil/Gas Marine Gulf Coast Atlas also shows that areas S-1 through S-4 are in muddy-bottom areas. It is important that the consistency--the "stiffness"--of the sediment at each site within an area be determined before a Liberty Ship is placed there.

William Bryant, oceanographer and specialist on geotechnical properties of marine sediments, notes that an average non-sandy gulf sediment may have a shear strength of 50 pounds per square foot, whereas the highly compact and stiff Beaumont Clay may have a shear strength of 2,000 pounds per foot (personal communication). The Beaumont Clay could easily support an artificial reef but soft muds would allow a heavy structure to sink to a depth where the mud has adequate "strength" to support it (mud becomes stiffer with increasing depth of burial). Sandy bottoms have a great load-bearing capacity, but because they are not cohesive, they tend to be mobile and may drift. A large ship may become buried or may shift locations on a pure sand bottom, especially during storms.

Pre-existing Bottom Obstructions

Pre-existing bottom obstructions are important in the selection of an artificial reef site because of the following facts:

- They are avoided by trawlers (shrimpers and bottom fishermen).
- They provide some cover for reef and bank organisms and therefore are natural "nuclei" on which to develop larger artificial reefs.
- They may provide support for the reef structure and prevent its becoming dislodged during storm surges.

Many existing bottom snags have been mapped by Gary Graham of the Texas Agricultural Extension Service and his maps are available through the Texas A&M University Sea Grant Program. Graham's snags are not sufficiently identified as to the kind of obstruction--wreck, reef, hole, etc.--and these identifications should be made prior to final site selections.

Sub-bottom Characteristics

The geological characteristics of site locations may include shallow subsurface structures such as faults or diapirs. These structures can be detected by geophysical (seismic) investigations prior to final site selection. Most structural deformation along the Texas Gulf Coast takes place very slowly and presents little hazard to an artificial reef. The time required for substantial seafloor deformation is usually many years. For example, salt diapir movement or growth-fault movement may be only a fraction of an inch per year and the motion is generally not rapid or jerky.

Average Water Turbidity

Water clarity is a prime requisite for reef development because many reef dwellers need to photosynthesize in sunlit water and the sedentary reef organisms are filter-feeders that do not thrive in muddy water. Artificial reefs must enhance the biological potential of a site and they must then be visible in order to fulfill their partial purpose as a place for underwater study and recreation.

Sites should be selected in areas where Gulf currents are not abnormally swift to minimize the chance of encountering resuspended marine muds. The sites should be away from river-sediment plumes and semipermanent Gulf currents which carry consistently large quantities of terrigenous detritus.

Oil and Gas Seeps

Natural oil and gas seeps have been detected in the Gulf of Mexico (Geyer and Sweet, 1974). These seeps may not be detrimental to the marine communities at-large, but it is doubtful that sedentary filter feeders and delicate epiphytes would thrive on a structure placed on or in the path of an oil or gas seep.

Detection of the seeps is not difficult and can best be accomplished in conjunction with a local geophysical survey.

PRIORITIES FOR SITE SELECTION

A well-planned program for site selection will involve a synthesis of existing geological data in the five areas mentioned above and on-site studies to obtain answers to specific scientific questions.

Sources of information for the initial synthesis may include the offshore petroleum operators, the major universities in Texas and various research agencies in the state. The information available should include the following items:

- Wave forecasts
- Storm-surge forecasts
- General water circulation patterns
- General bathymetry
- General geology

On-site studies should be planned as part of ongoing research efforts, if possible, to minimize cost and startup time. Then, the studies and services could include the following items:

- Direct observation of the terrain by divers
- Sediment coring for engineering analysis
- Detailed bathymetric mapping of the proposed site and its surroundings
- High-resolution, sub-bottom profiling with digital recording capability
- Measurement of water turbidity by divers
- Emplacement of a temporary buoy

POTENTIAL TRADEOFFS ON SITE STUDIES

It would be advantageous to have the cooperation of industry and universities in the site investigation process. Those who have a direct interest in either the scientific data from the sites or helping to establish a reef which may aid their business are logical candidates for tradeoffs.

Potential participants include (1) the charter boat industry (detailed bathymetry), (2) the oil industry (detailed sub-bottom profiling, among others), (3) consulting engineering firms (geotechnical properties of sediments) and (4) geoscientists from Texas' universities (photography, observations by divers, currents, turbidity, etc.).

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Comparative Study of the Sport Fishery Over Artificial and Natural Habitats off Murrells Inlet, S. C.

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Paradise Artificial Reef off Murrells Inlet, South Carolina is one of many artificial reefs built or being expanded off the southeast coast of the United States. The impact of these reefs on local sport fisheries is relatively unknown. The purpose of this study was to determine if Paradise Artificial Reef had any effect on the species composition of private boat catches, the number and success of anglers and the amount of business in nearby communities from June through September, 1972-1973.

Paradise Artificial Reef, located three miles offshore of the Inlet, was begun in 1963 and covers .01 square miles or about seven acres (Figure 1). It is composed of several thousand car tires and four vessels and is marked by four buoys. The majority of the private boat anglers concentrated their fishing effort within a 13.5 mile radius of Murrells Inlet and were the only users of the reef. Natural habitat within the survey area (13.5 miles radius of the Inlet) consists of about 264 square miles of sandy bottom and 22 square miles of rocky bottom.

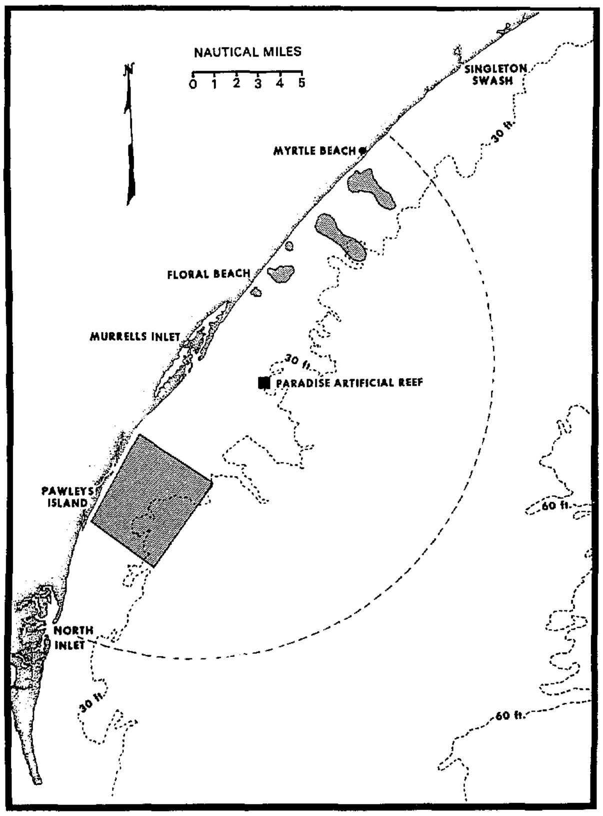

Figure 1.

Paradise Artificial Reef and rocky bottom (shaded area) within the survey area (dotted line).

FISHING EFFORT

In order to estimate fishing effort, we counted the number of private boats leaving the Inlet during stratified random sampling periods and expanded the sample counts to obtain estimates of the number of angler-hours. From these counts, we estimated that private boat anglers spent over 21,000 angler-hours in the survey area during the summer of 1972 and nearly 38,000 during the summer of 1973 (Table 1). About 47 percent of the bottom

		SURFACE FISHING	BOTTOM FISHING	TOTAL
1972	REEF	2,632 (23%)	4,553 (47%)	7,185
	ROCK AND SAND	8,810 (77%)	5,134 (53%)	13,944
	TOTAL	11,442	9,687	21,129
1973	REEF	2,779 (11%)	8,909 (70%)	11,688
	ROCK	505 (2%)	2,927 (23%)	3,432
	SAND	21,983 (87%)	891 (7%)	22,874
	TOTAL	25,267	12,727	37,994

ANGLER - HOURS

Table 1.

fishing and 23 percent of the surface fishing in 1972 was over the reef while, in 1973, 70 percent of the bottom fishing and 11 percent of the surface fishing was over the reef. Private boat anglers expended nearly 14,000 more angler-hours seeking pelagic fishes in 1973 than they did in 1972. Sandy bottom received nearly all of this increase while the reef received about the same number of angler-hours as in 1972. Private boat anglers also expended over 3,000 more angler-hours for demersal species in 1973 than in 1972. The reef received nearly twice as many angler-hours in 1973 as in 1972, while natural habitat received less effort.

Private boat anglers fished more intensively over the reef than over sand or rock habitats, even though the reef made up less than .01 percent of the survey area (Table 2). The number of angler-hours spent surface fishing per square mile of habitat (fishing intensity) over the reef in 1973 was almost 13,000 times that spent over sand. Bottom fishing intensity over the reef in 1973 was almost 7,000 times the intensity over rock and 222,000 times that over sand.

We cannot compare estimates of fishing intensity between years because information from sandy and rocky areas was pooled in 1972. Bottom fishing intensity in 1972 over the reef was nearly 26,000 times that over natural habitat, and surface fishing intensity over the reef was nearly 8,000 times that over natural habitat.

SURFACE FISHING

HABITAT	SQUARE MILES	FISHING INTENSITY 1972	FISHING INTENSITY 1973
SAND	264	31 (sand and rock)	84
ROCK	22		21
REEF	.01	258,400	272,800

BOTTOM FISHING

HABITAT	SQUARE MILES	FISHING INTENSITY 1972	FISHING INTENSITY 1973
SAND	264	18 (sand and rock)	4
ROCK	22		132
REEF	.01	460,000	887,500

Table 2.

Fishing intensity, number of angler-hours per square mile, for private boat anglers over the artificial reef, rocky bottom and sandy bottom off Murrells Inlet, S.C. June - September, 1972 - 1973.

FISHING SUCCESS AND CATCH COMPOSITION

We collected information to estimate fishing success (catch per angler-hour) and catch composition from private boat anglers by mailed questionnaires in 1972 and interviews at docksides in 1973. We estimated that in 1972, private boat anglers caught nearly 13,000 fishes while surface fishing and 34,000 while bottom fishing, representing 28 species (Table 3). In 1973 they caught nearly 46,000 fishes while seeking pelagic species and 38,000 while seeking demersal species, representing 30 species. Ninety-nine percent of the bottom catch came from the reef and rocky habitat.

Spanish mackerel (Scomberomorus maculatus) dominated the surface catch from each habitat type in both summers. Sea basses (Centropristis spp.), grunts (Pomadasyidae) and porgies (Sparidae) dominated the bottom catch in both summers. Since the data from 1972 were pooled, species composition of the catch from natural habitat is not comparable between summers. Sea basses, grunts, porgies and flounders (Paralichthys spp.) in 1973 composed over 83 percent of the catch from the reef and rocky bottom and zero percent from sandy bottom (Figure 2). Sea basses dominated (40 percent) the catch from rocky bottom while grunts and porgies dominated (47 percent) the

		SURFACE FISHING	BOTTOM FISHING	TOTAL
1972	REEF	4,802 (38%)	14,165 (42 %)	18,967
	ROCK AND SAND	7,972 (62%)	19,927 (58%)	27,899
	TOTAL	12,774	34,092	46,866
1973	REEF	360 (1%)	21,226 (56%)	21,586
	ROCK	270 (1%)	16,533 (43%)	16,803
	SAND	44,766 (98%)	294 (1%)	45,060
	TOTAL	45,396	38,053	83,449

CATCH

Table 3.

Number of fish caught off Murrells Inlet by type of bottom and method of fishing, June - September, 1972 - 1973.

catch from the reef. Flounders represented nearly 29 percent of the catch from the reef and less than 1 percent from rocky bottom. No game fishes were caught over sandy habitat while bottom fishing.

Sea basses, flounders, grunts and porgies were caught over the reef during both summers, although not in the same proportions (Figure 3). The percentage of grunts and porgies differed by only 2 percent. Sea basses decreased nearly 10 percent and flounders increased by 20 percent in 1973. Increases in 1973 of both effort with live bait and abundance of flounders probably contributed to the increased catch of flounders. Although we did not separate fishing effort by bait categories in 1972, we suspect that less than 25 percent of the fishing effort was with live bait. During underwater surveys of the reef, we observed that flounders were more abundant in 1973 than in 1972.

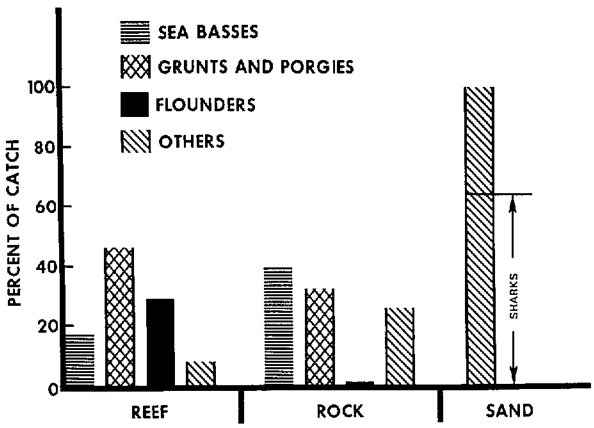

Figure 2.

Catch, in percent, of major species groups by private boat anglers while bottom fishing off Murrells Inlet by type of bottom, June - September, 1973.

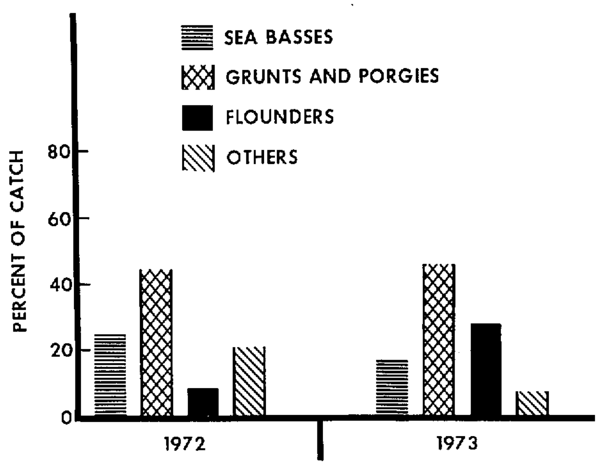

Figure 3.

Catch, in percent, of major species groups by private boat anglers while bottom fishing on Paradise Artificial Reef, June - September, 1972 - 1973.

Success while surface fishing over each habitat type varied between summers (Table 4). Private boat anglers in 1973 had their highest catch rates (catch per unit of effort) over sandy bottom, whereas in 1972 their catch rates did not differ between habitats. Success over the Reef in 1972 was higher than that over the Reef in 1973. (Mann-Whitney U test; U = 247; P <.007).

Certain pelagic gamefishes such as king mackerel (Scomberomorus cavalla) and little tunny (Euthynnus alletteratus) are attracted to an artificial reef by the presence of baitfish (i.e., scads, herrings), while other pelagic gamefishes, such as dolphin (Coryphaena hippurus), cobia (Rachycentron canadum), and great barracuda (Sphyraena barracuda) are attracted by the structure. Although no studies have been conducted to determine why Spanish mackerel frequent artificial reefs, we believe they are attracted to the baitfishes. During our underwater surveys of Paradise Artificial Reef in 1972, we often observed schools of scads (Decapterus spp.) and Spanish mackerel. Only occasionally in 1973 did we observe similar schools of these fishes. The possible reduced abundance of baitfishes on the reef in 1973 may indirectly have caused the fishing success for pelagic gamefishes over the reef to be low compared to sandy bottom.

We found no difference between fishing success for demersal species over the reef in 1972 and that over natural habitat (Table 4). In 1973, however, success over the reef was greater than that over sand and less than that over rock. The failure to detect a similar difference in 1972 may have been due to a masking effect caused by combining data from highly successful fishing over rocky bottom with data from relatively unsuccessful fishing

	1972			1973		
	HABITAT	CATCH PER ANGLER-HOUR	MANN-WHITNEY U TEST AT 5% LEVEL OF CONFIDENCE	HABITAT	CATCH PER ANGLER-HOUR	MANN-WHITNEY U TEST AT 5% LEVEL OF CONFIDENCE
SURFACE FISHING	ROCK AND SAND VS. REEF	0.9 1.8	NO DIFFERENCE	SAND VS. ROCK		INSUFFICIENT DATA
				SAND VS. REEF	1.9 0.1	DIFFERENCE
				ROCK VS. REEF		INSUFFICIENT DATA
BOTTOM FISHING	ROCK AND SAND VS. REEF	3.9 3.0	NO DIFFERENCE	SAND VS. ROCK	0.3 5.7	DIFFERENCE
				SAND VS. REEF	0.3 2.4	DIFFERENCE
				ROCK VS. REEF	5.7 2.4	DIFFERENCE

Table 4.

Catch per angler-hour by habitat and method of fishing, June - September, 1972 - 1973.

over sandy bottom.

The low catch rates while bottom fishing on the reef probably resulted from the fact that fishing intensity on the reef was several thousand times greater than that on rocky bottom. High fishing intensity increases the rate of stock reduction and angler competition. This will result in reduced catch rates. Replenishment of the reef's stock by immigration from surrounding areas will cushion the effect of fishing intensity, but immigration is limited by the size and behavior of peripheral stocks. Catch rates on Paradise Artificial Reef probably will remain lower than those over rocky habitat unless fishing intensity on the reef is reduced or the size of the reef is increased relative to fishing effort.

In order to manage an artificial reef for maximum or optimum sustained yield we must know the relation to one another of fishing success and effort, reef size and profile, and the amount of each kind of natural habitat in the surrounding area. Insufficient information is available to define this relation. A theoretical relation of fishing success, reef size and fishing effort is presented in Figure 4. In general, success should not increase as the reef size increases if effort increases proportionally with reef size, because fishing intensity will remain constant. Accordingly, if effort varies disproportionally with reef size, success should vary indirectly with fishing intensity. This is the portion of Figure 4 within which Paradise Artificial Reef fits. Success should increase with increased reef size once effort becomes constant because fishing intensity is decreasing (Point A). The reef size at point A is the minimum necessary to support the maximum effort at a given level of success. Beyond point A, success should continue to increase with reef size until the gear efficiency limitations are reached (Point B). Any increase in reef size beyond point B should not improve the catch per unit of effort. The size of the reef at point B is the ideal for a fishing reef. Verification

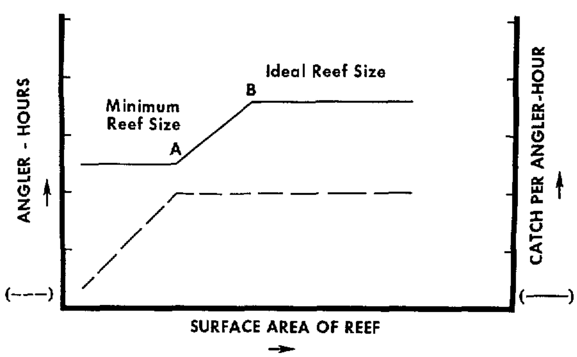

Figure 4.
Theoretical relation of fishing success, reef size and fishing effort.

of this concept will permit refined management procedures.

INFLUENCE OF REEF ON ECONOMY OF THE AREA

At the end of summer in 1972, we requested information from non-resident anglers who participated in the fishing survey concerning their expenditures and non-fishing activities in the Murrells

Group I: anglers who would not return to the Murrells Inlet-Myrtle Beach area if Paradise Artificial Reef did not exist.

Group II: anglers who fished over the reef but would return even if it did not exist.

Group III: anglers who did not fish over the reef.

Of the anglers who responded, only 14 percent (Group III) had not fished over the reef (Table 5). Of those who had fished over the reef, 82 percent said they would return if it were absent (Group II), and 18 percent said they would not return (Group I). Anglers in Group I represented the net increase in the number of anglers due to Paradise Artificial Reef.

We estimated that non-resident private boat anglers spent $36,000 in the area during the 1972 summer; Group I spent $3,132 (8.7 percent), Group II, $28,800 (80.0 percent) and Group III, $4,068 (11.3 percent). This money was spent mostly for gasoline, oil, bait, tackle, food, launching fees and lodging. We did not include in our estimate money spent for taxes, maintenance cost and related expenses for seasonal homes.

	GROUPS		
	I	II	III
AVERAGE NUMBER IN PARTY	5.7	5.4	5.6
AVERAGE DISTANCE TRAVELED	121	105	93
AVERAGE TRIPS/YEAR	5.6	13.8	11.8
AVERAGE DAYS/TRIP	2.5	5.2	2.5
LODGING			
PRIVATE	47%	67%	89%
RENTAL	53%	33%	11%
AVERAGE COST/TRIP	$54	$44	$37
AVERAGE COST/DAY	$21	$9	$15
ESTIMATE OF EXPENDITURES DURING SUMMER	$3,132	$28,800	$4,068
PERCENT	8.7%	80.0%	11.3%

Table 5.
Characteristics of non-resident anglers fishing out of Murrells, S.C. in privately owned and operated boats, June - September, 1972.

CONCLUSIONS

Paradise Artificial Reef and rocky bottom were essential to the private boat anglers seeking demersal fishes off Murrells Inlet. During both summers, anglers expended most of their effort and caught most of their fish over the reef and rocky bottom. Each summer, the reef received nearly 50 percent or more of the effort. Although effort in the survey area increased by 32 percent between 1972 and 1973, the effort on the reef increased by nearly 100 percent. Even with this tremendous increase in effort, anglers experienced similar success on the reef during both summers. Private boat anglers caught the same species from the reef as from rocky bottom, but in different proportions and at different catch rates. Success over rocky bottom in 1973 was nearly twice as great as that over the reef. The reef covered considerably less surface area than rocky bottom and received fishing intensity several thousand times that over rocky bottom. Sandy bottom received only a small portion of the effort and yielded catches of nongame fishes.

Neither Paradise Artificial Reef nor rocky bottom were important to the angler seeking pelagic species. Both habitats received only a small portion of the total surface fishing effort. In 1972, we found no difference in success among habitats, whereas private boat anglers in 1973 had their greatest success over sandy bottom. The fluctuation in success over the reef between summers may have resulted from the presence or absence of baitfishes.

Paradise Artificial Reef attracted anglers and had a positive effect upon the economy of the Murrells Inlet-Myrtle Beach area. Nearly 16 percent of the private boat anglers active during the summer were attracted to this area because of the reef. The money spent by the additional anglers amounted to nearly 10 percent of the money spent by all private boat anglers.

This study reveals only the number of each species that private boat anglers caught, the number and success of these anglers and distribution of fishing effort among the habitats. It is not an evaluation of the effectiveness of the reef in providing a fishery similar in quality to that over rocky bottom because of the tremendous differences in habitat size and fishing intensity between habitats. Controlled fishing over habitats of equal size is necessary to determine the maximum angler benefit that can be obtained with artificial reefs.

Florida's Fish Attractor Program

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The origin of fish attractor usage in freshwater is uncertain, but the Michigan Conservation Department was probably the first conservation agency to experiment with attractors. In the early 1930's they placed brush shelters in several lakes, and, although their primary goal was enhancement of lake habitat, they noted with interest the attraction of many varieties of fish to these shelters (Hazzard, 1937). Following this initial finding, Rodeheffer (1939, 1940 and 1945) worked extensively with various kinds of brush shelters in Douglas Lake, Michigan.

Fish attractors were used for the first time in Florida in the mid-1950's when several hundred Christmas trees were sunk in Lake Tsala Apopka. It was not until the mid-1960's however, that renewed interest stimulated the building of a 1,000 automobile tire attractor in Lake Minneola, an orange brush attractor in Lake Palatlakaha, and experiments with cement blocks, soybean cake and pelletized cattle feed in Lake Juliana. Methods for evaluating the effectiveness of these attractors consisted primarily of interviews with fish camp operators and fishermen and observations by scuba divers. The results of these evaluations, although promising, were inconclusive.

Recognizing the need for management tools and the potential value of fish attractors, a study to determine the effectiveness of fish attractors was proposed by the Florida Game and Fresh Water Fish Commission and initiated in 1969. Vitrified clay pipes and a combination of brush and cement blocks were the two attractor types selected for this 5-year evaluation in Lake Tohopekaliga (Wilbur and May, 1970). Positive preliminary findings from this study launched a statewide program of fish attractor construction using a wide range of materials and evaluation methods.

*presentor

Many of these attractors have been designed for small, sterile or non-productive lakes. More recently fish attractors have been found to enhance catches in highly eutrophic lakes with typical low game fish production. Attractors, however, have probably had their greatest success in moderately productive waters with limited cover.

TYPES OF ATTRACTORS

Historically, brush is probably the oldest material used for fish attractors. In Florida, old citrus trees and scrub oak have been found to outlast the softer pines by far. Scrub oak used in Lake Tohopekaliga was virtually as resilient after five years in the water as it was the day it was cut, according to Wilbur (1973). Design variations for brush are endless. Tall brush structures should prove to be more effective in deep water by enabling fish to seek out the water strata they prefer.

Old automobile tires have become popular recently due to their low cost, availability and ease of handling. They can be bundled easily with either nylon rope or plastic banding, or they can be placed individually at attractor sites. Weighting with cement blocks or with cement poured into the tire cavity is done generally to facilitate rapid sinking and maintain bottom position. Holes can be drilled to allow escapement of trapped air. Like brush shelters, imagination is the key ingredient for successful design.

Rubble and cement block rejects have been used in Florida. Their weight to surface area ratio however, does not make these rocky materials an ideal material for attractors. However, where weight poses no particular problem, such ma-

TABLE 1

Data pertaining to fish attractor installation in Florida lakes from 1965 to 1973

Attractor Types	No. Sites	Date	Water Body	Acres	County	Meters Offshore	Water Depth(M)	Trophic Level
Old Car Tires	1	12-72	L. Wire	21	Polk	15	2.5	Mesotrophic
	1	8-73	L. Agnes	386	Polk	35	3	Mesotrophic
	1	7-72	Crooked L.	5,536	Polk	45	3	Oligotrophic
	1	7-73	L. Tarpon	2,534	Pinellas	100	4	Mesotrophic
	1	2-73	Compass L.	600	Jackson	10-25	2-3	Oligotrophic
	5	8-73	L. Osborne	360	Palm Bch.	5	3	
	1	7-72	Wildcat L.	232	Lake	25	4	Oligotrophic
	2	11-72	L. Dias	711	Volusia	50	4	Mesotrophic
	2	11-73	L. Minneola	1,888	Lake	100	5	Mesotrophic
	1	7-73	L. Lotta	45	Orange	25	3	Eutrophic
	2	12-72	Georges L.	816	Putnam	225	4	Mesotrophic
	1	4-70	Perch L.	30	Clay	60	8	Oligotrophic
	1	7-73	Lowery L.	1,263	Clay	50	3	Oligotrophic
	1	4-73	Magnolia L.	205	Clay	200	6	Oligotrophic
Brush Attractor	3	7-73	Red Beach	335	Highlands	300	5	Mesotrophic
	6	8-73	L. Juliana	926	Polk	8-40	3-5	Mesotrophic
	3		Starr L.		Polk	10-75	4-6	Mesotrophic
	1	7-73	L. Tarpon	2,534	Pinellas	85	4	Mesotrophic
	2	8-73	Crooked L.	5,538	Polk	100-800	4-6	Oligotrophic
	1	9-71	Smith L.	358	Marion	125	3	Mesotrophic
Clay Pipe	1	5-73	Watertown L.	46	Columbia	10	2	Mesotrophic
	1	6-73	L. Helene	62	Polk	35	4	Oligotrophic
	6	7-70	L. Tohopekaliga	22,000	Osceola	100-1000	3-4	Eutrophic
Stake Beds	1	15-73	Sante Fe L.	5,836	Alachua	25	4	Oligotrophic
	1	6-73	L. Harris	18,000	Lake	400	4	Eutrophic
Hay Bales	—	12-73	Bear L.	107	Santa Rosa	5-15	2-3	Oligotrophic
	—	6-73	Koen L.	110	Lafayette	25	1-3	Oligotrophic
Soybean Cakes &	—	1965	L. Juliana	926	Polk			Mesotrophic
Pelletized Foods	1	1973	L. Tohopekaliga	22,000	Osceola	100	4	Eutrophic
Brush & Rubble	6	7-70	L. Tohopekaliga	22,000	Osceola	100-1000	3-4	Eutrophic
Brush & Clay Pipe	1	4-73	Koon L.	110	Lafayette	85	2	Oligotrophic
PVC Pipe	1	7-73	L. Tarpon	2,534	Pinellas	225	4	Mesotrophic
Old Rowboats	1	5-73	Newman's L.	7,427	Alachua	1000	4	Eutrophic

terials will concentrate fish effectively (Wilbur, 1973).

Vitrified clay pipes and PVC pipes have been used in several Florida lakes. Pipes often are bundled in groups to give the attractor height, but individual pipes also can be dropped (Wilbur and May, 1970).

Petit (1973) discussed the use of stake beds in Tennessee which consisted of four or five foot shafts of one by two inch lumber nailed upright to a rectangular four by six foot base. Although they may effectively concentrate crappie (Pomoxis), stake beds are relatively expensive to make and are not easily handled.

Old car bodies have been used as fish attractors in Kentucky (Charles, 1967). Their weight and bulk make handling difficult, and they should be steam-cleaned and stripped of upholstery prior to sinking.

Old rowboats, although of very limited supply, can easily be pulled out to the desired drop-spot before making holes in their hulls and sinking them.

In sterile lakes of northwest Florida, hay has been found to greatly stimulate growth of zooplankton, and fish species of all kinds gather around the hay to feed.

Soybean cakes and pelletized fish foods will concentrate many fish which gather to feed directly on the food. In combination with the other attractors above, such foods will often greatly enhance utilization of attractors.

All of the above fish attractor materials, with the exception of physical stimuli and car bodies have been used in Florida lakes (Table 1). To date, there are 66 fish attractors operative in 28 lakes throughout the state. Automobile tires have been used most often, and at present, there are 21 tire attractors constructed in 14 lakes. Brush attractors using either orange limbs or scrub oak have been installed at 13 locations in eight lakes. These attractors generally cover a much larger area of the bottom than do the other attractors.

Most of the lakes selected for attractor placement are small (400 acres or less) and are near urban centers or military installations. Many attractors have been located close to shore or a fishing pier to provide fishing for the public without boats or boat access. Fish attractors are marked with a buoy supporting a sign describing the fish attractor constructed below.

EVALUATION RESULTS

Unfortunately, time and funds did not permit evaluation of all the attractors constructed. However, cursory evaluations were undertaken on about half of those installed.

Visual Observation and Word-of-Mouth

Underwater observations with scuba gear is one of the easiest and least involved methods of evaluation. Densities via time period counts at the attractor and control site provide a quick and reliable indication as to the concentrating effectiveness of the attractor. Use of this method, however, was frequently precluded due to low visibility in many of the lakes selected for fish attractors. Fourteen fish attractors have been checked periodically by underwater observation, and only three of these have failed to produce more fish than control areas. In most cases, the attractor concentrations far exceed concentrations noted anywhere else in the lakes. Of the three failures, one was a tire attractor, one a stake bed and one a pipe attractor. The 11 successes included tires, orange brush and cement block attractors.

Observations of the number of boats or fishermen using an attractor also has been used to provide an indication of its success. Where this is followed up with fisherman or fish camp operator interviews, the information is frequently all that is necessary to determine how well an attractor may be operating. Fifteen attractor sites have been evaluated in this way and in most instances fishermen expressed confidence in the worth of the attractor.

Fish Population Samples

Electro-fishing, spot rotenone, trammel nets and fish traps are but a few fish sampling methods which could be used to check attractor colonization. Although trammel nets and electro-fishing were used to test the colonization of the 12 fish attractors in Lake Tohopekaliga, population sampling of attractors has not been used elsewhere in Florida either due to heavy fisherman usage or because the biologist-in-charge did not want to tamper with the population.

Six sites were selected in Lake Tohopekaliga and a brush, pipe, and control area was situated at each site. Each area was shocked with a 220-volt alternating current Milwaukee generator for 30 seconds on two days in each quarterly sample. Results of quarterly electro-fishing samples of the 12 attractors demonstrate brush attractors in this lake attracted more fish than did pipe attractors of similar size and that both attractors were more productive than control areas (Table 2). Bluegill (Lepomis nacrochirus), and white catfish (Ictalurus catus) were the most abundant species in these samples.

Creel Surveys

Since the purpose of investigating fish attractors in Lake Tohopekaliga was to determine whether they could be used to increase the harvest of sport fish, a creel survey to compare lake and attractor catch rates was necessary. The creel design[1] called for five sample days every two weeks with one or two weekend days included. The 22,000-acre lake was divided into six areas with a control area, and brush and pipe attractor in each area. The roving census interviews were conducted between the hours of 6 a.m. to noon or noon to 6 p.m., the sampling frequency within the a.m. or p.m. periods to be determined by fishing pressure variations. Results of this creel investigation between the fall quarter 1970 and the winter quarter of 1972-73 are shown in Table 3. Although catch rates of black crappie (Pomoxis nigromaculatus) and bream species (Lepomis) were higher at attractor locations than elsewhere in the lake, the differences were not significant in paired t-testing. Significantly higher catch rates of largemouth bass (Micropterus salmoides) were realized at attractors. Bream and crappie catch rates might have been higher had not limitations of the computer program required that control fishing effort be lumped with effort expended at the attractors. In spite of this, catch rates for these species were nearly significant at the 5 percent level.

Stake beds described by Petit (1973) produced up to six times greater catch rates of crappie than did other areas of this Tennessee lake. Consequently, stake beds were installed off the end of a fishing pier-bridge in Lake Harris, Florida during the summer of 1973. The following winter, when crappie fishing effort is usually maximum, a night creel survey was conducted employing creel procedures similar to those used on Lake Tohopekaliga. Whereas 0.83 crappie/hour were caught elsewhere on the bridge, at the stake beds only 0.55 crappie/hour were realized. Whether this poor utilization was the result of the stake beds not attracting crappie, or due to the fact that crappie were seeking out other areas at that time could not be determined.

Expert Angler Evaluations

Rupp (1961) suggested that to measure the fishing potential of a water body inefficient anglers

TABLE 2

Electro-fishing results from control sites, and pipe and brush attractors in Lake Tohopekaliga between February 1971 and May 1973.

SPECIES	SITE	FEB. 1971	MAY 1971	AUG. 1971	NOV. 1971	FEB. 1972	MAY 1972	AUG. 1972	NOV. 1972	FEB. 1973	MAY 1973	TOTAL
	control	—	—	1	—	—	—	1	—	—	—	2
Largemouth	pipe	19	9	2	21	1.	2	6	—	—	3	63
bass	brush	35	21	18	12	6	7	7	4	4	4	118
	control	1	2	3	—	—	—	1	—	—	—	7
Bluegill	pipe	34	42	101	45	22	17	14	—	1	53	329
	brush	487	83	243	375	142	33	—	7	24	92	1486
	control	—	—	1	—	—	—	—	—	—	1	2
Redear	pipe	—	—	—	—	3	1	—	—	—	3	7
	brush	2	1	2	1	2	1	—	—	—	2	11
	control	—	—	—	—	—	2	—	—	—	—	2
Black	pipe	—	7	—	—	—	1	—	—	—	1	9
crappie	brush	2	5	3	1	—	—	—	—	—	2	13

SPECIES	SITE	FEB. 1971	MAY 1971	AUG. 1971	NOV. 1971	FEB. 1972	MAY 1972	AUG. 1972	NOV. 1972	FEB. 1973	MAY 1973	TOTAL
	control	—	—	—	—	—	—	—	—	—	—	—
Warmouth	pipe	4	2	4	—	—	—	—	—	—	2	12
	brush	7	14	7	—	2	3	1	—	—	20	54
	control	—	—	—	—	—	—	—	—	—	—	—
Chain	pipe	2	—	—	—	—	—	—	—	—	—	2
pickerel	brush	3	—	—	—	—	—	—	—	—	—	3
	control	—	—	—	—	—	—	—	—	—	—	—
Florida	pipe	—	1	—	—	—	—	—	—	—	—	1
gar	brush	—	—	—	—	—	2	—	—	—	—	2
	control	—	4	—	—	—	—	15	3	—	—	22
White	pipe	—	—	552	252	—	119	1098	30	—	1	2050
catfish	brush	—	5	225	30	—	144	1955	225	—	1	2614
	control	—	—	—	—	—	—	—	—	—	—	—
Brown	pipe	—	—	—	—	—	—	—	40	—	—	40
bullhead	brush	—	—	1	—	—	—	—	30	—	2	33
	control	—	—	—	—	—	—	—	—	—	—	—
Golden	pipe	—	—	3	—	—	2	—	2	—	—	9
shiner	brush	—	—	—	—	2	—	—	2	—	—	4
	control	2	—	—	—	11	1	1	1	—	—	16
Gizzard	pipe	3	71	1	6	11	2	3	4	4	2	107
shad	brush	3	—	1	3	13	2	—	—	1	—	23
	control	—	—	—	—	—	—	—	—	—	—	—
Longnose	pipe	—	—	—	—	—	—	—	—	—	2	2
gar	brush	—	—	—	—	—	—	—	—	—	1	1
	control	—	—	—	—	—	—	—	—	—	—	—
Bowfin	pipe	—	—	—	—	—	—	—	—	—	—	—
	brush	1	—	—	—	—	—	—	—	—	—	1

should be excluded from any data and that only the catch of proficient anglers should be measured. Taking this concept a bit further, the use of a single expert fisherman or small group of fishermen has been used in Florida to determine fishing potential of attractors in comparison to potential at control sites or other areas of the lake.

The fish attractors in Lake Tohopekaliga were fished by an experienced fisherman five days every two weeks. The six hours of a fishing day were equally divided between the control areas and the pipe and brush attractors. Fishing was done either in the morning or afternoon, and various tackle and baits were tested. Results of continuous fishing between July 1970 and May 1973 show that although catch rates using minnows and plastic worms were not as high as catch rates with earthworms, both types of bait produced far greater catches at pipe and brush attractors than at control sites. Whereas a total of only 59 fish were caught at control sites, 474 fish were taken from the pipe attractors and 703 fish over brush attractors (Table 4). Quarterly catch rates with earthworms at brush attractors varied from 0.0 fish/hour to 5.9 fish/hour and averaged 1.15 fish/hour. Quarterly catch rates at pipe attractors varied from 0.0 to 4.65 and averaged 0.89 fish/hour. These figures are probably on the conservative side of what the attractors could have produced, in that fishing was done regardless of bad weather and fishing effort followed a fixed schedule.

TABLE 3

Fishing success estimates in Lake Tohopekaliga and at attractors between fall 1970 and winter 1972-73.

	BREAM/HOUR LAKE	ATTRACTOR	BASS/HOUR LAKE	ATTRACTOR	CRAPPIE/HOUR LAKE	ATTRACTOR
Fall 1970	2.2	6.8	0.2	0.4	1.4	3.2
Winter 70-71	1.7	NE	0.3	0.6	1.2	NE
Spring 1971	2.1	4.5	0.6	0.7	1.4	2.7
Summer 1971	2.3	NE	0.4	0.4	NE	NE
Fall 1971	3.0	NE	0.3	0.4	0.7	NE
Winter 71-72	2.6	3.1	0.3	NE	0.5	1.0
Spring 1972	1.8	1.0	0.3	NE	0.1	NE
Summer 1972	2.1	2.9	0.3	0.7	1.4	NE
Fall 1972	2.2	1.7	0.4	NE	1.2	NE
Winter 72-73	2.2	NE	0.3	NE	0.6	NE
Mean	2.2	3.3	0.3	0.5	0.9	2.3
Paired t[1]	1.410		3.051*		3.172	

[1]only calculated where paired date occurred.
NE no estimate due to insufficient fishing effort.
*statistically significant at 0.05 confidence level.

TABLE 4

Comparison of harvested fish numbers caught by an experienced fisherman at control and attractor sites in Lake Tohopekaliga between July 1970 and May 1973.

BAIT	CONTROL	PIPE	BRUSH
Earthworms	45	425	550
Minnows and plastic worms	14	49	153
Totals	59	474	703

TABLE 5

Results of short-term-experienced fisherman evaluations of fish attractors in seven Florida lakes.

WATER BODY	ATTRACTOR TYPE	HOURS FISHED	CATCH RATES AT: CONTROL (SPECIFIC AREA)	LAKE (GENERAL)	ATTRACTOR
L. Lowery	Tires	30	< 0.07	—	0.13
Perch Pond	Tires	40	—	0.33	3.13
L. Magnolia	Tires	30	—	0.13	2.47
Wildcat L.	Tires	11	0.09	—	3.09
L. Dias	Tires	15	0.24	0.08	3.20
L. Stella	Tires	15	—	< 0.07	0.20
L. Stella	Brush	15	—	< 0.07	0.60
Smith L.	Brush	9	< 0.10	—	2.00

Similar fishing studies were carried out for a short term evaluation of attractors in seven other lakes. Fishing effort in these studies was more flexible, but like the Lake Tohopekaliga study, fishing time was always equally divided between the attractor and control or other areas of the lake. Bait and tackle were always the same for both attractor and control sites within a given fishing period.

Results of these studies in Table 5 show that all attractors demonstrated significantly higher catch rates than did controls. Minnows and earthworms were the baits most commonly used and were responsible for catches consisting primarily of largemouth bass, bluegill, and black crappie.

ACKNOWLEDGEMENTS

Regional fishery biologists with the Florida Game and Fresh Water Fish Commission Norman Young, Thomas Vaughn, Robert Schneider, Phillip Chapman and Cobia Goforth are thanked for supplying much information on construction and evaluation of fish attractors in their respective regions.

Creel clerk and experienced fisherman Roy Land was responsible for accurate and dependable data collection from the attractors in Lake Tohopekaliga.

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California's Artificial Reef Experiences

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California's man-made reef studies, financed through Dingell-Johnson (D-J) Federal Aid to Fish Restoration Funds, began in 1958. Increased fishing pressure from California's expanding population and a decline in giant kelp (Macrocystis) beds prompted the study of potential new habitat. Old automobile bodies and wooden street cars were the first materials used. These first reefs emphasized the study of fish, fish populations and giant kelp development. While these reefs added some productive habitat for California fishermen, they served more importantly as study sites for Department of Fish and Game biologists. California Fish Bulletin 124, "Artificial Habitat in the Marine Environment" by John G. Carlisle, Jr., the late Charles H. Turner and Earl E. Ebert details the study and its results.

As a result of their first efforts, Department biologists, in 1960, developed a program to determine the best materials to use for reef construction in southern California. Chosen for comparison were automobile bodies, a street car, concrete fish shelters and quarry rock. Three replicate reefs were constructed in areas of Santa Monica Bay which would be readily accessible to small boat fishermen at the conclusion of our studies.

In addition to fish population studies, our biologists made detailed studies of reef microfauna, using wooden test blocks and quadrat sampling techniques. These invertebrate studies defined several community development phases during the reef's first years of life. A barnacle-hydroid phase was followed by mollusk-polychaete, ascidian-sponge and encrusting ectoproct stages during the first year. Subsequent years saw the development of aggregrate anenomes, gorgonian corals and stoney corals. From these observations Department biologists concluded that true animal succession occurred on these reefs.

Fish population studies on these replicate reefs showed that some adult fish (particularly embiotocid perches and serranid basses) appear within hours of reef construction. These families were dominant on the reefs during the first two years after construction. As the reef "matured" other families (gobies, cottids, rockfish) increased in importance until a "natural" equilibrium was reached.

During the four years of study, Department biologists spent more than 480 man-hours on nearly 200 survey dives. They observed a total of 78 species of fish during this time. As might be expected, the average number of fish observed during a dive at each of the three locations in Santa Monica Bay was different. The average on the reef at the north end of the Bay was about 1,000 fish, while the reef at the south end averaged 800. The reef in the center of the Bay averaged only 740 fish per observation. Thus the effectiveness of any given reef material can vary considerably due to natural environmental conditions.

The fish also showed differential preference by material. We built each reef with approximately 4,400 cubic feet of each material, using one street car, 14 automobile bodies, 44 concrete fish shelters and 333 tons of quarry rocks. The street car averaged 826 fish, while the quarry rock attracted an average of 870. The concrete shelters were most attractive to fish, an average of over 1,000 individuals being recorded per dive.

Cost and ease of handling considerations caused us to select quarry rock as the material of choice in southern California reef construction. In 1963, the cost of 1,000 tons of quarry rock delivered and dumped in Santa Monica Bay was $6,000. The bottom dump barges loaded at Santa Catalina Island have merely to pass over the reef site and open the hopper doors to allow the rock to fall to the sea floor. A comparable volume of fish shelters (132) cost $9,900 (in 1960) delivered dockside to Long Beach. Handling and tugboat costs added about $2,100 to this for a total of $12,000. Current prices for a barge load of quarry rock (1,000 tons) range from $8,000 to $10,000 depending on tonnage ordered.

The Department has only recently begun to work with tires as reef materials. The first tire reef in California was built by students at Humboldt State University in Humboldt Bay. A second reef has been constructed under the Santa Cruz Municipal Pier in northern Monterey Bay. A third reef, experimental in nature, is under construction off Ventura, California.

The fish populations at the Humboldt Bay reef have been well studied, but to date only casual observations have been made on the fish populations of the Santa Cruz and Ventura projects. Studies of invertebrate succession have been done on the Humboldt Bay reef, and some preliminary observations indicate that both barnacles and hydroids have readily settled out and grown on the Santa Cruz and Ventura tires.

Since the replicate reefs were built in Santa Monica Bay, the street car and automobile bodies have disintegrated. We are currently planning a project to rebuild the reefs using tires and at the same time conduct detailed studies on invertebrate succession and fish population dynamics. We would like to be able to make direct comparisons to the earlier work done with quarry rock, concrete shelters, autos and street cars.

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Comparative Observations on an Artificial Tire Reef and Natural Patch Reefs off Southwestern Puerto Rico

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The Department of Marine Sciences, University of Puerto Rico at Mayaguez, Puerto Rico has been studying artificial reefs for over two years. This work was originated with one main purpose in mind. It was selected as part of a thesis research by the senior author to fulfill a partial requirement leading to the degree of master of science with specialization in the marine sciences. In December of 1971, an artificial reef system of used vehicle tires was constructed in 21.5 meters of water on the southwest coast of Puerto Rico, 2.5 nautical miles south of Magueyes Island, La Parguera, P.R., site of the Department of Marine Sciences research facilities. The specific objectives of the research were to determine:

- the sequence of species of fish entering the artificial reef over an 18-month period
- the population densities of all species of fish found on the artificial reef
- the trophic level of food preference of the species of fish entering the artificial reef
- if movement of fish occurs between the artificial and the natural reefs in the area
- the biomass of fish per surface area on the artificial reef and on a natural reef of comparable area
- the total species present on the artificial reef as compared with those species observed or collected on the adjacent natural reefs

METHODS AND MATERIALS

We chose the area for constructing the artificial reef by adhering to the general criteria of having a minimum low water depth of about 20 meters, a stable bottom substrate and a minimal bottom current. Further criteria included choosing an area that was as barren of resident fish as possible, had sufficient visibility to allow for comprehensive visual observations and had nearby natural patch reefs to permit comparative species recording and biomass estimates. The area which fulfilled all these requirements was located by using a depth recording fathometer and scuba (Self-Contained Underwater Breathing Apparatus) surveys. Scientists from the fields of marine geology, physical oceanography and marine botany assisted in the evaluation of sites prior to the final selection.

Used vehicle tires were selected as the reef construction material because they were readily available, small in size and easily handled by one person. Vehicle tires do not desintegrate in the marine environment, they provide a good substrate for the growth of algae and invertebrates and they provide many crevices in which fish can seek shelter from predators. A total of 504 tires were prepared for placement by drilling a one-quarter-inch air escapement hole through one side of the tire and placing a 20-pound cylindrical concrete plug between the sidewalls on the opposite side. The tires were transported to the offshore site by boat. They were consolidated into four separate reef sections on the ocean floor. The largest reef section, designated as artificial reef I (ARI) covered an area of 84 square meters and was composed of 328 tires. Artificial reef II (ARII) consisted of 52 tires and covered 18 square meters. ARIII had 77 tires covering 45 square meters, and the final reef ARIV, had 47 tires on an area of approximately 18 square meters.

RESULTS AND DISCUSSION

Three methods of data collection were employed during the study: visual observations, trapping and tagging and terminal collection stations.

*presentor

Using scuba, we made a total of 87 hours of visual observations on the artificial reefs during the 18 months of the study. The species of fish and number of fish per species were recorded on plastic slates during each observation period. Individuals from a total of 56 species comprising 23 families of fish were recorded by this method. Species invasion of the artificial reef was rapid at first, then tapered off slowly until the final observed number of 56 species was recorded. These 56 species all had been recorded by the end of the first year of study. No additional species were observed until after the termination of the study.

We also made visual observations on the nearby natural reefs. Many natural reefs in the area were surveyed to obtain a list of species found on them. With these data, we compared the species present on artificial and natural reefs. A total of 74 species of fish were observed on the natural reefs. Thus, at the end of one year the artificial reef had 75 percent of the number of species found inhabiting the natural reefs.

Visual observations also were used in recording the numbers of fish per species. It was observed that the number of fish per species on the artificial reef increased throughout the study, but at a decreasing rate. Thus the fish populations grew rapidly at first then leveled off as the "carrying capacity" of the reef was approached.

Of the 56 species observed and recorded on the artificial reef, there were 37 species of carnivores (66 percent), 14 species of omnivores (25 percent), and five species of herbivores (9 percent). There was no observed trophic level succession. Of the first 10 species to appear on the reef, eight were carnivores, one was an omnivore and one was a herbivore. Herbivores and omnivores did not preceed carnivores in colonizing the reef.

Trapping and tagging studies were conducted to make population calculations and to observe if there was movement of fish between the artificial and natural reefs. Color coded anchor tags were used - - yellow tags on the artificial reef and blue tags on the natural reefs. Several fish marked with blue tags (natural reefs) were observed on the artificial reef. No fish tagged on the artificial reef were observed on the natural reefs. Thus, there was movement from the natural to the artificial reef, but no movement from the artificial reef to the natural reefs.

At the end of 18 months, terminal collection stations were made on the two small artificial reefs ARIII and ARIV, and on a natural patch reef of comparable area. Rotenone fish poison was used and the fish were collected, identified and weighed. The results of these terminal collection stations are presented in Table 1. As can be seen from these results, the artificial reef had a higher biomass of fish per square meter than did the natural reef.

From the three methods of collecting data a composite of the total species of fish observed, trapped and poisoned was made for both the artificial and the natural reefs. It was found that a total of 70 species of fish were recorded from the artificial reef and 92 species from the natural reefs.

CONCLUSIONS

It can be concluded from the results of this study that the artificial reef colonized rapidly at first then leveled off in both species and numbers of fish per species as the "carrying capacity" of the reef was approached. There was no noted trophic level succession of food preference by the fish observed on the artificial reef. Movement of fish did occur from the natural reefs to the artificial reef, but was not observed in the opposite direction. The biomass of the fish present on the artificial reef was found to be nearly eight times that of the natural reef. The artificial reef had fewer species than the natural reefs.

FUTURE PLANS

The two artificial reefs not poisoned in this study (ARI and ARII) are still being observed in continuing studies of colonization by species and numbers of fish. In addition, new reefs of different configurations and in different areas are being observed to determine optimum design and location for maximum fish production. Also, guidelines are being developed for construction of future artificial reefs in Puerto Rico.

TABLE 1

	Area	No. of Fish	No. Species	Total Wt.	Wt./Sq. M.
Artificial	63 sq. m.	305	42	13,732 g.	217.97 g.
Natural	72 Sq. M.	149	40	1,964 g.	27.29 g.

New Artificial Reefs of Oahu

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Since 1963, three artificial reefs have been constructed in the shallow coastal waters around Oahu, Hawaii. The three sites chosen for the experimental emplacement of these reefs are at Polai Bay on the Waianae coast, Maunalua Bay, and at Kualoa on the windward shore (Figure 1).

Reef construction during the first years utilized auto bodies and parts. The shoals constructed later consisted largely of concrete pipe. The most recent construction, during 1972, was initiated as part of a junked car cleanup program conducted on Oahu.

During the past several years, a number of investigations have been conducted to determine the influence of these new artificial reefs on fish population, total biomass and water pollution. While these studies have provided necessary preliminary data on environmental aspects of Oahu's artificial reefs, no comprehensive investigation of all locations has been initiated to establish environmental effects during the years following emplacement.

The artificial reef which has received the most attention is the Waianae Artificial Shoal at Pokai

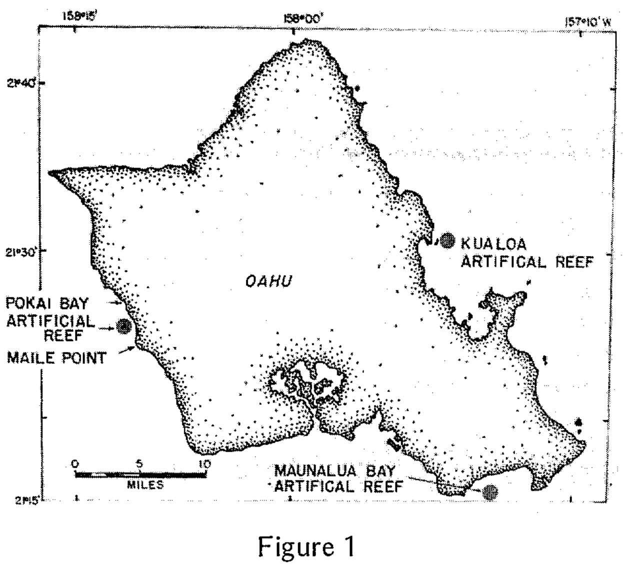

Figure 1

Bay. A group headed by John Maciolek at the University of Hawaii has conducted studies under contract to the U. S. Bureau of Sport Fisheries and Wildlife. Similarly, a group headed by Carla S. Myamoto of the Marine Options Program at the University has conducted studies for the National Science Foundation. These workers have spent considerable time amassing data on the physical and biological aspects of the reef environment, and much of the background information presented here represents the work of these groups.

In addition to these investigations, the Department of Land and Natural Resources, Division of Fish and Game of the State of Hawaii has requested that the newer artificial reefs be monitored for possible release of toxic metals into the marine environment. We have been carrying out that program for the past two years under a grant from this agency.

A primary goal of fishery management agencies in using man-made reefs is to enhance the abundance of fishes in fish-poor areas. In Hawaii, increase in fish population has been accompanied by several interesting chemical developments associated with artificial reef construction. In order to place these chemical developments in perspective, the observed physical and biological environment of the reefs will be summarized briefly.

The Pokai Bay reef, the only one for which a body of data exists, has an average bottom water temperature of 27° C, and the variation in this parameter is slight. Salinity appears to be relatively stable as well, and measurements of solar radiation show a two to three month lag with respect to bottom temperature variations. Transparency is very variable, and as tidal currents change, waters become clear or turbid.

The Pokai Bay reef is constructed in part of damaged concrete pipe. Pipe is concentrated over an area about 200 meters by 150 meters, and scattered over a considerably larger area. A separate smaller site for the pipe was established nearby several years ago, principally for the study of fish population.

The concrete pipe has been shown by Maciolek's group (1974) to provide an initial fresh surface for attached organisms. On the top surfaces, diatoms, green algae, blue-green algae, brown algae and red algae develop rapidly. These are grazed almost immediately by fishes, urchins and other herbivores. Other invertebrates soon follow, and corals and mollusks become common within weeks of construction.

A large number of sedentary and motile invertebrates also live on the interior surface of the pipes. Tunicates, sponges and bryozoans are common, along with coelenterates and mollusks. These organisms do not require the same amount of light as the top surface algae, and therefore are more common on the interior surfaces of the pipes.

The fish community has developed rapidly on the Pokai Bay artificial reef. During a one and a half year survey by the marine fisheries group at the University of Hawaii, both the number of total biomass of the fish community increased by eight and four times respectively, compared to pre-reef substrate (Figures 2, 3). Fish population has been found to vary in response to various factors. More fishes are observed early and late in the day, according to feeding habits. Population also is higher around smaller pipes, especially those which are grouped or nested. Turbid water at the reef site has a higher fish population.

Fish on the Waianae Shoal have also been classified as resident or itinerant members of the community, depending on whether they can be found at the same location during successive surveys. Itinerant fishes are most often the large predators, many of which arrive early in reef construction. Examples are the surgeon fishes and the Mu, which are both relatively large carnivores. Smaller resident fishes increase in population during the months succeeding reef construction. Examples are the redfishes and goatfishes, small carnivores and herbivores actually living within the pipe structures.

It is obvious that the primary goal of increasing the fish population utilizing artificial reefs has been successful. While the reef cost versus production for human consumption has not been evaluated, an examination of the total biomass at the Pokai Bay site during 1973 shows more than a two-fold increase in an area where auto bodies were added to the pipe construction, compared to an area of natural substrate nearby.

While the increase in fish population has been encouraging, the dumping of auto bodies to create new reefs at Maunalua Bay and Kualoa, as well as at Pokai Bay has raised serious questions as to the possibility of pollution in the form of toxic metal release into seawater, and other chemical reactions in the shallow water environment.

Water quality investigations have therefore been instituted during the past two years to assess the potential pollution problem. Preliminary results indicate that levels of Co, Cu, Fe, Mn, Cr, Cd, and Pb are well within normal seawater values (Figure 4). Samples taken at monthly intervals have shown no change in trace metal concentration.

In addition to the water quality study, chemical reactions within the metallic auto structures, and between the metal reef materials and the substrate have been investigated on a preliminary basis. While biological activity around auto bodies and concrete pipes have been observed to be similar, chemical

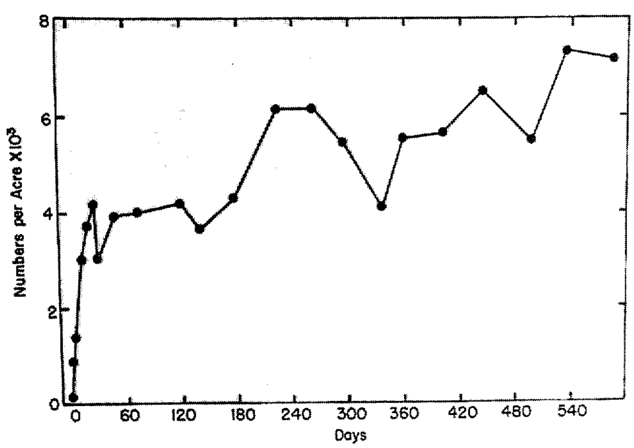

Figure 2

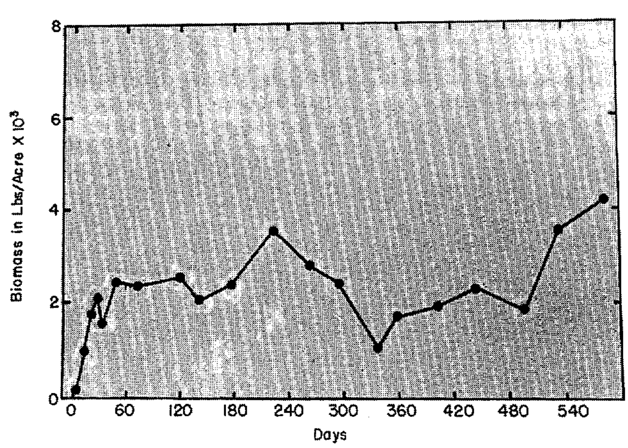

Figure 3

reactions in these two environments are distinctly different.

The introduction of foreign metallic debris into the marine coastal zone represents a dramatic environmental shock which has both short and long term implications. We have investigated some of the short term changes during water quality monitoring, and we are looking now toward the long term stabilization of metallic artificial reefs and their effect upon the onshore and offshore zones. Chemical dynamics suggest that artificial reefs composed of auto bodies are not in equilibrium with the environments of the marine coastal zone, and therefore, they have a limited resident time. This time can be defined as that period necessary for a car body to change its chemical and physical form to a more stable product in its new environment.

The chemical stabilization reactions take place in two geographic environments, the shallow marine reefal zone and the beach zone below the storm berm. Within this coastal zone, there are both reducing and oxidizing micro-environments which control the chemical reactions.

In general, reactions among dissolved and solid materials below the sediment surface at the beach

TOXIC METAL ANALYSES

	Nov. 1972	Sept. 1973	Literature Values
Co	2 PPB	2 PPB	0.1 - 5 PPB
Cu	3 PPB	1 PPB	1 - 5 PPB
Fe	10 PPB	12 PPB	0.1 - 20 PPB
Mn	2 PPB	5 PPB	0.1 - 15 PPB
Cr	< 1 PPB	< 1 PPB	0.05 - 0.1 PPB
Cd	< 1 PPB	< 1 PPB	0.3 PPB
Pb	< 1 PPB	< 1 PPB	0.05 - 1 PPB

Figure 4

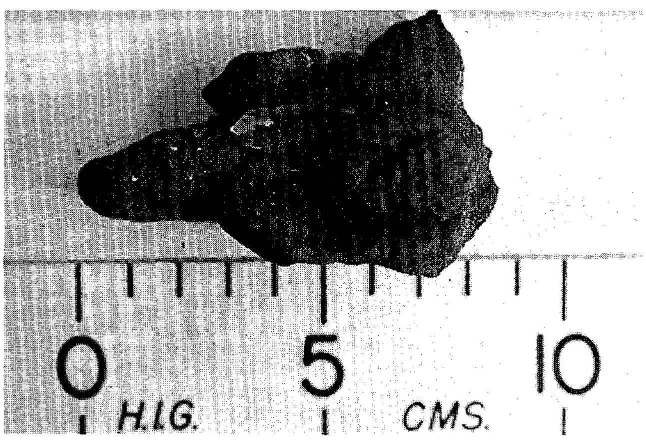

Figure 5

are reducing due to the high concentration of organic matter and the presence of anerobic and iron fixing bacteria. As a consequence, car body fragments brought to the beach mechanically and buried react with gases produced by bacteria in the relatively acid substrate. Divalent iron reacts in the presence of hydrogen sulfide to form amorphous black precipitates of iron sulfide — $Fe(HS)_2$ to FeS_2 (Figures 5, 6). With aging (growth in particle size) these precipitates tend to crystallize and can be recognized as hydrotrallite, marcasite and pyrite. In addition to the sulfides, iron II hydroxide is formed from ferrous salts during neutralization by a hydroxide in the absence of oxygen. This precipitate is white colored and is often observed as a banded layer between the amorphous black iron sulfide growths.

In the oxidizing and highly circulated reefal environment, goethite and hematite are formed from the car bodies. Generally, yellow amorphous iron hydroxide is precipitated directly on the surface of the car as typical "rust". This material reorganized to form crystallized goethite

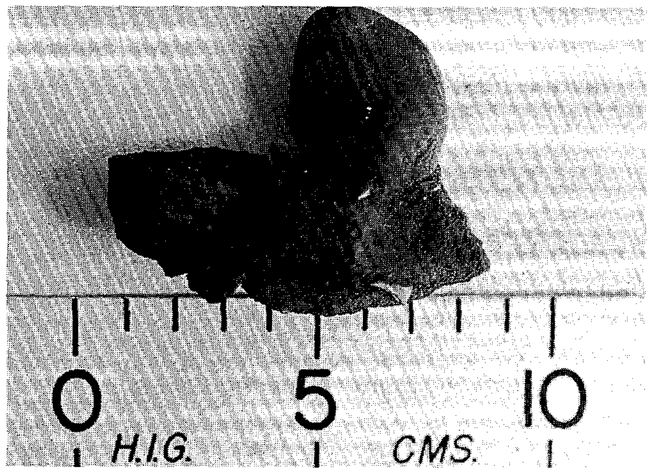

Figure 6

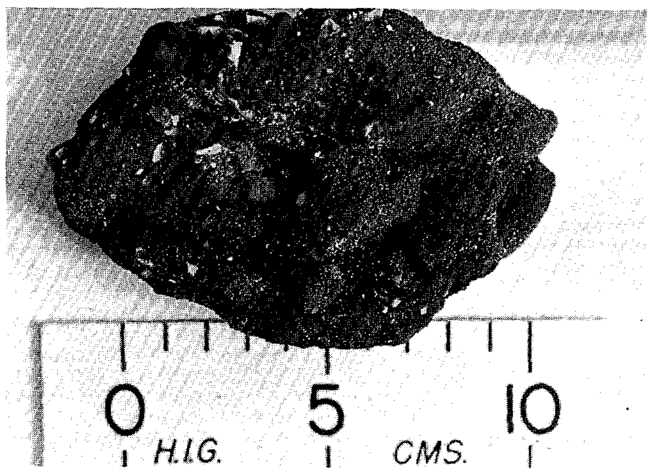

Figure 7

and hematite (Figure 7). The problem of stability of goethite versus hematite has been discussed by Garrels (1959), Berner (1969), Bischoff (1969), Langmuir (1971) and others. Langmuir (1971) suggests that since goethite crystals generally are smaller than 0.1 microns, they are unstable relative to coarse-grained hematite. However, goethite can precipitate at low temperatures and pressures, whereas hematite generally forms by dehydration or by long term aging of amorphous material. Calculations by Langmuir (1971) suggest that goethite can dehydrate to form hematite. However, the rehydration of hematite appears to be kinetically unlikely.

The ferric oxyhydroxides which form from the car bodies are highly supersaturated with respect to hematite and goethite. The kinetic calculations and particle sizes of these minerals do suggest that during long term exposure, hematite will survive as the stable product in the marine coastal zone. In addition to hematite, the ferric oxyhydroxides react with calcium carbonate sands on the beach and offshore sediments to form small concentrations of siderite ($FeCO_3$).

Siderite along with goethite and hematite act as cementing media in the carbonate sands and on the surface of the car parts to form "corrodoliths" (a term first used by R. M. Garrels).

Returning to the problem of residence time and the factors influencing the stability of metallic artificial reefs, we find six major factors affect the reef stability. The factors are the following:

- Thickness of the metal
- The surface area of the car bodies
- The length of exposure to either an oxidizing or reducing environment
- The strength of currents and breaking waves as abrasive forces during mechanical breakdown
- The rate of oxidation, reduction, hydration and dehydration as well as the adsorption catalysis of manganese, copper, nickel etc. on iron oxyhydroxide surfaces
- The percentage of surface area covered by organic activity, such as biocarbonate secretors.

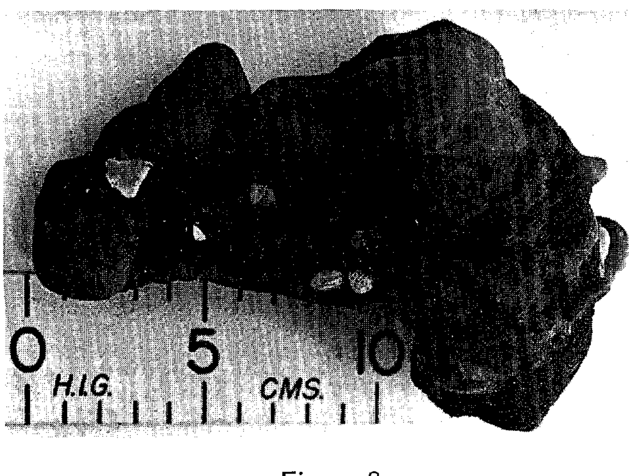

Figure 8

As might be expected, the artificial reefs are not chemically or mechanically stable. Small portions of the car bodies are broken from the reef and act as clastic particles in the coastal zone. These particles find their way to the beach environment principally during quiet seas when most of the beaches have a convex profile. These oxidized goethite and hematite coated particles eventually are buried in the beach and undergo reduction, forming amorphous iron sulfide coatings. During the "winter seas" when beach profiles change to principally concave, and portions of the beach are removed to the offshore environment, the corodoliths are again oxidized (Figure 8).

This seasonal transport history produces

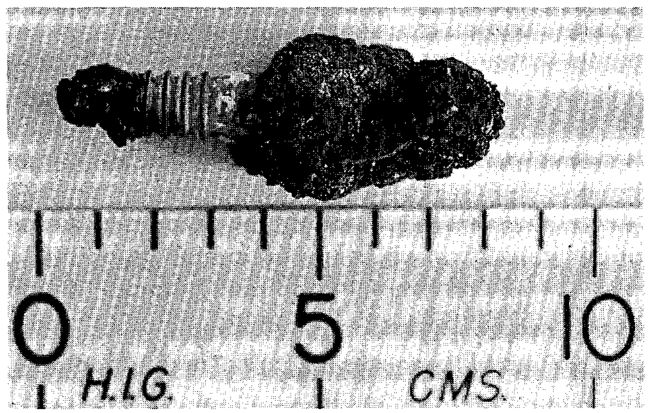

Figure 9

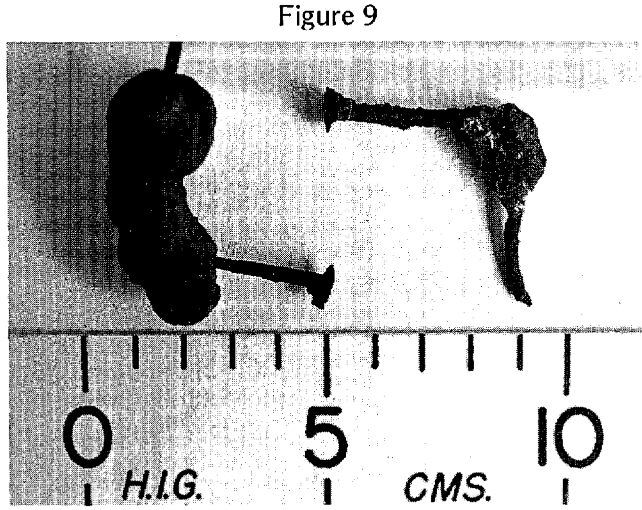

Figure 10

cyclic banding of iron oxyhydroxides and sulfides combined with entrapped carbonate clastics in the corrodoliths. Large corrodoliths, principally transported by storms, remain on the beach and become monuments to man's anthropological history. These corrodoliths can be viewed as short term visual pollutants, since they will eventually undergo mechanical abrasion and will be incorporated as sand size particles in the coastal environment. Similar corrodoliths are formed at the reef, except that the iron oxyhydroxide surface of these particles and larger reefal material act as metal scavengers, via surface catalysis, incorporating manganese, copper, nickel and a host of other elements in their structures. Ferromanganese oxide coatings are exhibited in nodules containing Champion spark plug seeds (Figure 9, CO_2 cartridges, nails (Figures 10,11), bottle tops (Figure 12), and assorted auto parts which have lost their identity. In rare cases there are traces of oligonite ($MnCO_3$) and kutnohorite $CaMn(CO_3)_2$ in these corrodoliths.

There had been some concern when the dumping of car bodies was proposed, due to a possibility that toxic elements may have leached out of the auto bodies and concentrated in solution around the reefs. As was previously mentioned, no such concentrations of toxic elements were observed during our studies. Any leaching of elements such as copper essentially would be undetected in the water column, due to the probability of readsorbtion on the oxidized car body surfaces (Figure 13). Thus, the auto bodies may act as a pollutant control mechanism regulating the chemical balance in the reefal zone. Future studies in this area may provide information which can be useful to the development of ferromanganese filters. These may be utilized as adsorber oxidation catalysts for the removal of trace metals from automobile and industrial waste gases. We view this possibility as a sound ecological mechanism for recycling old car bodies.

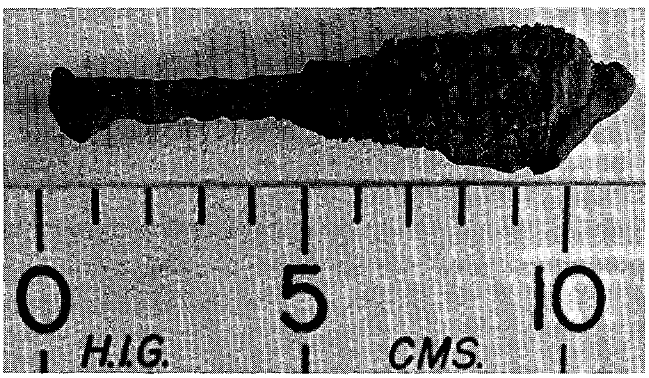

Figure 11

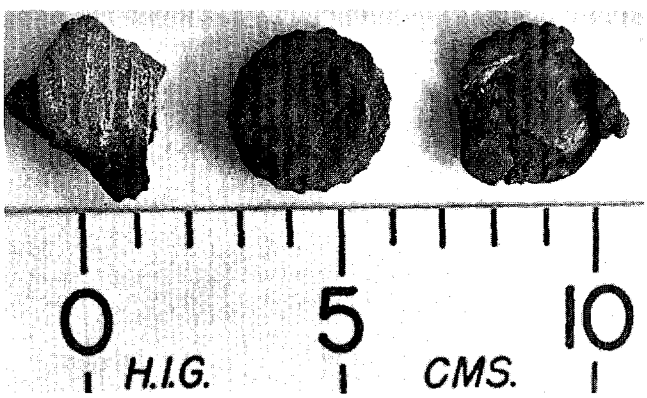

Figure 12

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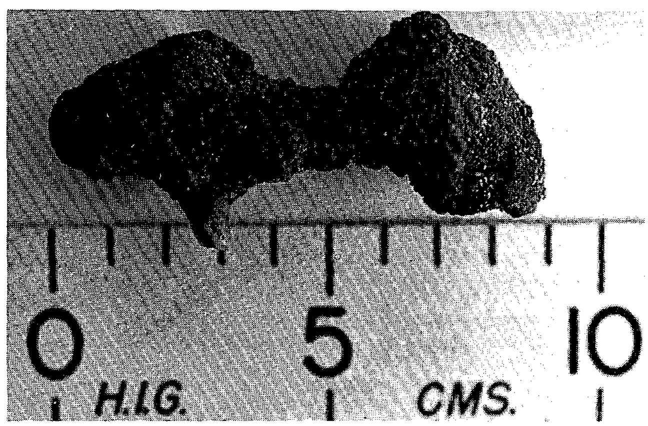

Figure 13

Experiments Using Baled Urban Refuse as Artificial Reef Material

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Man has been constructing artificial reefs and underwater structures designed to attract fish populations for many years. One of the earliest U. S. artificial fishing reef seems to have been built during the 1930's off the New Jersey coast and was constructed of waste materials commonly used today (Stroud and Massmann, 1966). Today there are hundreds of artificial reefs constructed on all coasts of the United States and around the world. Most of these reefs have been constructed of solid waste materials including old ships, junk cars, scrap tires, and concrete pipe and building rubble (Stone, 1972; Steimle and Stone, 1973).

The type of materials presently used for reefs represents a small percentage of the total solid waste material generated each year. The disposal of domestic refuse is becoming an increasingly complex problem each year as land fill sites become more difficult to find and as air pollution problems increase with incineration. New York City alone produces greater than 10^7 tons of garbage per year. Some ocean dumping of refuse has occurred in recent years although no major amounts are being dumped at present, since New York City and San Diego stopped dumping loose garbage in the late 1960's. Ocean dumping of compacted and baled solid waste has been suggested by Dunlea (1967), Devanney, et al. (1970), and NIPCC (1970), while incorporation of waste material in tectonic sink areas has been suggested by Bostrom and Sherif (1970). Actual tests of baled solid waste as reef materials were first started by Stone (1968) and Pearce (1972) while effects of pressure on baled refuse were reported by Blumenberg (1971). An up-to-date summary of the problems of deep ocean dumping of compacted solid waste was reported by Little (1973).

Although most papers discussing ocean dumping of compacted solid waste suggest dumping in deep water, the few tests that have been conducted have usually been in shallow water. In 1971, Bogost (1973) placed solid waste bales in several salt water lagoons in Hawaii and monitored the chemistry of the water. A year later Pratt monitored the biological and chemical changes in shredded compacted waste material in the laboratory (Pratt, et al., 1973).

In the experiments we are reporting, baled solid waste materials have been emplaced in shallow marine water (15 m) since the summer of 1971. This depth was chosen because of proximity to land, providing relatively easy access to divers for substantial diver observation and sample collection time. In addition, this depth is well within the photic zone, providing enough light for the growth of algae that might attach to the bales. One study was conducted off the coast of New Hampshire near Appledore Island in the Isle of Shoals using experimental cylindrical bales (about 40 kg each) composed of shredded solid waste materials. In a second study, bales of shredded compacted urban refuse (about 1,200-1,500 kg each) were placed in Woods Hole Harbor.

METHODS AND RESULTS

The University of New Hampshire mini-bales (UNH bales) were sized so that they could be constructed in the lab of material of known composition and easily emplaced by divers later. Dampened shredded solid waste materials (Table 1) were compacted in batches in a splittable steel cylinder under a final maximum pressure of 70,000 lbs. (about 530 psi). Due to baler limitations, the metal and glass content was increased somewhat over the national average to make a bale with the required density (Table 1). Five of the ten bales were made without food wastes to determine their effect on attraction or repulsion of organisms and on rates of degradation. The completed bales were about 33 cm in diameter and 45 to 55 cm in length with a density of about 71 lbs/cu. ft.

The bale was strapped tightly with one-half inch polypropylene strapping and metal clips, and wrapped in one-quarter inch polypropylene mesh. The mesh was chosen as wrapping material because it prevented loss of the materials, yet allowed interaction of the waste materials with both organisms and water. Plastic tubes were placed in the bales to allow divers to later sample the interior water of the bales for bacteriological and chemical samples. The bale construction is described in more detail by Loder, et al. (1973).

The ten waste bales and six control bales (concrete cylinders, 33 cm in diameter, 50 cm long) were placed in about 15 m of water at a site about 0.1 km west of Appledore Island, Isle of Shoals in a pattern of both individual and grouped bales. Bottom topography at the site is relatively flat and featureless with sediments composed of a gravelly, calcareous sand. Nearby (about 5-15 m) is a rocky outcrop area rich in both fauna and flora. The waste bales were initially tied to the bottom with rope and stakes to prevent movement and loss such as reported by Stone (1968). However, the ropes were removed a year later because of their inconvenience to divers. There has been no movement of the bales since then, even though currents of greater than 0.5 kn have been measured on the bottom during storms.

The site was monitored about once a month during the first year and every several months since then. Photographs of each bale, organism counts and samples for chemical analysis were taken during each visit by SCUBA divers.

PHYSICAL CHANGES

The bales showed little or no physical changes throughout the study period except for slight swelling (estimated to be about 10 percent). The metal clips holding the strapping have become corroded, and some have failed. The bales have stabilized physically and will probably hold together even after all strap clips corrode. A bale was cut and carried to the surface for biological examination and the half left on the bottom with all straps cut has remained a discrete bale with very little loss of material.

Table 1.
Composition of experimental UNH bales and average residential solid waste (R.S.W.)

	Non-food (%)	Food (%)	R.S.W. (%)*
Paper	43.3	23.3	43.8
Wood	4.4	4.4	2.5
Textiles	2.2	2.2	2.7
Glass	20.0	20.0	9.0
Metal	30.1	30.1	9.1
Food Wastes	--	20.0	18.2
Garden Wastes	--	--	7.9
Rocks and Dirt	--	--	3.7
Plastics	--	--	3.1

*Compiled by the Council on Environmental Quality (1970)

CHEMICAL CHANGES

Interior bale water samples were taken by divers with 50 ml syringes, which were then stored on ice until analyzed. An initial drop in the dissolved oxygen from 6 to 2 ml/l occurred within hours after immersion, but it took several months for total depletion. Initially, the pH dropped below 7, then rose to an average of about 8.8 after two months for food waste bales and less for non-food bales. After several months the bale interiors contained hydrogen sulfide and other gases. These chemical changes, including nutrients, are described in detail by Loder, et al. (1973).

The oxygen demand by a bale of solid waste is of concern if we are to estimate the ecological impact of solid waste materials. Estimates of oxygen consumption by solid waste materials submerged in running seawater for several months range from 23 to 90 ml O_2 / m^2 / hr. depending on temperature, age of materials and extent of bacterial coverage (Pratt, et al., 1973). Estimates of the total oxygen consumption of a UNH mini bale and its biological community after one year of submersion were made by placing a plexiglass box over a bale and determining the oxygen depletion rate. At 8 C to 11 C these rates were found to be 10 to 17 ml/m^2/hr. (Loder, unpublished data). These lower rates of oxygen consumption may be due to the nature of the solid waste and input of oxygen by algae attached on the bales.

BIOLOGICAL CHANGES

The biological changes may be divided into several catagories including bacterial mats on the bales, infauna in the bales, attached organisms on the bales, and motile organisms both on and around the bales. White bacterial mats appear on the outer surface of the bales after the bale goes anoxic and hydrogen sulfide is produced. The amount of bale covered by the bacterial mats varies seasonally and is probably a function of water temperature. These mats are composed of sulfur oxidizing bacteria such as Beggiatoa and Thiothrix, and are described in more detail by Pratt, et al., 1973; Loder, et. al., 1973; and Burton (unpublished data, 1974). Infauna organisms colonized the bales and after

13 months were found within 2-3 cm of the bale surface at a density of about 45 organisms per 100 cm^2. The most prevelent organism was the boring isopod, Limnoria lignorium, while also common were several species of polychaetes and bivalves, Hiatella sp. (Gundlach, 1974).

Within a month after bale emplacement, algae were growing directly on the bale mesh. After about ten months, all meshed bales and controls had good growths of a number of species of algae, the most prevelent of which were Ptilota and Agarum. All of these algae attached to the mesh, and there did not appear to be much difference between food and non-food bales. The mesh appears to enhance growth since no algae have attached to several tightly wrapped bundles of newspaper placed on the bottom in the same area. The materials released by the bale do not appear to have any effect on the growth of the attached algae; in fact, there were more algae species on the waste bales than on the meshed concrete control bales (Gundlach, 1974).

Motile invertebrates and fishes were observed around the bales soon after emplacement. These organisms included lobsters, crabs, rock eels, eelpouts, starfish and sea urchins. They migrated into the bale site from the nearby rocky outcrop area. The number of organisms reached a maximum about a month after emplacement with fewer organisms found around the food waste bales than the non-food and control bales. Lobsters and crabs utilized either the grouped bales as shelter or dug burrows beneath the bales. Lobsters were found only around the non-food and control bales during the first five months, after which they were found around all bale types (Gundlach and Loder, 1974). Unoccupied crab- or lobster-dug burrows often were used by juvenile eelpout or rock eels. We did not observe any organisms utilizing the bales as a food source.

The food waste bales appeared to be less desirable as shelter during the first five months of the study, indicating that these bales may initially release compounds which reduce normal thigmotropic behavior. Motile organisms were not observed on these food waste bales during this initial period. The number of motile organisms on the bales increased rapidly after 7 to 8 months, partly as a result of colonization by a large number of juvenile sea urchins. These urchins were found both above and below the mesh and many became trapped beneath the mesh as they grew. The grouped bales of each type had greater numbers of organisms than the individual bales (Gundlach, 1974).

In summary of the UNH bale study, we found that baled solid waste will attract both fauna and flora soon after emplacement, but it takes a period of greater than one-half year for the bales to be attractive to a number of different organisms. This time period may be longer if commercial size bales are used. The effect of the mesh covering the bales in our experiment was a important factor in determining the amount and types of fauna and flora that attached to the bale exterior.

But how do these experiments with small, laboratory-built bales compare with what a city might dump in the ocean? To answer this, experiments were conducted with seven 1,350 kg bales in the Woods Hole, Massachusetts harbor. The results, as with the UNH study, are somewhat variable between bales, but overall are surprisingly similar to the UNH study. Chemical and microbial reactions are similar, but fewer large algae are present, probably because of greater water turbidity. The invertebrates and fishes are similar to those found on the UNH bales.

This preliminary work demonstrates that bales of city refuse, produced by a process of shredding and compaction, can be put in the ocean to form a structure which is at least semipermanent. Whether or not it can compete with car bodies or tires is as yet unknown.

THE REFUSE REEF AND PRIMARY PRODUCTIVITY

An important but unresolved question plaguing the participants of this conference is whether a reef stimulates productivity, or simply moves populations to different locations. This is difficult to assess because a reef builder is interested in the terminal components of the food chain and secondary productivity is difficult to measure, especially on a short term. The basis for all production, it must be remembered, is photosynthesis by plants, producing organic matter from sunlight and inorganic nutrients. Therefore, if the reef is not near the surface, absence of light will be limiting and if nutrients are not easily renewed, they, too, will be limiting.

A reef of tires or car bodies cannot add nutrients to a natural system. They may accelerate mixing processes to move bottom-produced nutrients upwards, and provide attachment sites for benthic plants, but they cannot, by any natural process, supply nutrients for photosynthesis. A refuse reef, however, if properly constructed, could do so. If the refuse bales contain food wastes, and most refuse is from 5 to 20 percent food wastes, the heterotrophic bacteria and invertebrate community metabolism near the bales' surfaces should supply as much as 100μg-at ammonia per square meter surface area of bales per hour. A benthic alga on the bales could use this to flourish and support large populations of invertebrates and fishes, something tires and cars cannot do.

Bale construction strategy may become important if no garbage is available, and paper, which composes about 50 percent of common domestic refuse, is broken down readily. In this case, nitrogen may not be available and it would have to be scavenged by denitrifying bacteria from the surrounding waters. This would, at least theoretically, act to diminish productivity. We have found that the Woods Hole bales both with and without garbage have added rather than removed nitrogen to the water. This may change as the bales age.

CONCLUSIONS

- Solid waste refuse, from an economic standpoint and its durability in the marine environment, is a potential source of reef material, depending on refuse preparation.
- Research to date does not indicate that solid refuse is an ecological hazard when properly processed.
- Monitoring of a baled refuse reef always would be necessary to assess the ecological impact.

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Artificial Reefs as Experimental Tools

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Many species of fishes associated with small coral patch reefs in the lagoons of Indo-Pacific atolls show high correlation with and dependence upon hard, high-profile substrates. These structures function both to provide shelter from roving inter-reef piscivores and as attachment sites for benthic algae. Natural patch reefs occur in a great variety of sizes and shapes from simple, isolated Pocillipora and Acropora heads to massive pinnacles with high coral diversity (Figure 1). Studies currently in progress indicate that fish abundance and diversity are generally related to overall reef size and amount of shelter available. Some species of damselfishes (family Pomacentridae) are associated with specific coral types. The shelter seeking response of the Caribbean damsel, Chromis cyanea, to predators or disturbance has been well documented (Hartline, et al., 1972). In this species the distance of individuals away from their resident coral head reflects the nearness of potential predators. Chromis caerulea in the Marshall Islands remains closer to shelter when subjected to strong current flow, or the presence of the many jacks, groupers, snappers and sharks that patrol these reefs.

Patch reefs are significant refugia from predators and strong currents during the night as well as the day. Many schooling herbivores, which often constitute a considerable proportion of the fish biomass, forage over reef or rubble areas during the day and at night seek shelter in reef caves and crevices. Conversely, some species are found deep within the water column or over bare sand areas (Hobson, 1968, 1972). Randall (1963) was able to markedly increase fish populations by constructing a concrete block reef in the Virgin Islands. His study has been followed by many practical efforts to increase standing stocks by the provision of artificial shelter (Steimle and Stone, 1973). To gain insight into the relative importance of shelter as opposed to food in limiting populations of reef fishes, standardized artificial reefs were installed on sand regions between small, natural patch reefs in the lagoon of Enewetak Atoll, Marshall Islands (Figure 2). The reef design used has the advantage of providing precisely controlled amounts of shelter as well as ease of construction and installation.

ARTIFICIAL REEF DESIGN AND CONSTRUCTION

Reef modules were constructed of 7.6 cm (3 inch) I. D. plastic perforated drain pipe imbedded in cement. Each module consists of 3 m long pipes inserted into each face of a concrete cube 26 cm long on each side. This gives the module a "jack" shape reminiscent of the children's game. Twenty modules were stacked together to form a reef with a mean height and width of 1.6 m. These reefs provide a great range in shelter grain size from small spaces inside the tubes to the larger interstices at the base and within the reef.

Modules were formed by pouring cement into 1 cubic foot cardboard boxes in which the pipes had been inserted through pre-cut holes. The modules can conveniently be cast in number by packing the pipe-box units together as they are supported by two parallel boards (Figure 3). Modules retained their integrity even when 30 to 40 percent of their volume consisted of filler (e.g. beer bottles). The cardboard forms disintegrate within a month, freeing bare concrete surfaces which are rapidly colonized by algae and invertebrates.

At Enewetak the modules were easily transported by small skiff, dumped overboard and arranged into a reef with the help of a single assistant. If a large "sports" type reef of this design was executed, the modules might be assembled and cast on board barge deck utilizing ready mixed concrete. Installation of a high profile reef would result merely from dumping the jacks overboard.

The feasibility and practicality of such large reefs would be determined by the economics of artificial reef construction. Auto body reefs may improve the esthetics of suburban landscapes, but show little promise as reef building materials due to their limited longevity and high cost of preparation and transport (Stone, 1972). Stacked tire reefs of varying configuration do meet the requirements of economy, shelter and durability and are increasingly being used along Atlantic coastal regions (Stone et al., 1974).

A comparison of the surface area of the Enewetak experimental reefs and a hypothetical concrete pipe reef similar in size to ones in use at Pokai Bay, Hawaii is made in Table 1. It is apparent that the modular design provides over six times the available surface of a bare, single pipe. Weight per module ranged from 41 to 57 kilos on land (roughly 14 to 19 kilos in water). Total weight of a 20 module reef that occupied 4.1 m^3 was 980 kilos (323 kilos in water).

Module costs were moderately expensive as a result of using high quality plastic pipe. Cost per module in 1973 was $5.17 ($103.40 per 20 unit reef) not including labor or transportation. A less expensive substitute for the plastic pipe would lower the costs considerably. Plastic pipe has the attributes of being rapidly colonized by benthic organisms (Figure 4) and fishes, and of being extremely resilient. Enewetak jack reefs have withstood large typhoon generated wave surge on a number of occasions with little dispersion. Nearby natural reefs, however, suffered extensive damage to fragile Acropora heads.

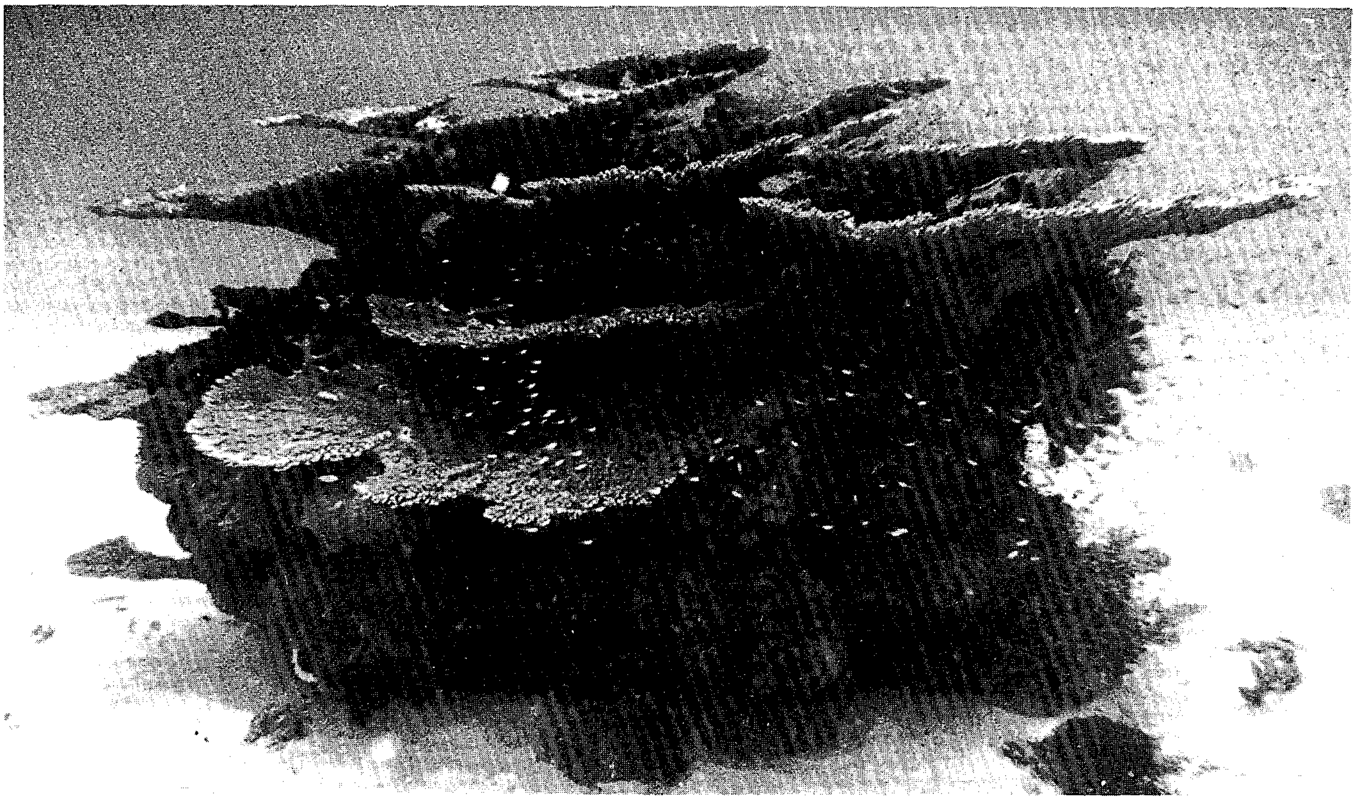

Figure 1

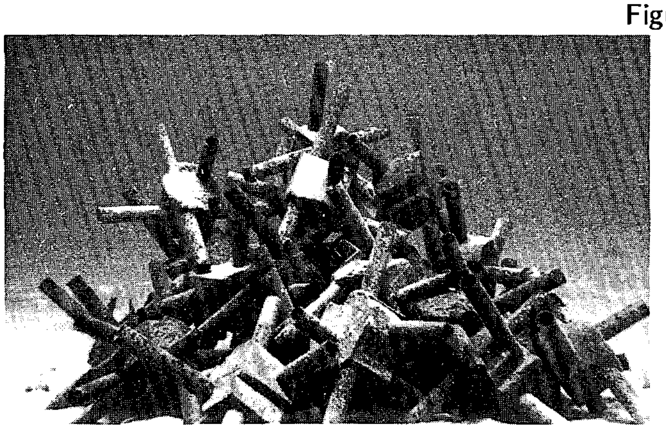

Figure 2

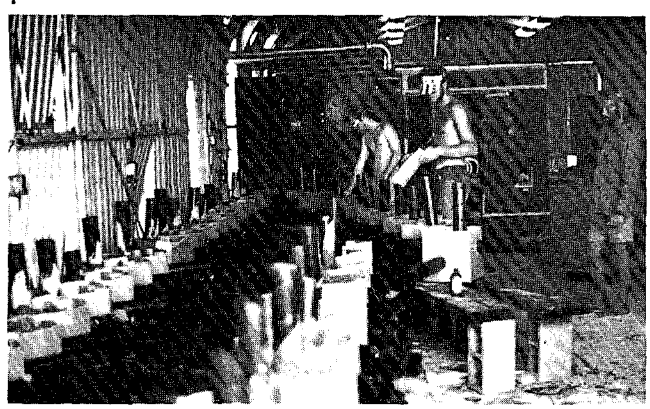

Figure 3

EXPERIMENTAL CAPABILITIES

The standardized components of this reef design permit an investigator to build replicate reefs of known shelter parameters (surface area, volume). To successfully mimic a small, natural Enewetak patch reef of 27 m^3 a 40 module reef was necessary. Pomacentrus pavo is a pomacentrid that numerically dominated the artificial reef communities. This species normally seeks shelter in cracks or crevices at the base of natural reefs. Chromis caerulea, however, has more precise shelter requirements and most frequently occurs in small Pocillipora heads of fine grain shelter. When dead Pocillipora heads were cemented into small couplers (normally used to hook sections of the plastic pipe together) and added to the artificial reefs, C. caerulea juveniles soon settled out from the plankton and were able to successfully invade the fish community (Figure 5). Their populations could be transplanted easily at night when the fish were deep within the head by simply removing the coral unit from the reef. The use of these detachable minihabitats has permitted a regime of experimentation designed to determine how species interactions act to shape community structure.

Table 1

Comparative surface areas of Eniwetok modular reef and a hypothetical concrete pipe reef

ENEWETAK MODULAR REEF

Each module consists of three 3-meter pipes with I. D. of 7.6 cubic inches and one concrete cube 30.5 cm in length.

PIPE SURFACE AREA	
Inside	1.71 m2
Outside	2.25 m2
CONCRETE BLOCK SURFACE AREA (not including area occupied by pipe cross section)	0.53 m2
Total module surface area	4.49 m2
20 module reef with dimensions 1.6 x 1.6 x 1.6 m and occupying a volume of 4.1 m3	89.80 m2

CONCRETE PIPE REEF

Single pipe with dimensions of above completed module reef

PIPE SURFACE AREA	
Inside	5.53 m2
Outside	8.04 m2
Total reef surface area	13.57 m2

The artificial reefs also serve as substrates for blooms of benthic algae; Hormothmanion and Calothrix rapidly colonize the cement and plastic surfaces and are browsed frequently by parrotfishes and surgeonfishes. It is interesting to note that these algae are important nitrogen fixers (Bill Wiebe and Robert Johannes of the University of Georgia, personal communication). Midwater feeding Pomacentrus pavo and Chromis caerulea ingest

Figure 4

Figure 5

much energy in the form of algal filaments, detritus and zooplankton that continuously flow over the small reefs along the windward side of the atoll (Gerber and Marshall, 1973). Groupers, jacks and other predators feed opportunistically on any damselfish that exceeds its escape distance from shelter.

The small size of the artificial reefs allow them to be surrounded by predator exclusion cages (Figure 6). These consist of a reinforcing rod frame onto which a nylon net one and one-quarter inch stretch mesh, is sewn. The net is secured at the base by a chain around the perimeter. These experiments are designed to investigate a phenomenon documented by Dayton (1971) for the rocky intertidal of the north Pacific coast. He found that predation pressure from sea stars prevented the competitively dominant mussel from excluding other benthic organisms — in effect maintaining species diversity. The exclusion of inter-reef piscivores from the reef would be expected to result in a decrease in species diversity.

Small reefs of this construction may find practical application in Hawaii. In recent years the commercial collection of small reef fishes has become of economic significance to aquarium suppliers; in fact, there is concern among environmentalists that this resource may some day become over-exploited. Dr. Leighton Taylor of the Hawaii Cooperative Fishery Unit has suggested that small reefs might be installed to encourage the settlement of reef fish larvae from the plankton (personal communication). These fishes might subsequently be collected and raised to market size in aquaria. This would free regions of shelter for further larval recruitment. The modular design would be well suited for reef construction by individual collectors.

My gratitude to Professors Paul Dayton, John Isaacs and Richard Rosenblatt of Scripps Institution of Oceanography and Professor Joseph Connell of University of California at Santa Barbara who have guided me through this endeavor. Dr. Philip Helfrich, Director of the Enewetak Marine Lab, has been a welcome ally in this study. Dr. J.E. Randall kindly read the manuscript and made helpful suggestions. Special thanks to the "Enewetak Artificial Reef Construction Company" who mixed by hand the ten tons of concrete now resting on the bottom of Enewetak Lagoon.

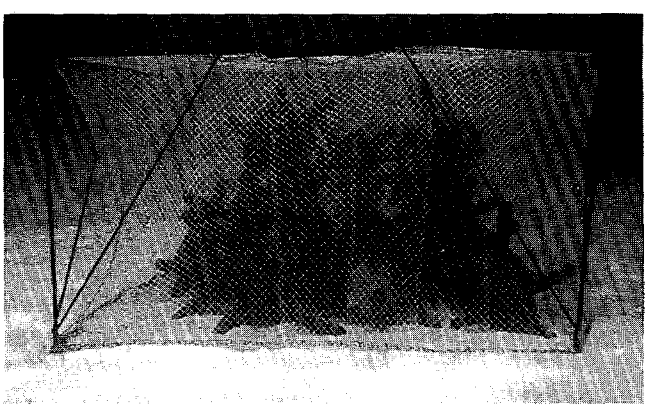

Figure 6

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Midwater Structures for Enhancing Recreational Fishing

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Little mention has been made at this conference about artificial structures located at midwater depths. Yet this method of attracting fishes offers many advantages over bottom reefs and may solve some of the real problems that we have discussed (labor, transportation costs and potential hazards to navigation). Requisite biological and environmental conditions must be present, as in all reef site locations, for this method to be successful.

Resourceful anglers are aware of the variety of pelagic fishes that can be caught around drifting objects at sea. Only a few, however, actively search and fish these floating objects. For most it is probably a fortuitous encounter, and their fishing success around these objects is also unpredictable. Some anglers devote most of their fishing effort trolling along debris and sargasso weed lines. These are the big game fishermen whose knowledge of oceanic conditions and seasonal distribution of pelagic fishes has improved their strategy.

Not all recreational fishermen can afford to pursue large game fish offshore. Closer inshore, a crude but effective fishing technique is employed in which small pieces of floatable material such as boards or cardboard are scattered on the surface. Hopefully, a few pelagic fishes will be attracted to this debris when the usual trolling methods are unproductive. Because of the low profile of these objects, many become lost from view or simply abandoned after a day's fishing (another source of pollution of the littoral zone). The flat shape and buoyancy of this material results in a low underwater profile as well, limiting the visual range of the structure to fishes. Better techniques are available to the coastal fisherman.

Marine biologists have been interested in the behavior of fishes associated with drifting objects for some time. They have examined questions such as: What are the mechanisms involved in attracting fishes to floating structures? What is the adaptive advantage for fishes commonly associated with this habitat? How can this information be applied to improve or develop new fish harvesting methods? Several hypotheses have been proposed explaining the various relationships between fishes and the objects. The effect of structure configuration and deployment on the attraction of fishes also has been tested (see References).

Edward Klima and Donald Wickham (NMFS) have developed the technique of using moored structures to attract coastal pelagic fishes. The number of bait fish attracted to their artificial structures was impressive, and the rapid rate of recruitment to these small objects was equally surprising (see References).

These experiments were conducted in the northeastern Gulf of Mexico. It is a unique area of the Gulf where oceanic waters impinge upon the beaches. Schools of herrings, anchovies and scads occur in the nearshore zone. In turn, migratory game fish, especially the mackerals and jacks, pursue this bait in coastal and inshore areas and also into the bays. The bait sometimes retreats behind the bars where some protection is afforded them. Offshore, they form "hard" schools in defense against attacks by predators, In this featureless environment, the prey species are attracted to almost any suitable floating object or bottom disconformity. It is a good place to experiment with midwater structures. The requisites here are clear water and attractable fish.

Donald Wickham and John Watson suggested that we collaborate to evaluate the effectiveness of midwater structures in attracting game fish (Figure 1). Results from this experimental fishing showed that significantly greater catches of game species (king mackerel, little tunny and dolphin) were made around the structures than in control

Figure 1.

John Watson inspects a midwater structure moored off Panama City, Florida. Round scad (Decapterus punctatus), an important bait fish in this area, were attracted to this object shortly after it was deployed.

areas. It is important to note that these results were obtained at a time when conventional trolling methods by charter boatmen were unproductive. By deploying the structures at various depths, we determined that more king mackerel were attracted around the structures in shallower waters than those placed in deeper waters. This was probably due to the greater abundance of bait inshore during the warmer months (Figure 2). As water temperatures drop, the schools of coastal pelagic fishes move offshore or southward. Robert Hastings, Michael Mabry and I have described the fish fauna associated with two U.S. Navy research platforms located off Panama City. Our observations give support to

Figure 2.

A school of round scad, Decapterus punctatus, "hardened" below a U.S. Navy research platform off Panama City, Florida.

these results and general statements about seasonal distribution (see References).

How does the concept of midwater structure design and deployment differ from conventional artificial reef construction and management methods? The obvious difference is in the choice of species to be attracted. The primary target species for midwater structures are pelagic fishes versus demersal species for bottom reefs. Another difference is the temporary nature of the midwater structure as opposed to the development of a benthic community on a conventional artificial reef. Relatively few organisms will be associated with the former, whereas many kinds of invertebrates and fishes will occupy the latter. As a tool for fishery management, midwater structures have the advantage of affecting fewer target species. You have more control over your methods by manipulating only a small segment of the coastal fish population. In addition, a pre-existing habitat and its associated fauna will not be permanently altered or displaced.

Pelagic fishes are more wide ranging in their habits than demersal species. Nocturnal movements of bait away from the structures may attract more predatory game fish to the site when they return at daylight. This possibility was supported by the repeatedly good catches made by charter boats.

Midwater structures are advantageous because of their simple construction and portability. They are readily deployed and moved about. Problems with labor and expensive transportation costs to the reef site are negligible when compared to bottom reef construction. They also offer less threat to a deep draft vessel if accidentally run down.

With restrictions placed on boat owners in terms of either rising fuel costs or shortages, judiciously placed midwater structures can reduce the time spent searching for fish. This is especially advantageous to the inexperienced fisherman.

Midwater structures can enhance the fishing experience in other ways. An abundant supply of live bait is usually present around the structure. An angler could easily capture several by snagging them, then bait a suitable rig and drift-fish in the same area. You can imagine the fight a king mackerel would give when caught in this manner as compared to trolling for them. Fly fishing, with its limited casting range, also would be exciting - especially if "school" dolphin are present.

To our knowledge, widespread application of midwater structures by sport fishermen has not occurred. Those who are dependent upon fishing for a living probably are reluctant to share their labors and rights to these objects with competitors. As in the case of bottom artificial reefs, good organization and cooperative efforts between interested groups will be necessary for this fishery method to expand.

The few fishermen who have adopted this method are well pleased with their results. A captain operating in the northeastern Gulf of Mexico has been fishing midwater structures of his own design for several seasons. He uses 1 x 2 inch wooden strips, 12 to 14 feet long for each structure. The slat is tied by a line to a heavy weight. The length of the line determines the depth each slat is suspended below the surface (usually six feet). A small piece of styrofoam is nailed to the top of the slat to prevent it from sinking in a current or when it becomes waterlogged. About six slats are placed overboard per trolling site.

Another enterprising individual is hoping to develop a market for live round scad, locally called "cigar minnows," for the mackerel fishery. He has constructed a trawler-type hull out of ferro cement from which to fish. A large live well has been built to hold the bait. He may use midwater structures to "harden up" the bait in order to catch them with a purse seine, then anchor in the vicinity of the pass and sell his catch to passing fishermen.

More research is needed to determine the effectiveness of midwater structures in other coastal areas. Additional quantitative data is necessary to support the subjective statements made from numerous, but incidental, field observations. Biologists might consider using this method to increase the efficiency of in situ life history studies. We are presently planning to study the biology, ecology, and migrations of coastal pelagic game fish. These structures might provide us with a dependable source of fish for tagging purposes. If they are visited regularly throughout the season, information on seasonal distribution also can be obtained. Improvements are necessary to increase the structures' longevity at sea and their value as research tools.

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Progress of the Smith Mountain Reservoir Artificial Reef Project

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Rocky outcrops, ledges and submerged islands all are good examples of bottom structure occurring naturally in freshwater lentic environments. The amount of naturally occurring cover is often insufficient to furnish adequate shelter for cover-seeking fish species (Hubbs and Eschmeyer, 1938). Providing additional artificial cover, therefore, remains a realistic management technique. In this paper we consider only those bottom structures that are built by man.

For our purposes, an artificial reef may be described as any collection of rigid structures placed close together in an aquatic environment to improve fish habitat. The terms "fish attractors" or "fish hides" are often used to refer to freshwater artificial reefs (Crumpton, 1972; Davis, 1969). "Artificial reef" is a more descriptive term since reefs may serve as spawning habitat, shelter and a source of food, as well as simply attracting fish. Although researchers have concentrated most of their efforts in marine waters (Steimle and Stone, 1973), the application of artificial reefs as a freshwater fisheries management technique shows considerable potential.

Some of the earliest research on freshwater habitat improvement by means of artificial structures was published by Hubbs and Eschmeyer (1938) and Rodeheffer (1938, 1940, 1944). Results from these and later studies confirm that artificial structures can attract large numbers of fish. Lack of data on how reefs affect freshwater fish populations and prohibitively high construction costs have, however, curtailed the utilization of artificial reefs as a freshwater fisheries management technique.

Smith Mountain Reservoir covers an area of nearly 20,000 acres (8,100 ha) and is located within 45 miles (72 km) of Roanoke, the second largest metropolitan region of Virginia. The reservoir supports a sport fishery of considerable magnitude, as many as 330,000 angler visits per year. Habitat improvement in Smith Mountain Reservoir on an experimental basis seemed warranted because of the general lack of shelter in shallow water areas (a result of clearcutting prior to impoundment) and increasing fishing pressure.

Research was initiated in April, 1973 to evaluate the use of artificial reefs in Smith Mountain Reservoir, Virginia. Objectives of the project are to assess artificial reefs in terms of: (1) construction costs; (2) preference of fishes for materials and locations; (3) sequence of occupation, permanence of station, and feeding habits of reef fishes; and (4) contribution of reef fishes to angler harvest.

REEF CONSTRUCTION

Twelve experimental areas were randomly assigned as either reef or control sites. Four reefs were constructed of scrap automobile tires tied into pyramid units (Figure 2) and four of discarded Christmas trees (Figure 3). The remaining four sites were designated control areas. Two tire reefs and two tree reefs were constructed on point locations and two of each type in cove locations (Figure 1). Of the four control sites, two were on points and two in coves (Figure 1). All reef structures were situated along the 7-12 foot depth contour. Over 3,600 tires and 400 trees were used in construction of the reefs. Research on these twelve experimental areas involved determining preferred reef materials and locations, as indicated by game fish population size and catch per unit effort.

In addition to the first 12 randomly selected reef areas, a larger multi-component tire reef was constructed at a carefully selected location (Fig-

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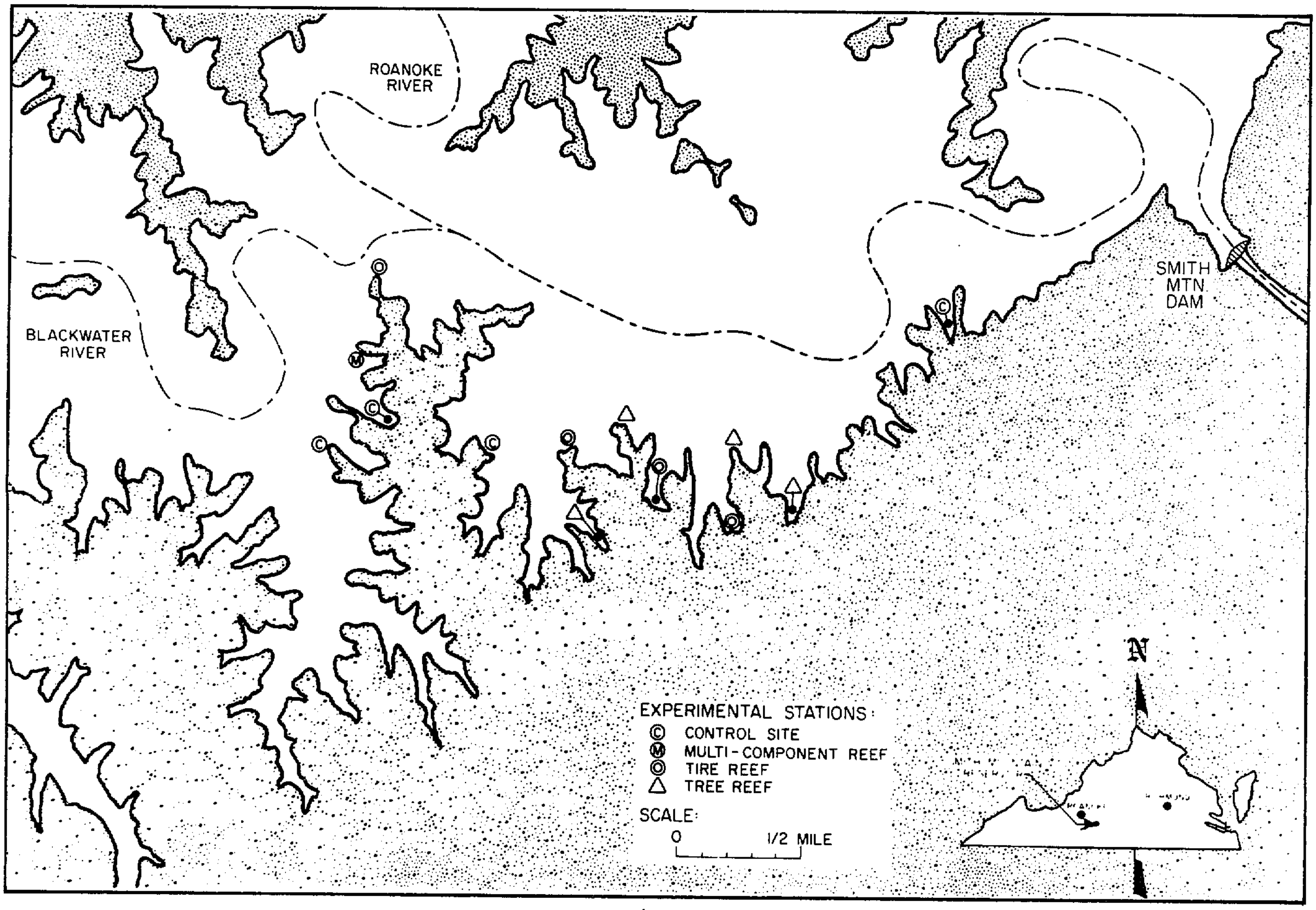

Figure 1.
Location of artificial reefs in
Smith Mountain Reservoir, Virginia.

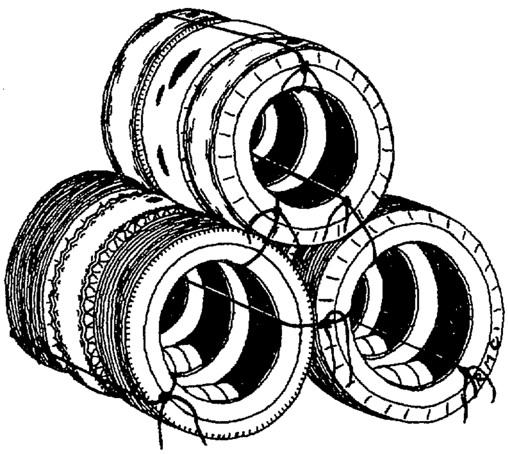

Figure 2.
Pyramid tire unit.

ure 1). This reef consists of triangle tire units (Figure 4) along the 4-5 foot depth contour, pyramid tire units (Figure 2) along the 7-10 foot depth contour and high profile tire units (Figure 5) placed along the 15-20 foot depth contour. The reef is approximately 150 yards long and extends from the tip of a point into the adjacent cove (Figure 1). More than 3,400 tires were used in

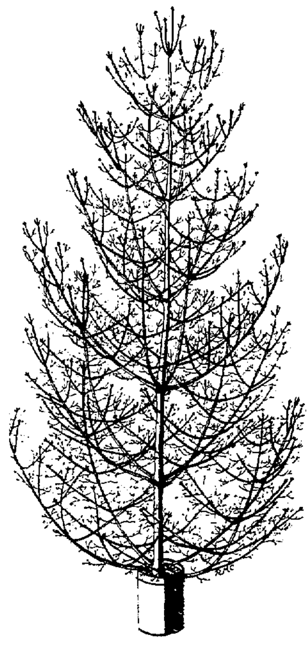

Figure 3.
Christmas tree unit.

constructing this reef. Research on this large reef involves determining the sequence of occupation, permanence of station and feeding habits of fishes associated with the reef.

Sampling methods employed to collect data at experimental sites include: underwater scuba transects, gill nets, hook and line, electro-fishing and fish traps.

Over 7,000 tires, 400 Christmas trees and 650 man-hours of labor were used to construct the artificial reefs. More than 50 percent of this labor was donated by Bass Anglers Sportsmen Society (B.A.S.S.) members and other interested individuals. Some of the construction materials (such as polypropylene rope) and equipment also were donated by these and other groups. Reef construction expenses (excluding donations) totaled \$1,270.87. Reef installation was completed in mid-October, 1973. Instructions on how to build these and other artificial reef units are given in Brouha and Prince (1974).

UNDERWATER OBSERVATIONS

Initial underwater observations (within one week after reef installation) indicated that young fish occupied the reefs almost immediately and were followed later by adults. Scuba surveys indicated that at least 12 species of fish were associated with the artificial reefs (Table 1).

We observed the following fish species utilizing the reefs for shelter during summer months: bluegill, redbreast and pumpkinseed sunfish; largemouth bass; smallmouth bass; and white and channel catfish. Bluegill were the most abundant fish species observed during surveys from June through November, 1973. White and channel catfish, and largemouth and smallmouth bass were commonly observed, but their numbers fluctuated periodically. Scuba surveys indicated that the occupation pattern of fish species associated with the reef is seasonal. Reduced numbers of fish were observed around the reefs during the colder months of December, 1973 and January and February, 1974. Gizzard shad and sunfishes have been observed grazing directly on the periphyton attached to reef substrate. Periphyton was evident on reef substrate within three weeks after reef installation.

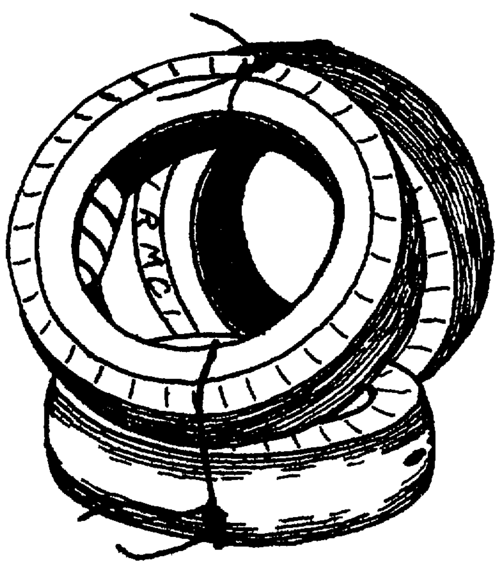

Figure 4.
Triangle tire unit.

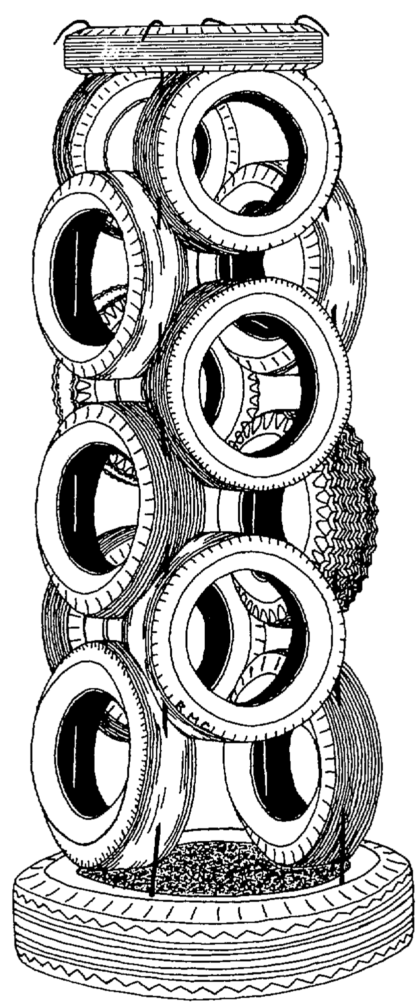

Figure 5.
High profile tire unit.

CONCLUSION

We are encouraged by the active participation and continuing interest of segments of the community in the project, as well as by the results of our studies to date. The successful completion of the project should help assess the value of artificial reefs as a freshwater fisheries management technique.

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TABLE 1

Fishes observed during SCUBA surveys of the artificial reefs in Smith Mountain Reservoir, Virginia, June-November, 1973.

Scientific Name	Common Name	Occurrence
Lepomis macrochirus	Bluegill sunfish	common
Lepomis auritus	Redbreast sunfish	common
Lepomis gibbosus	Pumpkinseed sunfish	occasional
Micropterus salmoides	Largemouth bass	common
Micropterus dolomieui	Smallmouth bass	common
Morone saxatilis	Striped bass	rare
Stizostedion vitreum	Walleye	occasional
Ictalurus punctatus	Channel catfish	common
Ictalurus catus	White catfish	common
Pomixis annularis	White crappie	rare
Cyprinus carpio	Carp	occasional
Dororsoma cepedianum	Gizzard shad	occasional

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Building Artificial Reefs

SESSION CHAIRMAN: JOHN S. GOTTSCHALK, International Association of Game, Fish and Conservation Commissioners, Washington, D. C.

Building Artificial Reefs Through Inter-Governmental Effort With the Private Sector of the Economy

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It is indeed a pleasure to be here today and to pass along some thoughts and ideas on the technique the Broward Artificial Reef, Inc. is using to construct an artificial reef off the coast of Fort Lauderdale.

Late in 1966, Virgil Osborne, a local fishing boat captain, became concerned with the decrease of fish being brought in by charter and private boats. Catches of bottom feeders such as snapper and grouper, as well as the more migratory species, sailfish, marlin and kingfish were on the wane. Divers reported pollution was killing our natural reefs and spearfishermen were on the increase.

After lengthy discussions with private individuals and fishing groups, Osborne decided the community should build an artificial reef. Stories of dumped automobiles, refrigerators and other refuse were circulated. However, all these efforts seemed fragmented and expensive and locations were closely-guarded secrets. What was needed then was a county project utilizing as many individuals, groups and corporations as possible.

The next task was to determine the best structure to accomplish this purpose. A club, an organization or a corporation? Osborne wisely elected the corporate route, but chartered as a non-profit, tax-exempt corporation, providing a vehicle whereby funds might be raised and donations received, affording definite tax advantages to contributors. Early in 1967 the Broward Artificial Reef, Inc. (BARINC) was incorporated and chartered under the laws of the State of Florida and a board of directors and officers were appointed.

Now that the mechanism was established the question arose, where to build a reef and out of what? One of the directors, Dr. Raymond F. McAllister of Florida Atlantic University suggested that perhaps a group of graduate students from his department might undertake a study to answer these problems. Money was raised, two students were funded and the project got underway using pre-formed concrete modules as a substrate.

For two years things went smoothly. The American Broadcasting Corporation came to the area and photographed a concrete aero-jack drop. Later in the year, ABC's Wide World of Sports aired the film and more contributions rolled in. And then it happened - - the public lost interest and the money stopped.

At this point the directors and officers examined the situation critically. What was the group doing to effect such a calamatous situation? The answer was nothing and that was the point. Jacks were costing $11 per unit on the bottom. Money was being solicited from the same sources and the volunteer labor force had dwindled to eight or nine individuals. BARINC had temporarily come to a full halt.

It was at this point that the reef group investigated the efforts of Stone, et al. and the federal government. Here lay the solution to acquiring a cheap substrate, but how to raise the money to process and dispose of tires? Local industry was incapable and unwilling to underwrite such an extensive program and contributed funds were not sufficient to defray operating expenses, let alone salaries.

One alternative remained, the tire manufacturers themselves. BARINC contacted three major tire companies. One responded with a form letter, one failed to respond and the Goodyear Tire and Rubber Company responded requesting more information. Corporate records and scientific reports were immediately dispatched to Akron; a corporate representative visited Fort Lauderdale and negotiations followed whereby Goodyear donated a tire bundling machine to the group. Goodyear not only provided the hardware, but the technical expertise to train personnel in the operation and maintenance of the equipment.

What personnel? Clearly, if this were to be a continuing project, permanent employees were a necessity. In 1971 the Broward County Pollution Control Board unanimously passed a resolution endorsing the reef project and recommending that it be considered a county purpose. This was done subsequently and the City of Fort Lauderdale followed suit. The county provided three employees from the Department of Parks and Beaches to operate and maintain the equipment. Port Everglades Authority leased five acres of land to BARINC for $1 per year. The project gained momentum. The year was 1971.

Early in 1972 the Broward Artificial Reef, Inc. and the County Administrator coordinated personnel and equipment and the reef moved into Phase II. In April of that year we conducted our first drop. In concert with Goodyear's public relations department, BARINC held a breakfast with speakers from the National Oceanic and Atmospheric Administration, the State Department of Transportation representing the Governor's office and local elected officials whose agencies actively supported the project. Over 100 small boats carried single tire units to the reef site. The United States Naval Reserve, on board the USS Thrush carried compacted modules and at a signal from the Goodyear Blimp thousands of tires splashed to the bottom.

What has been stated so far appears relatively simple and devoid of difficulties. Do not be misled. Innumerable numbers of man-hours went into meetings, planning and workshop sessions. A partial listing of agencies and organizations contacted includes:

The National Oceanic and Atmospheric Administration

The United States Navy - Naval Ordinance Laboratory Test Facility

The United States Naval Reserve

The United States Army Corps of Engineers

The Environmental Protection Agency

The Florida Department of Natural Resources

The Florida State Board of Conservation

The Florida Department of Pollution Control

The Broward County Commission

The Broward County Pollution Control Board

The Broward County Department of Parks and Beaches

The Broward County Department of Transportation

The Broward County Port Authority

The City of Fort Lauderdale

and numerous local corporations who donated time, material and equipment to the cause.

To put all this into perspective, I would like to recap what transpired and then talk a little about benefits and economics.

1) An individual, concerned with changes in the environment, founded a tax free corporation to build a county reef.
2) Monies were raised and professional expertise enlisted to locate a site and select a substrate, and the project was initiated.
3) The project faltered due to material and associated costs and due to the lack of a permanent, scheduled labor force.
4) Re-examination of goals and objectives indicated fresh capital, equipment and personnel were required if the project were to continue.
5) Industry, along with federal, state and local government joined together and salvaged a viable project.
6) The project is continuing with inputs from each of these groups.

Perhaps the two most critical items mentioned above are three and five, namely, the ability to re-examine priorities and effect a solution and to bring local government into the picture.

The latter deserves consideration here, for without government cooperation, the project would have failed.

Broward County is not unique in having tremendous difficulty in disposing of tires. Existing incinerators are incapable of burning them in an environmentally safe fashion and county dumps seemed to catch fire mysteriously three or four times a year. Therefore, the local Pollution Control Board adopted a resolution which became the vehicle for the County Commission to deem the tire reef a county purpose. In effect, they were disposing of tires. Tires, which were an esthetic pollutant ashore could be recycled, so to speak, to build a fishing reef at sea. Although revenue was lost at county dumps, additional benefits accrued. Citizens participated in clean-up campaigns and brought tires to the processing site, allowing the county's mosquito control trucks to concentrate their efforts at one location. Air quality improved, eliminating costly fines by pollution control officials.

More significantly, the county has benefitted very substantially by the fact that compacted tire modules will be utilized to repair existing fringing reefs damaged by the construction of a new sewer outfall line. The contractor intends to rebuild these reefs with 15,000 modules, or approximately 202,000 tires. If the County were not to use tires, an alternate substrate would cost a considerable amount. It is interesting to note that both the Environmental Protection Agency and the United States Corps of Engineers approve of the proposal.

Since April 1972, the Broward Artificial Reef, Inc. has placed approximately 270,000 tires on the reef site. Although this does not represent a very large number of units compared with supply, additional equipment is on site and a total of eight employees are in the process of reorganizing the operation. It is intended that the reef will process between 400,000 and 500,000 tires a year and charge a fee which will allow the reef project to be self-supporting and self-liquidating.

Here ends the reading of the narrative and we are at the bottom line. What has all this cost? The intricacies of financing are too complex to describe here; however, I shall quote two figures. The first represents actual out-of-pocket expenses. That is, exactly what it has cost to build the reef. The second represents what it might have cost if we were to have paid our "fair share."

Actual cost $55,188 or 20 cents per tire

Fictional cost $107,550 or 40 cents per tire

What the Broward Artificial Reef group has done is not necessarily unique. Hopefully, other groups around the world will adopt and modify the scheme to suit their requirements. Let them be encouraged and not let the initial wave of accomplishment wallow in the trough of apathy when the cause appears defeated.

ACTUAL COST

<u>COUNTY to Date</u>		
Salaries	$26,885	
Commissions & Fees (barge & tug)	<u>$ 9,522</u>	
	$36,407	$ 36,407
<u>BARINC to Date</u>		
	$18,780	<u>$ 18,780</u>
		$ 55,188 = 20 cents

FICTIONAL COST

<u>COUNTY to Date</u>		
	$36,407	
P.E.A. Lease		
5 acres @ $45,000 acre X 10% X 2 =	$45,000	
Capital Equipment	<u>$ 7,300</u>	
	$88,707	$ 88,707
<u>BARINC to Date</u>		
	$18,780	<u>$ 18,780</u>
		$107,487 = 40 cents

Texas' Liberty Reef Program

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The sinking of surplus World War II Liberty Ships off the Texas coast for recreational purposes could greatly enhance existing fishing opportunities. The federal government has recently made surplus W.W. II Liberty Ships available to the states for use as offshore artificial reefs. If properly cleaned and partially stripped to eliminate undesirable materials and safety hazards, the 440-foot ships could be a unique and beneficial resource for Texas saltwater fishermen and divers. The ships must be located for easy access while not threatening navigation. Proper marking with lighted buoys must be provided to enable fishermen to locate the reefs and allow shrimp trawlers to avoid them. Artificial reef ventures in Texas and elsewhere have demonstrated that they can improve fishing opportunities without interfering with other uses of the sea or causing environmental damage. Efforts to convert 12 Liberty Ships into four artificial reefs are currently underway along the Texas coast.

WHY ARTIFICIAL REEFS

Artificial reefs are constructed from materials which man has discarded. More than 150 artificial reefs have been constructed in U.S. coastal waters since the first automobile body reef was built off the coast of Alabama in 1953. More than a dozen have been built at various locations along the Texas coast in both the bays and offshore since 1955. Though there have been some individual problems, most reef building efforts have generated substantial followings among saltwater anglers and divers.

The scientific basis for why artificial reefs improve fishing is easily understandable. The reefs provide a hard, exposed substrate of increased surface area for barnacles and other sedentary marine forms to attach themselves. Additionally, the many crannies provide hiding places for small fishes which, in turn, attract larger fishes sought by anglers.

Obviously then, an area surrounding a large sunken vessel or other bottom obstruction is more conducive to fishing than the flat Gulf bottom.

Two schools of scientific opinion exist concerning the value of artificial reefs. Some scientists maintain that such reefs significantly increase the biological productivity of a large area. Others contend that such reefs serve only to concentrate existing populations into a small area which is readily accessible to fishermen.

Whichever is correct, the fact remains that artificial reef programs, if properly conducted, can greatly enhance fishing and provide desirable sites for divers.

TEXAS' PROGRAM

Under the terms of PL 92-402 the Secretary of Commerce will provide Liberty ships to the states upon approval of application made by the Governor or his designee. Included in this application must be an environmental impact statement showing proposed locations and details for cleaning and partial salvaging. The application must also include an EPA certification, a Corps of Engineers (USCE) permit for construction in navigable waters, and a Coast Guard permit for a buoy.

The state of Texas made one false start before it got its Liberty Reef program underway. Initial contact came in the form of a telegram from the Secretary of Commerce to the Governor's Office in September 1972. After referring the "offer" to the appropriate state agency for comment, the state said "no thanks." Oddly enough, at the same time, the Legislature sitting in a special session during October 1972 passed two resolutions urging the construction of these reefs. Business as usual -- little or no communication between the executive/administrative and legislative branches!

At a Texas Coastal and Marine Council public hearing on fisheries resources in February 1973, Tom Johnson, an "independent driller" (dentist -- not oil man!) from Corpus Christi showed up with a petition containing several thousand signatures urging the Council to get the state involved in a Liberty Ship reef program. Needless to say this petition got the attention of the Council members -- especially the elected official members. The Council directed the staff to find out just what was involved and report back as soon as possible.

It quickly became apparent that the planning and construction of these Liberty Reefs was an involved process with many complex considerations. For example:

Site Location — How do you select reef sites that satisfy all the conditons of accessibility, navigation clearance, non-interference with offshore oil and gas operations and shrimping, legal issues, diving safety, sound bottom condition, favorable currents, etc., and still satisfy all the Chambers of Commerce along the coast? (See later section on Site Location)

Institutional — A Liberty Reef built beyond the 12-mile limit constitutes an unprecedented offshore construction venture on the continental shelf, and there is no clear legal rule out there concerning structural measures for fisheries enhancement.

Preparation and Construction — Liberty Reefs are like icebergs - there's an awful lot of painstaking work to be done from a mechanical standpoint of cleaning, moving, emplacement, etc. These details must be thought through carefully and planned meticulously. Without proper attention to such details, the entire effort could easily become a disaster.

Marking — Arrangements must be made for the long-term marking of the reefs. Adequate marking is required for two main purposes: (a) to enable shrimpers to avoid the reefs and (b) to help fishermen locate the sites. Big buoys are required: we are proposing lighted buoys 30 feet by 6 feet, weighing 2-plus tons -- and costing in the vicinity of $600 - $700 per month.

SITE LOCATION

Many factors must be considered in determining the best locations for Liberty Reefs.

Obviously, it is necessary to locate them a safe distance from established shipping fairways and anchorages. Also, the U. S. Corps of Engineers requires that there be a minimum of 50 feet clearance between the top of a reef and the water surface. Since these ships, when partially cut down, would be about 30 feet high, they must be sunk in at least 80 feet of water.

Accessibility to the reef by small boat owners is vital. About 30 miles beyond the jettied passes is considered a reasonably safe distance for such boats to venture. Therefore, reefs should be within this distance.

Approximately 100-110 feet is considered the maximum safe depth for amateur divers to go. Thus, reefs should be located in water depths of not more than 110 feet.

Although no specific studies have been conducted along the Texas coast, assorted data and related experiences indicate that water depths of about 100 feet should be desirable to enhance the marine ecosystem. Much of the Gulf near shore has a soft bottom in which reefs would sink into the sediment, so it is mandatory that the reefs be located on firm bottoms.

Numerous obstructions, both natural and man-induced, exist on the Gulf bottom and pose constant threats to shrimpers' trawls. Artificial reefs, suitably marked, located near these obstructions could indicate clearly the location of presently unmarked obstructions.

Ultimate decisions on specific reef locations cannot be made until more details of the project are determined, including the number of ships available, amount and sources of funding, timing, the degree to which the ship will be cut down, and what agency will be responsible for the reefs. However, enough is known already to make it clear that a series of deepwater Liberty Reefs could be built along the Texas coast accessible from different areas.

Regardless of the locations of Liberty Reefs, it will be mandatory that they be well marked with a lighted buoy, radar reflector and whistle or bell. Provisions must be made to maintain the buoys properly. This must include relocation and remarking if the original buoys are lost in a hurricane. Costs for maintaining such buoys vary depending on the specific case, but estimates generally approximate $6,000 - $7,000 per buoy annually.

The first step, once a general region has been selected, is to eliminate the areas in which a reef cannot be located, such as those discussed above. By the time these areas have been eliminated due to possible conflicting uses or safety precautions, the number of possible reef sites has been substantially reduced. To select a specific site it becomes necessary to locate firm bottom conditions, identify known obstructions and determine several candidate sites. After selection of candidates, it will be necessary to do some on-site investigations including bottom coring, biological sampling and current measurements before a final decision can be made. Hearings also will be necessary to get public input on the matter.

CURRENT STATUS

To summarize briefly the current status of the Texas Liberty Reef Program, as of March 1974, I'd like to make the following points:

- We have our EPA certification, and hope to get the permit as soon as we resolve a point raised by one federal agency. The Department of Interior's Bureau of Land Management has expressed concern that under certain hurricane conditions bottom currents of 8-10 knots might move the reefs long distances and possibly damage oil and gas platforms.

- Once the USCE permit is obtained, we must get a coast guard permit -- and then we submit our formal application for the dozen ships.

- A salvage/preparation services contractor will be chosen by a competitive process in compliance with state procedures.

Currently we are continuing with the mechanics of permitting and construction. I will be glad to provide further information on this project – just contact the Council. Hopefully, by the time these proceedings are published, the Liberty Reefs will be completed.

OTHER REEF MATERIALS

I certainly don't suggest that Liberty Ships are the only feasible reef construction materials. In fact, the worsening shortage of scrap, coupled with its skyrocketing cost someday may preclude the use of Liberty Ships as artificial reefs.

Many other excellent materials exist. All it takes is imagination, energy, and an interested user group, and a reef can usually be built. The Texas Coastal and Marine Council and TAMU's Center for Marine Resources did a joint study on potential reefs for Texas. (Available from the Texas Coastal and Marine Council, Box 13407, Austin, Texas; or the Center for Marine Resources, Texas A&M University, College Station, Texas.) This effort revealed a wide spectrum of possibilities.

I'd like to leave you with one closing thought: If you are going to build a reef you must admit that you are in the junk business. Do this – and then HUSTLE.

Techniques for Fabrication and Utilization of Baled Automobile Tires in Artificial Reef Construction

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The Saltwater Sport Fish Section of the South Carolina Wildlife and Marine Resources Department has used baled automobile tires as components of its artificial fishing reefs for two and one-half years. This experience with baled tires has led to the design and production of a machine that assembles tires into units ready for sinking at a reef site. We have also developed methods to handle the units produced by this machine.

Various applications of the bales both singly and in clusters result in excellent low[1] and medium[2] profile habitat which greatly increase the capacity and productivity of South Carolina's six artificial reefs.

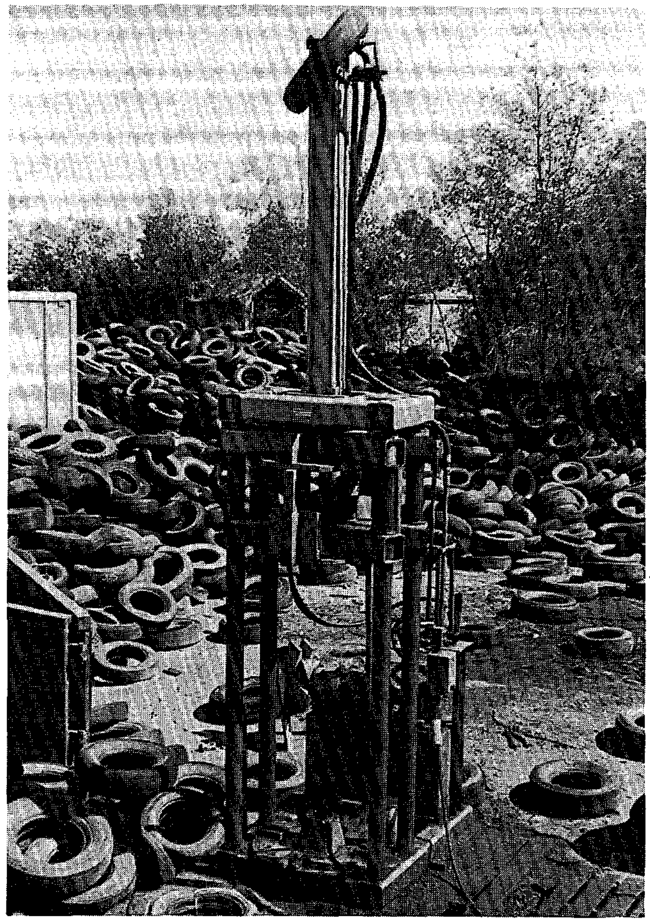
BACKGROUND

South Carolinians wear out three million truck and automobile tires every year. These worn-out tires may become eyesores, refuges for vermin and dangerous fire hazards. Since they are not biodegradable, can not be burned in conventional incinerators without causing substantial air pollution, are unsuitable for landfill and, aside from recapping, cannot be economically recycled, these tires present a serious disposal problem.

An adequate supply of scrapped automobile tires for artificial reef construction exists in Charleston, South Carolina, where a major automobile tire recapper operates. Approximately 180,000 tire casings unsuitable for recapping are available at this time; the factory rejects from 250 to 500 additional casings each day.

TECHNIQUES

An hydraulically actuated "Tire Krusher" is employed to compress nine tires simultaneously

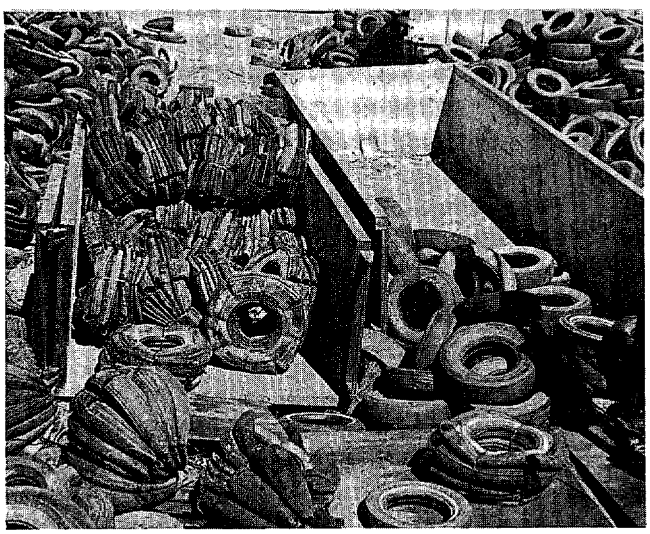


The "Tire Krusher"

into a bale approximately 50 cm (18 inches) high and 90 cm (32 inches) in diameter. Each bale weighs 77 to 91 kg (170 to 200 pounds) and is held together by four 9.5 mm (3/8 inch) Signode "Apex" steel bands.

The "Tire Krusher" was built to our specifications by the Gender Machine Works of Portland, Oregon and is being leased to the South Carolina Wildlife and Marine Resources Department by that organization. One of its significant features is a tire cutting accessory which cuts deep slits across the tread of each tire at four equally spaced locations. The cuts are essential to eliminate the positive buoyancy of the tires.

We have found that a 15.3 m^3 (20 yds^3) industrial trash container is ideally suited for handling baled tires over short distances on land. The cut and banded bales are removed from the "Tire Krusher" and rolled into open-topped industrial trash containers which are usually referred to as dumpsters. The dumpsters are at ground level and can be loaded quickly and easily by hand. As the bales are loaded, they are strung into 12 bale clusters by inserting 6.4 mm (1/4 inch) stainless steel cable through the center of two rows (of six bales) and splicing the ends together. Two dumpsters are kept near the "Tire Krusher"; when one is filled a disposal service sends a truck to carry it to the waterfront where the tires can be loaded on marine transport. While one dumpster is in transit, the other is loaded, thereby eliminating accumulation of bales near the machine and the necessity of attempting to load and move large numbers of bales at one time. Previous efforts to use semi-tractor-trailer vans proved to be inefficient, requiring our labor force to suspend baling activities and devote a full eight hour work day to load 150 bales. In contrast, an 85-bale dumpster is loaded as the tires are baled. When full, the container can be picked up and on its way to the waterfront within ten minutes. There, bales are loaded aboard barges or surplus landing craft 12 at a time by crane. The stainless steel cable eliminates the need to sling the bales, thereby speeding the loading operation.



Twenty cubic yard industrial trash containers, or "dumpsters", are used to haul baled tires for short distances.

At the reef site the barges are anchored and unloaded by pulling clusters overboard with a tug. If surplus landing craft are used, they are sunk complete with their full load of tires. A landing craft in "good" condition can carry 5,000 baled tires.

The "Apex" bands on the bales break within 90 to 120 days after sinking and the tires expand against the stainless steel cable that holds the clusters together. This creates a circular reef with most of the tires standing on their treads, thus providing a habitat of medium profile and allowing horizontal penetration by marine animals into the interior of the tires.

Another medium profile unit can be fabricated by looping a 1.5 meter (5-foot) segment of polypropylene rope through a bale. When the bands corrode, the unit assumes a fan-shaped array on the ocean bottom. This unit anchors itself in position by the nature of its asymmetrical shape and the entrapment of sand particles in the tires.

Construction Cost

A three-man crew can bale and load an average of 80 units per eight-hour work day with a resulting cost of \$48 for labor. The cost for material is \$3.20 per day and the cost for renting the machine is \$46.75 per work day for the first year. This rent will be reduced by 92 percent to \$3.90 per work day the following year. Our cost for producing 80 bales is thus a total of \$97.95 per work day or 13.6 cents per tire at present. This cost will decrease to about 7.7 cents per tire in subsequent years due to the reduced machine rental fee. The cost for dumpster service is \$35 per trip. This is paid by the tire recapping firm. The stainless steel cable is scrap obtained from the U.S. Navy at no cost. The cost for loading tire units aboard barges or surplus vessels and sinking the units at the reef site depends on the low bid submitted by marine contractors on a competitive basis. Successful bids in the past have ranged from 13.2 to 25 cents per tire depending on the distance the units must be hauled. Thus, total cost per tire to bale and transport waste tires to artificial reef sites ranges from about 26.8 to 38.6 cents.

Unit Stability

Since the bales are not ballasted, there was serious doubt as to whether they would remain at reef sites after sinking. To clear up those doubts, different types of baled tire units were sunk in 8.8 meters (29 feet) of water, 4.6 kilometers (2.5 nautical miles) off Murrells Inlet, South Carolina. The location of each study unit was marked by driving a 1 meter (3 -foot) long iron pin into the sand nearby. Periodic observations made by scuba divers revealed that these experimental units have remained in the same position for two years. Bales that were sunk without a corrosion-resistant retaining device broke open within 120 days and all the tires can be observed lying flat on the bottom within a 2 meter (7-foot) radius of the pin. Despite these observations, we do not recommend sinking baled tires without the non-corrosive bands and ballast unless further tests at the reef site indicate that they will not move.

To insure that the units stay in the desired locations in areas where stability is in doubt, an anchor may be attached via the corrosion-resistant cable. When the units are sunk with a steel boat hull or landing craft, cables are strung through the units and attached to the hull. Units delivered to the reef by barge are secured to sections of concrete culvert by stainless steel cables and sunk. Baled tire units cabled with stainless steel or attached to an anchor with plastic material are much less likely to break apart than tire units held together with steel reinforcing rods or other ferrous materials.

DISCUSSION

The ocean floor off the coast of South Carolina, like most of the Atlantic Continental Shelf, consists of sand and broken shell. In such topographically simple areas there is an apparent demand by many organisms for habitat (Stone, 1974). This is evidenced by the early occupation of our tire units by several species. In fact, scuba divers have observed black sea bass (Centropristis striata), octopi (Octopus sp.) and crabs (Portunidae) occupying the tire units within 24 hours after they were sunk.

Our observations indicate that black sea bass (Centropristis striata), sheepshead (Archosargus probatocephalus), spadefish (Chaetodipterus faber) and small grouper (Mycteroperca sp.) are particularly attracted to the type of habitat provided by expanded tire bales. Low profile units such as single tires lying flat on the bottom appear to be attractive to grunts (Pomadasyidae) and porgies (Sparidae).

CONCLUSION

Our experience with baled automobile tires indicates that these units lend themselves to techniques that offer great potential for alleviating solid waste problems on land, while providing a means for improving marine habitat for recreational pursuits.

ACKNOWLEDGEMENTS

I would like to thank the staffs of Office of Marine Conservation and Management and the Saltwater Sport Fish section for their help in developing this program and in preparing this paper. Mr. William Ripley gave invaluable assistance in the diving aspects of the project. Thanks are also due the Wholesale Tire Company and the Charleston County Board of Health for their cooperation in our endeavor. I am also grateful to Dr. Paul A. Sandifer for his editorial review and helpful comments on this paper.

MANUFACTURERS CITED

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Signode Corporation
Strapping Division
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20 cubic yard Dumpster
L&M Environmental Sales
P.O. Box 5876
Greenville, South Carolina 29606
Mr. William Martin
Phone: 803-242-4770

REFERENCE

Stone, R.B. "Artificial Reefs." Sea Frontiers, 1974, pp. 25-33.

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[1] Low profile artificial reef material may be defined as material which provides relief on the ocean bottom of less than one foot in height. A common example of low profile material is a single automobile or truck tire vented, ballasted and sunk so that it lies on its side.

[2] Medium profile artificial reef material is material which provides relief on the ocean bottom greater than one foot but less than six feet in height.

Artificial Reefs in Australia

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The construction of artificial reefs in Australia began in the early 1960's and was a result largely of favorable publicity given to reef building which had taken place in Japan and the U.S.A.

The first reef was established in 1965 when over 400 tons of concrete pipes were placed offshore from Carrum in Port Phillip Bay, Victoria. Shortly afterwards in 1966 a car body and 250 car tires were placed in Lake Macquarie in New South Wales. Today there are 21 artificial reefs, located between Hervey Bay in Queensland and Rottnest Island in Western Australia.

THE HERVEY BAY REEF

The most important reef building activity in Queensland was at Hervey Bay. There, in 1968, 50 car bodies, 1,800 car tires, 80 tons of concrete and three concrete "fish boxes" were dropped into 18 meters of water in a blind channel north of Woody Island. Since then many loads of similar material, each of about 150 tons, including three barges about 50 meters in length, have been dropped at the site. The reef now covers an area of about 32 hectares.

The idea of establishing a reef in Hervey Bay was first conceived by the Maryborough Skindivers Club which, together with the Queensland Littoral Society, subsequently conducted a detailed feasibility study to locate suitable sites. After selecting the site, the Skindivers Club launched a public appeal for support which ultimately led to the formation of the Hervey Bay Artificial Reef Committee.

The Committee obtained substantial support from anglers and businessmen. Financial assistance came in many forms, including a levy of $2 each on all local boat owners and a charge on motor-car wreckers of $1 for each motor-car body taken from their dumps. Timber barges used for transporting the materials were provided at a nominal rental.

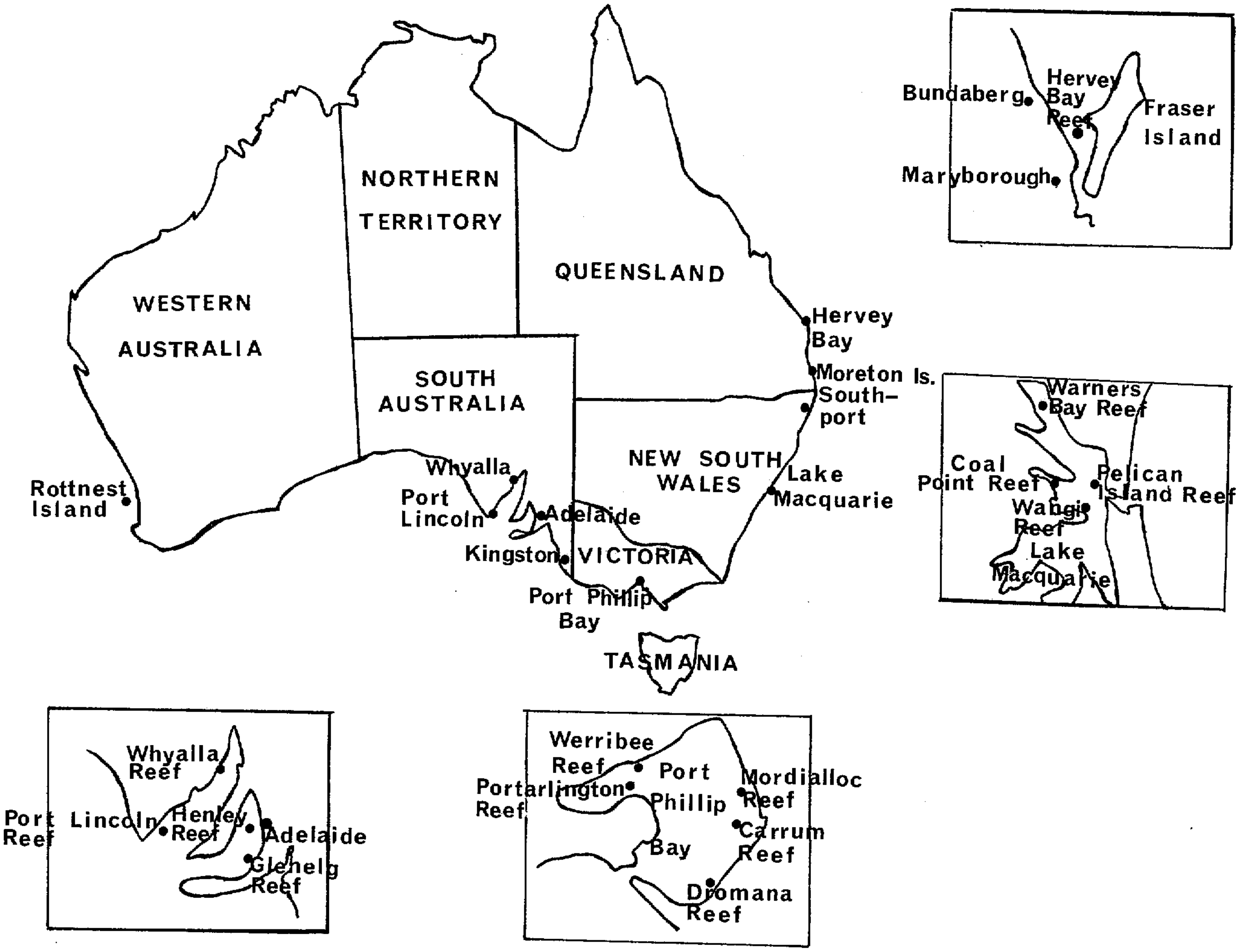
On the oldest parts of the reef, extensive growths of soft corals, gorgonian fans and certain forms of sponges have occurred. These communities cover the original substrate to a depth of up to one-half meter in a dense mat, and large fish populations now are associated with the reef. Local divers estimate that over 70 species now are present and this is a pleasing contrast to the pre-reef figure of 15 species (Thompson, 1973).

The general opinion is that the car bodies, the motor-car tires and the barges have been the most successful of the materials placed on the reef. The specially designed "fish boxes" were difficult to handle and these along with the concrete pieces do not appear to have attracted many fish. It is interesting to note that although in the early constructions the tires were bound in groups of five or six they were subsequently placed individually with apparently satisfactory results.

Soon after the establishment of the reef, a ban on spearfishing was imposed; however, this has been the only limitation on the taking of fish from the area. There has been a considerable amount of angling pressure applied to the reef fish population by both small charter boat operators and local anglers. A tentative estimate for 1973 was 200 man-hours per week with an average catch rate of 0.5 fish per man-hour (Ridge, personal communication). The major effort was centered over the older components of the reef. The target species were snapper (*Chrysophrys auratus*), tusk fish (*Choerodon sp.*), and sweetlip (*Lethrinus sp.*).

The concensus among fishermen in Hervey Bay is that the reef has been an outstanding success

LOCATIONS OF AUSTRALIAN ARTIFICIAL REEFS



in providing improved angling in terms of both total catch and variety of species, and the intention is to build on to the reef as funds and manpower permit.

OTHER QUEENSLAND REEFS

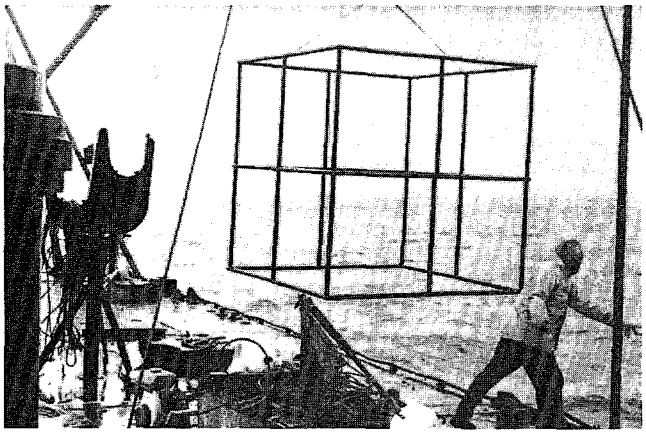
A reef has been established near Comboyuro Point, inshore of Moreton Island in approximately 25 meters of water. This was organized by the Queensland Littoral Society and started in 1969 when a barge and a number of car bodies were laid at the site. More car bodies and tires were added to the reef in the period 1970 to 1972.

The Comboyuro Point reef is closed to spearfishing, but, because of good visibility, it is frequented by sport-divers. The reef is subjected to considerable angling pressure.

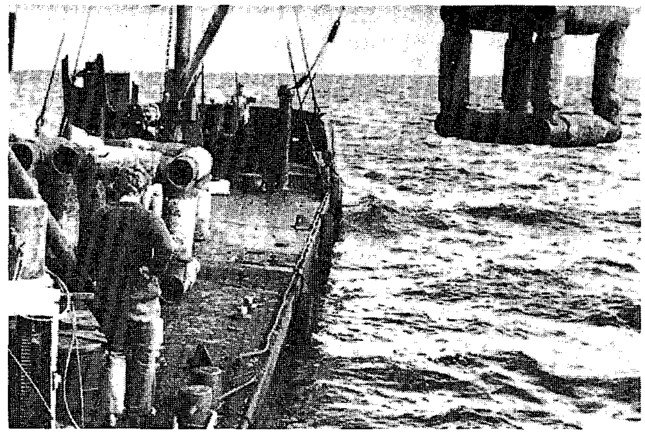
A motor-car tire reef covering half a hectare has been established in Southport Broadwater at a depth of about 10 meters in an area having a muddy bottom subjected to siltation. It was built by a local skin-diving group which was assisted by local organizations, such as Apex and Lions, but the reef is closed to spearfishing and the water is generally too murky for diving.

THE LAKE MACQUARIE REEF

The first reef established in Lake Macquarie was constructed by the Newcastle Underwater Research Group in 1966. It consisted of a motor-car body and about 250 tires and was situated on a barren sandy bottom at a depth of about eight meters. Despite the partial collapse of the reef due to disintegration of the motor-car body and the wire holding the bundles of tires, it has been reported that the reef attracted an abundance of



Lowering a 3 cubic meter open steel frame onto the Mordialloc reef site in Port Phillip Bay.



Lowering a 1.5 cubic meter open concrete and steel cube onto the Mordialloc reef site. (Photo by courtesy of Henry Bource Productions P/L).

fish (Malcolm and Mathews, 1970).

Following this effort, the Newcastle Underwater Research Group collaborated with the State Fisheries Branch in 1969 in conducting a survey of the lake for suitable additional sites. Four localities of different environmental character were selected and a reef of 650 tires was placed at each.

The first of these reefs was established at Coal Point in October 1969 about half a kilometer from the site of the 1966 reef. The remaining three reefs were constructed in early 1970 off Wangi, near Pelican Point, and in Warners Bay.

Each reef was carefully positioned by divers so as to form a horseshoe-shaped, two-tiered structure, the inner diameter of the horseshoe being about 15 meters. The tires were tied in groups of nine and five with vinlon rope and assembled with two groups of nine on the bottom supporting one of five on top. Holes were cut through the tread of each tire to facilitate sinking.

A number of underwater surveys conducted at the sites have shown that the reefs have remained intact and have been colonized by a range of attaching organisms, the dominant species being the mussel Mytilus planulatus. During a one hour dive at the Pelican Point reef in September 1972 it was reported (Anon., 1973) that 16 fish species were identified and that the greatest concentrations had been around one particular group of tires which had been slightly misplaced so that there was no clear line of sight through it.

Also, two small reefs consisting primarily of tires have been constructed at two localities in New South Wales by amateur underwater groups (Malcolm and Mathews, 1970).

THE PORT PHILLIP BAY REEFS

The laying of Victoria's first reef was commenced in October 1965 when 331 concrete pipes (412 tons) were placed in 20 meters of water eight kilometers off the Melbourne bayside suburb of Carrum. Several additions, including a concrete cabin cruiser sunk in September 1967 and a 52 meter timber hulk containing about 40 tons of concrete ballast sunk in November 1971, have since been made.

Although it was intended to lay the reef in a horseshoe pattern, poor weather conditions at the time of building made this difficult, with the result that the pipes were dropped rather randomly over about four hectares. The very fine silty nature of the seabed caused another problem. The large pipes, many of them up to 2.5 meters long and 1.8 meters in diameter, hit the bottom with sufficient momentum to partially and, in some cases, completely bury themselves, and it is thought that the pipes have continued to sink.

As with most of the Australian reefs, building the Carrum reef was very much a cooperative effort. The Victorian Fisheries and Wildlife Department played the major administrative role and provided the $9,600 required for chartering a vessel to transport the pipes and unload them at the reef site. The Self Contained Divers Federation assisted in choosing a suitable site and have subsequently monitored the colonization of the reef by periodic diving surveys. The National Museum also played an important role, particularly in sorting and classifying the samples removed from the reef.

Apart from short tufts of brown algae, the dominant organisms to colonize the reef have been the Bay oyster (Ostrea angasi) and the mussel

(Mytilus planulatus). A number of fish species have been recorded by divers but, because visibility is usually poor, it is unlikely that a complete species list has been obtained. Snapper is the prime target of anglers who fish over the reef and snapper has been taken in good quantities along with ling (Genypterus blacodes) and bearded rock cod (Physiculus barbatus).

Further reef building, the most important of which involved the establishment of three multicomponent reefs during mid-1973, has taken place in Port Phillip Bay. These reefs were constructed by Esso (Australia) Ltd. on behalf of the Fisheries and Wildlife Division (renamed during 1973). The company was at the time involved in laying an ethane pipeline across the Bay and the men, vessels and equipment on hand were used to construct the reefs.

The sites chosen were off Mordialloc, Dromana and Werribee in about ten meters of water on a flat sandy bottom. The material placed at each site consisted of 1,000 motor-car tires suitably slashed and bound into groups of about eight tires, 100 cubic meters of quarry rock, four open steel frames (3 meter^3) and three open concrete and steel cubes (1.5 meter^3). Each of the four components were grouped separately, about 60 meters apart. In the near future it is intended that 700 concrete pipes up to 2.5 meters long and 2 meters in diameter will be placed at each site, and strips of plastic sheet will be attached to the reef to simulate long strands of seaweed.

Except for the quarry rock which was dumped using a bottom-opening barge, the various reef components were carefully lowered to the bottom and positioned with the assistance of divers.

A comparison of the effectiveness of these materials in establishing reefs will be undertaken to provide information for the construction of large, production reefs. Although the reefs have been visited by divers and good quantities of fish have been observed, insufficient time has lapsed for a sound assessment to be made of these materials.

The most recent reef building in Port Phillip Bay occurred in August 1973 when 2,000 motor-car tires were placed in 10 meters of water offshore from Portarlington by the Barwon Grove Skindivers Club.

THE HENLEY REEF

The first reef to be established in South Australia is in 10 meters of water, four kilometers off Adelaide's Henley beach. It was laid during 1970 and consists of 15,000 motor tires put down over a period of two months at two locations about 500 meters apart.

Construction of the reef was organized by an Artificial Reef Committee whose membership included representatives from the South Australian Department of Fisheries and Fauna Conservation, the Piscatorial Council of South Australia, the Underwater Divers Federation and the bayside Municipal Councils.

The committee's decision to use car tires was based primarily on the low cost and ready availability of this material. Coincident with the project getting underway, the Adelaide Councils banned the burning of tires at refuse dumps and this resulted in an embarrassingly large number of tires being offered for disposal.

The major problem encountered by the Committee was the enlistment of sufficient volunteers to prepare the tires for dumping, despite an extensive publicity campaign.

The tires were slit across the tread to enable them to sink quickly when submerged, and laced together in bundles of eight with polypropylene strapping and plastic buckles. A variety of tools including special knives, punches, axes and power chain saws were used to cut the tires; however, the most effective proved to be the bushman bow saw.

For the first tire drop a bottom opening hopper barge was used. This proved unsatisfactory, however, as the tires jammed in the hold when the doors on the bottom of the barge were opened and had to be freed by divers. Once on the seabed the bundles were checked by the divers to ensure an even coverage of the bottom, and those around the periphery of the reef were tied together to restrict any subsequent movement. There was no attempt to build up the height of the reef by placing the bundles on top of each other as had been done with the Lake Macquarie reefs.

For the two subsequent drops, a grab hopper dredge, which scooped the bundles of tires from its hold and dropped them over the side was used.

Before the reef was built, an assessment was made of the probability of the tires being disturbed during heavy storms. It was estimated that only about once in ten years would the seas become sufficiently rough to dislodge the newly-laid reef and that after the reef had been consolidated the chances of dispersion would be remote. Unfortunately, however, in the winter of 1971 Adelaide's beaches were lashed by the most severe storms for thirty years and the storms, together with the fraying of the polypropylene lashings, partially dispersed the reef and covered the tires with sand eroded from the beaches.

Before these storms, it had been noted that weed growth and colonization by fish had occurred rapidly on the reef. Snapper, red mullet (Upeneichthys porosus), old wife (Enoplosus armatus), leatherjackets (Aluteridae family), boarfish (Histiopteridae family), and common and rough bullseye (Pempheris klunzingeri and Liopempheris multiradiata) and others had been seen on the reef within six months of its construction. The reef has been visited a number of times since 1971 and the latest reports indicate that the tires are being uncovered as the sand over the reef is being eroded away and the reef recolonized.

THE GLENELG REEF

The second of South Australia's reefs was commenced in March 1973 when 7,000 motorcar tires were laid in 18 meters of water 5 kilometers off the Adelaide suburb of Glenelg. An additional 18,000 tires were put down in January 1974 to complete the reef.

Construction of this reef was supervised by the Department of Fisheries.* In contrast to the volunteer labor force used in constructing the Henley reef, the labor for cutting and binding the tires was arranged through a private firm of contractors and financed by a Metropolitan Unemployment Relief Scheme.

The site chosen for the reef was near the edge of a natural calcareous reef of low relief. The original 7,000 tires were in fact inadvertantly dropped on the edge of this natural reef, but the 18,000 tires in the second drop were spread over the adjacent sand.

Colonization of the reef has occurred; tube worms (Galeolaria sp.) and small tufts of algae are present on most of the tires. A number of diving surveys have been conducted during which 17 species of fish were noted.

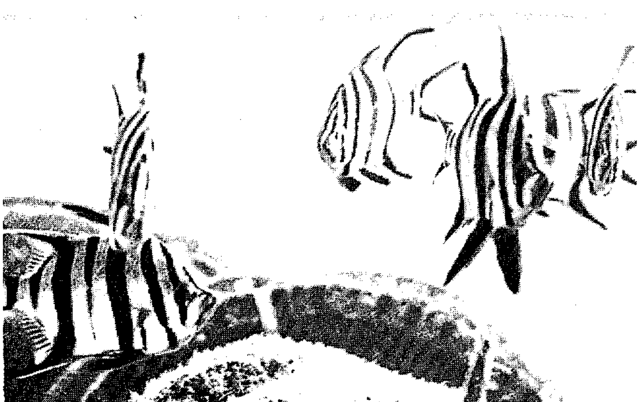
An interesting feature of the reef's construction was the use of a helicopter (Bell type 47G 3B1) to place the original 7,000 tires. The helicopter was used to transport 35 tires at a time from the beachfront to the reef site over a period of five days. The total cost of hiring the helicopter was $2,984, equivalent to $15 per trip of 41 cents per tire.

The second drop of 18,000 tires was accomplished using a barge hired from the Department of Marine and Harbors. The total cost of building the reef, including labor and material plus the cost of hiring the helicopter and barge, was about $11,000.

OTHER SOUTH AUSTRALIAN REEFS

With the assistance and supervision of the Department of Fisheries, a number of additional reefs have been built in other areas of South Australia.

*Previously the Department of Fisheries and Fauna Conservation.



Old Wife Enoplosus armatus on the Henley reef. (Photo by courtesy of the South Australian Department of Fisheries).

Common bullseye Liopempheris multiradiata on the Henley reef.

In October 1971, 5,000 tires were laid off Whyalla about two kilometers from a small motor-car body reef previously established by a local fisherman. This has been monitored subsequently by the Whyalla Spearfishing Club and good numbers of fish have been reported on the reef.

One thousand four hundred motor tires grouped in bundles of eight were placed in six meters of water four kilometers offshore from Black Point near Port Vincent.

Approximately 2,000 tires were laid 1.5 kilometers offshore from Tumby Bay jetty near Port Lincoln in January 1972 and in June of the same year the Kingston Lions Club constructed a reef from 700 tires in six meters of water about three kilometers off the Kingston boat ramp at Threadgolds Beach.

An interesting feature of the construction of the Kingston Reef was that the tires were not dumped but slid down a rope pulled taut between the boat and a heavy chain laid along about 105 meters of seabed. The tires subsequently were secured by means of the chain, and another 30 tires, secured by iron rails, were laid within 100 meters of the main reef.

THE ROTTNEST REEF

The only artificial reef established in Western Australia was put down in 1971 off Rottnest Island. It consists of 80 motor tires anchored by steel cables to a flat sandy bottom. The tires were dropped by the Underwater Explorers Club of Western Australia in the hope that they would provide home-sites for the rock lobster (Panulirus longipes cygnus). There are plans to place a further 100 tires on the reef although as yet its success in providing lobster habitat is not known.

A further interesting development in Western Australia is a study by the C.S.I.R.O. Division of Oceanography of the use of concrete shelters as home sites for juvenile rock lobster (Chittleborough, 1973). Fifty-two of these shelters were placed in 4.5 meters of water, two kilometers off Cliff Head in December 1971, and a similar number were laid nearby in February 1972. Although tagged juvenile lobsters were placed on the reefs, none were observed by divers four weeks after seeding. The success or otherwise of this type of structure is being studied further.

CONCLUSION

There is an increasing number of requests for more artificial reefs to be constructed in Australia, particularly in those localities where the intensity of fishing by recreational fishermen is high.

The government agencies have responded to this pressure by establishing guidelines to ensure that this activity is properly rationalized. All prospective reef builders are required to obtain the approval of the relevant port authority as well as the fisheries department. A written application which includes a description of the location, the reef material, depth of the reef and its configuration and safeguards against dispersion of the reef, etc., must be submitted. It is usually mandatory for a government official to be in attendance during construction of the reef.

When granting approval, care is taken to inform the builders that they cannot regard the reef as their private property, but must allow it to be frequented by anyone who knows its location.

In a few states, proliferation of reef construction is being discouraged, at least until valid assessments of the existing reefs have been made. This is a little incongruous, however, as nowhere in the country has a research program been designed to provide the type of assessment which is necessary. The present research is directed toward the preparation of species lists and the determination of the rates of colonization of the different reef materials. It would be more appropriate to assess a reef's success in terms of its enhancement of the area for recreational activities such as angling, spearfishing and sport-diving. For angling and spearfishing, research should aim at a comparison of the number and size of sport-fish taken from the fishing grounds (including adjacent natural reef areas from which fish may be attracted) per unit time before and after construction of the reef. For sport-diving, an assessment of the increase in the number and variety of fish species seen and the improvement in the aesthetic quality of the aquatic environment is the type of research required.

ACKNOWLEDGEMENTS

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Department of Fisheries, Adelaide, South Australia

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Oil Structures as Artificial Reefs

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There are approximately 1,700 artificial reefs in the northern Gulf of Mexico, of which about 575 are of major size, costing between one and five million dollars each (Figure 1). They have revolutionized fishing in the Gulf of Mexico, especially in Louisiana. This is evident by the hundreds of small boats that often venture more than 30 miles from shore on weekends to fish these reefs. Not only have these artificial reefs revolutionized small-boat sport fishing, but they have also spawned a sizable

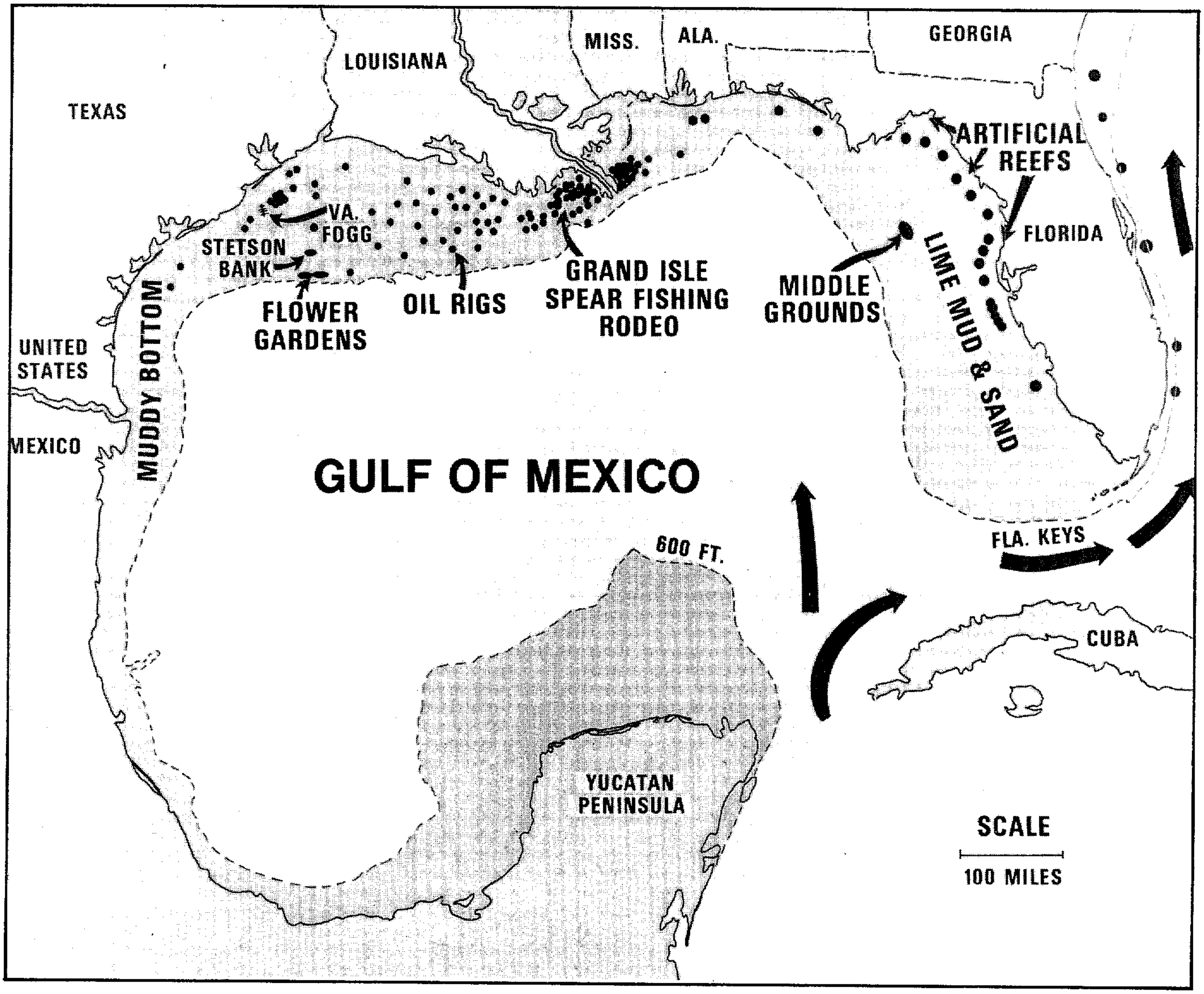


Figure 1

charter and "head-boat" (boats carrying large numbers of fishermen at a fixed cost per head) industry, concentrated in Empire and Venice, Louisiana. At times, even commercial snapper fishermen utilize these reefs.

Whereas construction of conventional artificial reefs usually requires formation of sport fishing committees, and two to three years of negotiations to obtain various permits, the 1,700 reefs discussed here cost sport fishermen neither time nor money.

The reader now is probably aware that these reefs actually are offshore oil and gas production platforms. Admittedly, they were not constructed for fishermen; but it did not take long for fishermen to discover them. Their popularity as fishing sites has grown progressively since the late 1940's. Only recently however, have we begun to understand why platforms attract and produce such large quantities of fish.

This paper will discuss various factors such as high profile and unimpeded water flow, that make platforms such efficient artificial reefs. In addition, the paper will discuss some ways to: (1) enhance these reefs; (2) suggest how obsolete platforms might be used for reef construction; and (3) make fishermen aware that, in compliance with government regulations, all platforms eventually will be removed from the sea.

ADVANTAGES OF OIL PLATFORMS AS REEFS

- Offshore oil platforms are easy to find since they extend more than 40 feet above water level and are equipped with lights and horns.

DISTRIBUTION OF TURBID LAYER NORTHERN GULF OF MEXICO

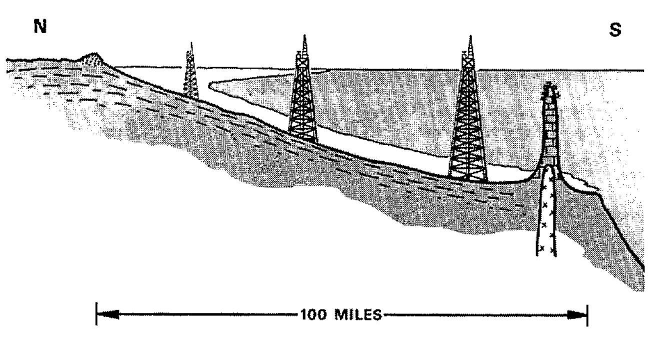


Figure 2

- Platforms have a high profile. There is agreement among artificial reef researchers that a high profile is desirable. It is especially desirable in the northern Gulf because of a persistent, 20-30-foot thick, murky layer that lies on the bottom of most of the Continental Shelf in this area (Figure 2). It has been shown that this murky layer reduces light penetration to such an extent that algae cannot exist over much of the bottom (Griffin, 1973). The effectiveness of a low-profile reef in this area would, therefore, be reduced (Figure 3). Very little algae, which is necessary for browsing herbivorous fish, could grow on such reefs. Oil platforms, on the other hand, extend the full range from clear, sunlit shallows to the murky cold depths.

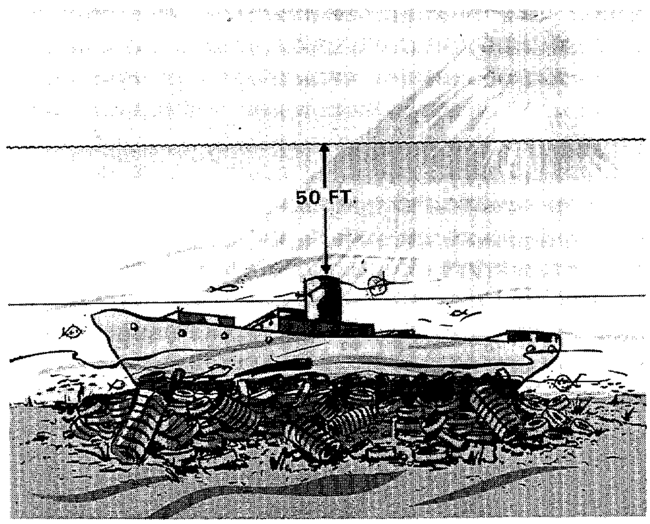


Figure 3

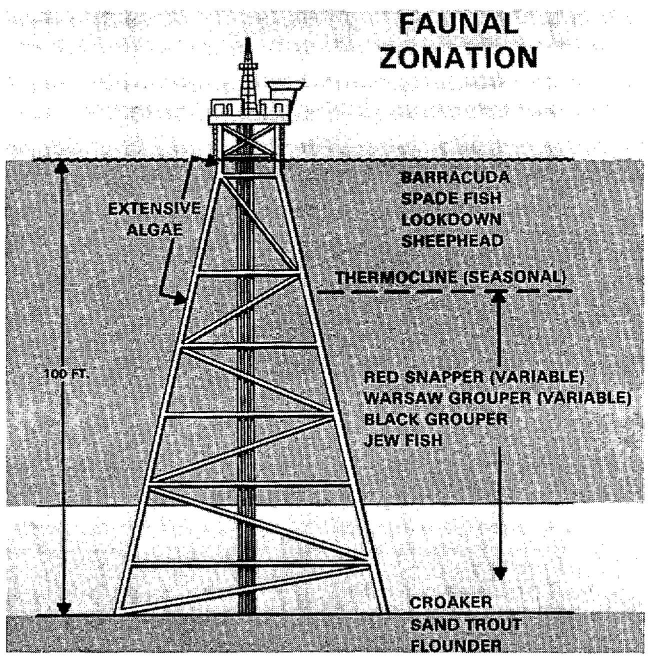


Figure 4

Many are in more than 200 feet of water; one such platform spans the entire range down to a depth of 375 feet. Diving observations by me and others have shown a noticeable faunal zonation with variable indistinct boundaries (Figure 4). Spadefish, for example, are almost invariably found in the upper zone along with barracuda and sheephead. Red snapper, which on natural reefs in this area are generally below the 200-foot contour, often swim to within 20 feet of the surface under oil platforms. Their upward limit ap-

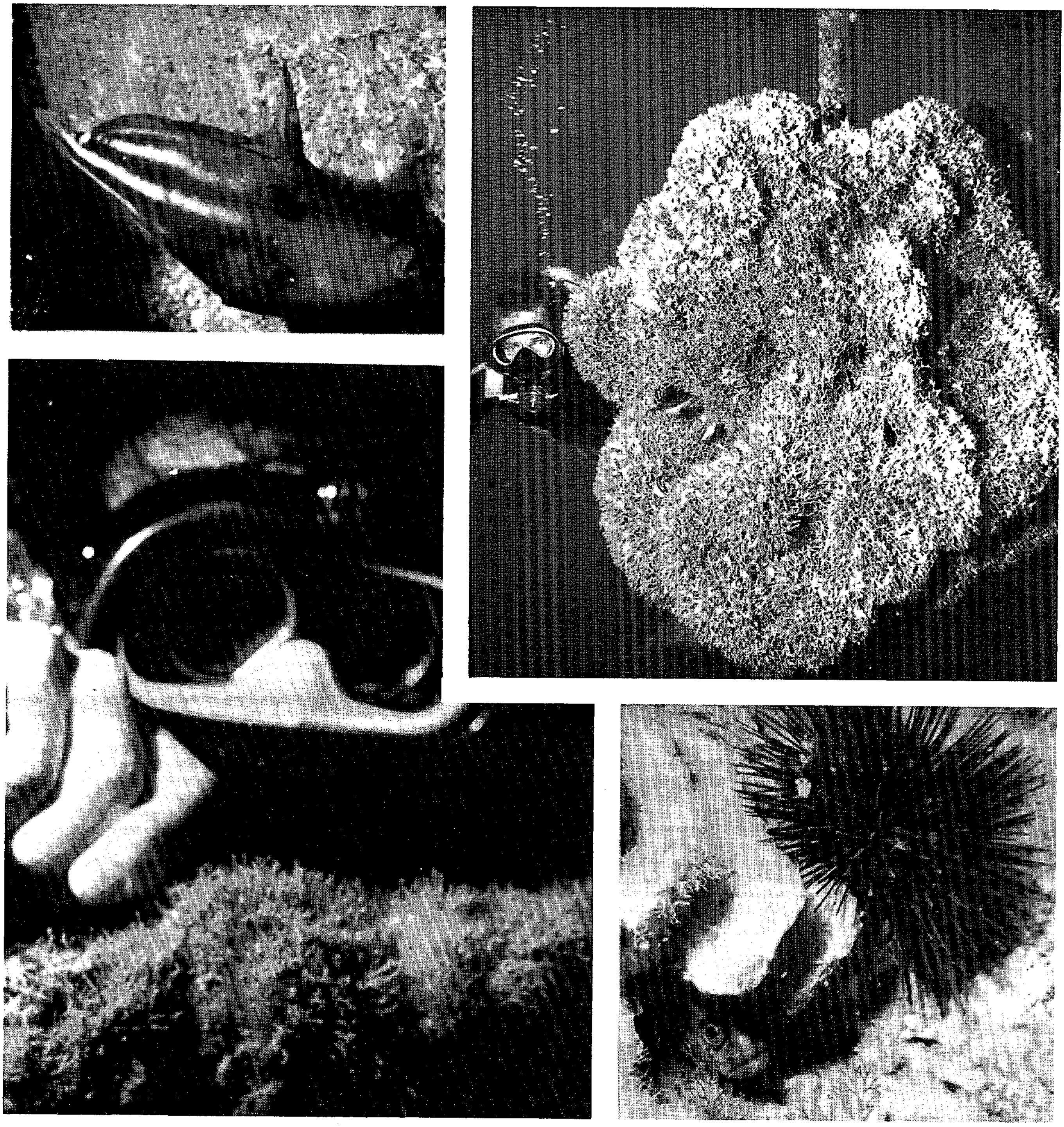


Figure 5

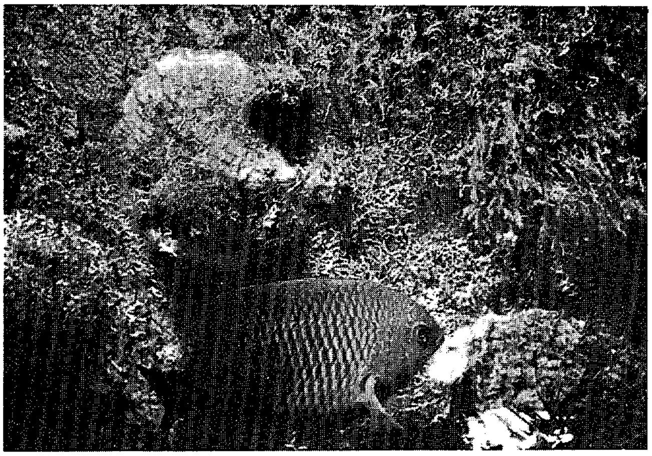
pears to be controlled by a seasonally variable thermocline. In many areas, the water above the thermocline is more turbid than below, but seldom as murky as the bottom layer. Large groupers, including blacks, warsaws and jewfish, are basically bottom-dwellers, but spend much of their time in the midwater range beneath platforms. Speckled trout, sand trout, and flounders, however, are restricted to the bottom.

- Platforms offer little resistance to water flow, an attribute thought to be desirable by most artificial reef researchers.
- Platforms offer a large surface area for the attachment of encrusting organisms. A typical platform in 100 feet of water, as shown schematically in Figure 4, has approximately two acres of hard surface exposed to the water column. This surface area compares favorably with the surface area of about 6,000 tires (including the interior surface of each tire).

Figures 5-7 are typical views of fish beneath oil platforms. Many species of fish can be observed browsing on the encrusting organisms that inhabit these surfaces.

In addition to high profile, most reef researchers agree that surface area and unimpeded flow of water are preferred. Schooling fish, for example, will not occupy the holds of sunken ships if these holds have restricted access to the exterior, probably due to reduced current, light, food and dissolved oxygen. The attractiveness of oil platforms to fish probably could be enhanced further by increasing surface area. Figures 8 and 9 illustrate two ideas for increasing surface area by adding tires. Addition of about 6,000 tires would approximately double the surface area available for algae production and fish habitation under a typical platform.

There are, however, reasons against adding tires to every oil platform. Besides considerable engineering and structural problems, existing Outer Continental Shelf regulations require that platforms be removed 15 feet below the sediment level when oil or gas production is terminated. The site must then be dragged clear of anything that could catch a fisherman's net. Cost of salvage is, therefore, extraordinarily high; and the removal of 6,000 tires would drive costs even higher. Since this salvage cost is borne by the platform owner, there is obviously little incentive to add material that would escalate removal costs. Salvage costs



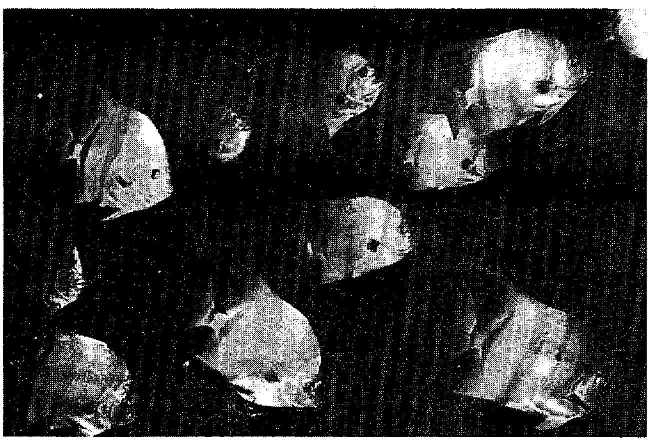
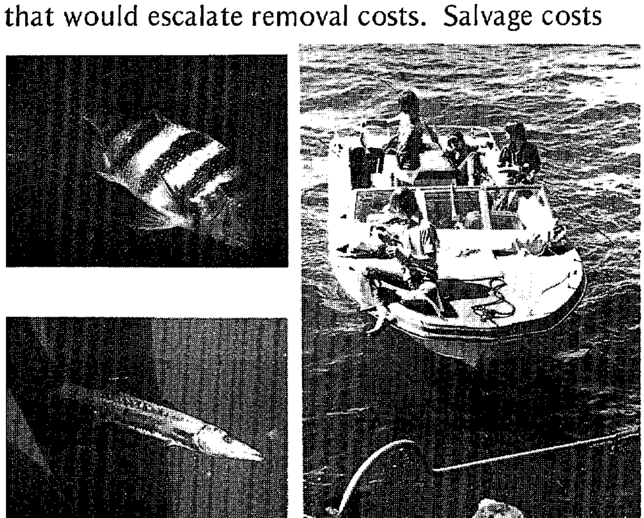


Figure 6



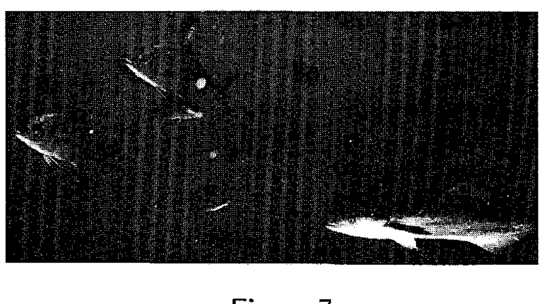


Figure 7

for typical offshore platforms range from one-half to two million dollars. The cost of salvaging future platforms planned for 500 to 1,000 feet of water could be several million dollars.

Gulf of Mexico fishermen should be advised that all offshore platforms will be removed eventually; and, unless a significant number of artificial reefs are established, fishing success will return to the level prior to offshore drilling. Such predrilling conditions probably will not sustain the tremendous fishing pressure that has developed over the past 20 years.

It is thought, therefore, that some obsolete platforms, especially those in convenient areas, should be left in place as artificial fishing reefs or sanctuaries for fishery-management purposes. Some platforms could serve as permanent markers for large-scale reefs built nearby or between platforms, as suggested in Figure 10.

Alternatively, salvaged platforms could be placed on their side in artificial reef sites composed of liberty ships, tires, autos, pipes and other nonpolluting solid materials to provide additional high profile material and surface area (Figure 11). There probably exists an economic incentive for barging salvaged platform components to established reef sites since a significant percentage of salvage cost is incurred on shore, where welders cut the scrap into small pieces for recycling. Presently, labor costs greatly exceed the value of the metal, making salvage and recycling an uneconomic venture. This could change if scrap prices rise significantly and labor costs remain fixed. However, it seems likely that federal or state agencies that wish to add platform components to existing reefs might obtain them free of charge, including towing costs, by contacting the oil companies that operate offshore. They should, however, have all necessary permits in hand before making a request.

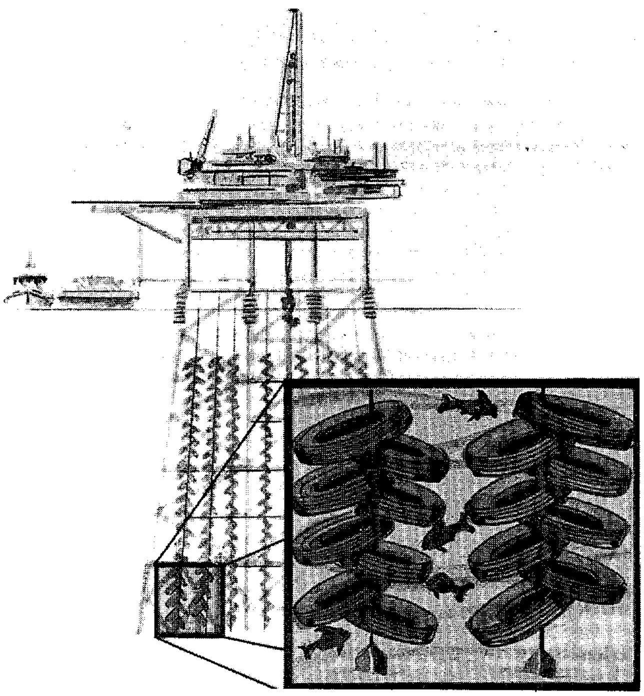


Figure 8

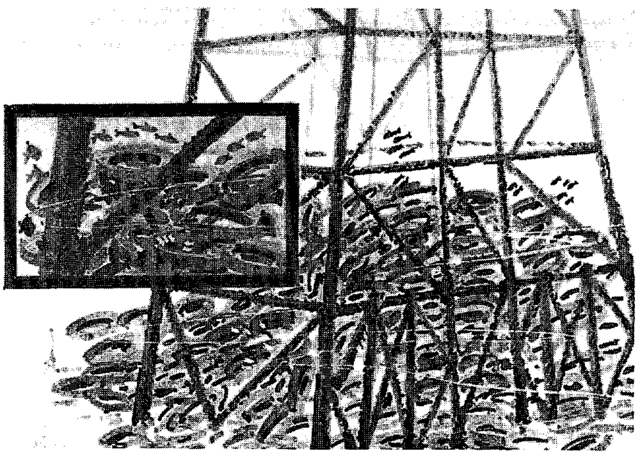


Figure 9

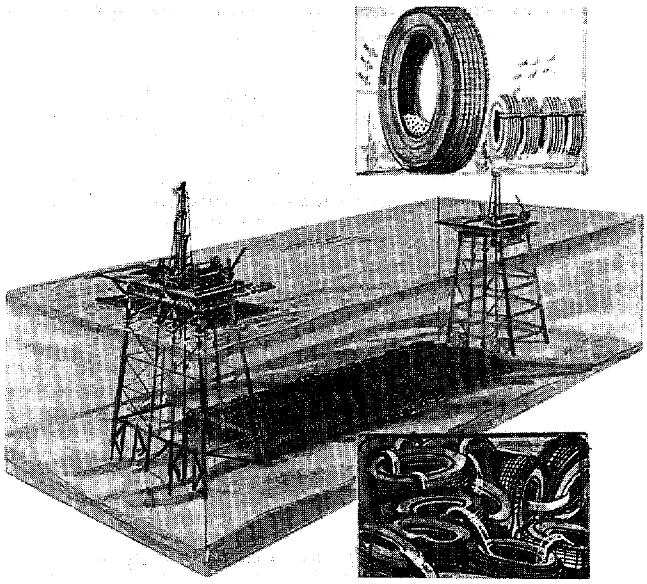


Figure 10

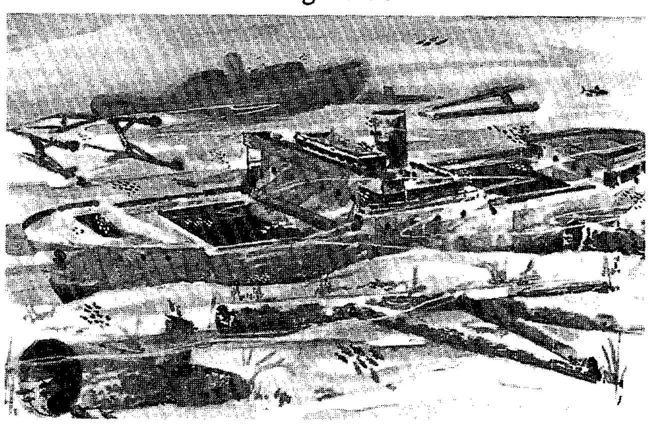


Figure 11

PRODUCTIVITY VS. CONCENTRATION

One significant issue remains unresolved. Do artificial reefs, whether composed of tires, cars, buses, trolley cars, train cars, culverts, logs or oil platforms, either in place or lying on the bottom, simply attract existing fish populations, or do they increase productivity? Stone has some evidence indicating increased productivity around tire reefs, but no one has enough proof to demonstrate that this is true of oil platforms. It should be clear, however, that oil platforms are essentially the same as any other artificial reef composed of ships, tires, etc. Therefore, if artificial reefs do increase productivity, then certainly oil platforms do this as well. Even the most casual observer can see the similarity between platform cross-members, etc., and the open-space structures employed in Japan that are described by Ino. Future studies hopefully will shed more light on this question.

CONCLUSIONS

- Working oil platforms are effective artificial reefs because: a. they have high profile, extending from the surface to the bottom; b. they do not significantly impede water flow; and c. they are found easily by fishermen, i.e., they do not require lighted buoys as do conventional reefs since they already are lighted in compliance with Coast Guard regulations.
- Disassembled oil platform parts would make excellent reef-building materials because: a. they could provide high profile; b. they do not impede water flow; and c. they may be provided to various agencies free of charge when available.
- The fishing public should be aware that this form of fishing reef eventually will be removed from the Gulf of Mexico and, therefore, some platforms should be considered natural resources and preserved for fishing and sanctuary purposes.

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Habitat Improvement on the Continental Shelf of Georgia

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An abundance of reef dwelling fishes may be found some 80 nautical miles off the Georgia coast at the edge of the continental shelf. The scope of current reef activities however, involves the creation of fishery habitat at locations sufficiently near shore to make a portion of our rich bottom fishery accessible to a greater number of sport fishermen.

Prior to 1971, various materials such as automobile bodies, refrigerators, stoves, etc. had been used to create fish habitats at several locations along the Georgia coast. Very little evidence remains today of these early efforts by local interest groups. Lack of technology was the single most significant factor contributing to the failure of these attempts.

As the concept of habitat improvement in the oceans gained popularity and with the development of technology associated with artificial reef construction, the Georgia Department of Natural Resources saw an opportunity to improve Georgia's offshore fishing.

In the summer of 1971 the Department of Natural Resources placed 13,000 scrap automobile tires on the ocean floor 13.5 nautical miles east of Cumberland Island, Georgia to augment habitat created by the World War II sinking of a Dutch refrigerator ship. Since that time, the Department of Natural Resources has completed three additional artificial reefs utilizing two salvaged vessels and approximately 102,400 scrap automobile tires. Reefs have been created at distances of 8.2, 9.0, 13.5 and 23.0 nautical miles offshore in depths of 40, 50, 55 and 75 feet, respectively.

TECHNIQUES OF ASSEMBLING AUTOMOBILE TIRES INTO FUNCTIONAL MODULES

The preparation and subsequent sinking of vessels for reef material is rather elementary and will not be discussed here. Designing a module using automobile tires requires considerably more engineering and ingenuity.

The module design with which the Department of Natural Resources started its offshore artificial reef program and is continuing to use is the multi-tire unit developed by the National Marine Fisheries Service at Highlands, New Jersey. The basic design is a column of eight automobile tires with the bottom tire filled with concrete for ballast. Steel reinforcing rods are anchored into the concrete and hold the module together. This particular design affords excellent habitat for reef dwelling organisms.

Prevalence of strong currents and bottom surge off the Georgia coast necessitated some modifications of the NMFS design. In order to insure the integrity of the unit under these conditions, a third steel rod was added to the NMFS unit. Heavier steel rods (½ inch diameter) with a 90 degree bend on the end set into concrete also were employed. These modifications produced a more rigid unit and minimized the possibility of the rods pulling out of the concrete under conditions of stress.

The NMFS prototype called for the drilling of holes in the sidewall of the tires to accommodate the steel rods and allow air to escape. Each individual tire was threaded onto the rods. Construction of this type of module was a very slow and costly process. Further modification of the NMFS unit reduced the time necessary to assemble each unit. By using heavier, preformed steel rods and allowing these to pass through the center of each tire, the need for drilling of the tires was eliminated. It has been found that provision for the escape of air from this unit during sinking is unnecessary if the unit is properly ballasted.

An assembly line technique utilizing preformed steel rods and a press has proved to be the most efficient means of assembling the modules. Ease of handling of this type of module made it very attractive to the Department of Natural Resources from the standpoint of getting the unit loaded and overboard. This particular module may be moved by hand or heavy equipment. The Department of Natural Resources has determined that the most effective means of loading involves the use of a dockside crane. The most functional technique for unloading appears to be by hand.

Many governmental agencies and local interest groups have initiated artificial reef construction programs by assembling and installing the materials themselves. The state of Georgia has taken another approach in which contracts are negotiated with marine oriented firms to assemble and place the modules on the ocean floor. The Department of Natural Resources, of course, inspects all phases of the operation to insure compliance with reef construction specifications. While this approach is slightly more expensive, it has been very popular in Georgia. Current cost to the state of Georgia to build and place one module on the ocean floor is $11.

TECHNIQUES OF PLACEMENT OF MATERIALS ON THE OCEAN FLOOR

Many artificial reefs have been created in recent years using a wide variety of techniques. The following discussion is an account of Georgia's successes and failures.

Early efforts involved the offloading by hand of modules from a slowly moving vessel. The end result was that units were sparsely distributed over a large area. These produced very poor fishery habitat and were virtually impossible for sport fisherman to locate.

The other extreme involved the anchoring of a large barge and unloading of the modules as the barge tethered on an anchor line. The end product was a massive heap of modules in a small area. While this technique afforded excellent habitat and was relatively easy for sport fishermen to locate, a great number of modules on the bottom of the pile were wasted by not being readily available for colonization by fish and invertebrates.

Most recently, reefs have been created by holding a large barge between two markers for offloading with the tow vessel. In this manner, Department of Natural Resources personnel can continually survey (depth recorder) the accretion of materials and reposition the markers as an area approaches the desired density of modules. This technique has produced the greatest amount of high quality fishery habitat with a given number of modules. It has been determined that the desired density of modules occurs when depth recorder survey indicates close clumping of modules over a large area with no more than six feet of vertical relief indicated.

We have further ascertained with respect to the configuration of components within a given reef that low profile material such as automobile tire modules primarily contribute individual niches for smaller organisms. Large masses of material, such as a large mound of tires or a vessel, provide not only a mass which serves to interrupt current patterns but also visual stimulus to many fishes, particularly the pelagic species.

DEVELOPMENT OF ADDITIONAL MODULE DESIGNS USING SCRAP TRUCK TIRES

The Georgia Department of Natural Resources has designed and installed modules composed of scrap truck tires. These tires are much larger and heavier than passenger car tires and, by the nature of their structure after recycling, afford more desirable habitat than that created by passenger car tires.

The integrity of individual modules is maintained through the use of nylon bands and clips. All modules were tested in areas exhibiting relatively heavy bottom surge. One unit was placed in 50 feet of water with no ballast. Within 30 days the unit had moved off the reef and could no longer be located. Another unit also was installed with no ballast at the same location. Sixty days later, the unit was in the vicinity of the reef but had moved considerably. At this point the unit had not yet sanded-in to a degree which would make it immovable.

Test results have shown that both of the previously discussed designs must be ballasted when used in areas with bottom surges such as those prevailing along the coast of Georgia.

These conclusions prompted some modification of our placement techniques. Eight of the modules were threaded onto a cable 50 feet long with 125 pounds of scrap iron at each end. One of these strings was recently placed in 40 feet of water and stability of this configuration is currently being monitored. Final results of these experiments will be available at a later date.

Tires used in these experiments were supplied through the courtesy of Al Mitchell, Mitchell Industrial Tire Co., Inc. Chattanooga, Tenn. 37407.

MARKING OF ARTIFICIAL REEFS

Georgia Department of Natural Resources has attempted to mark offshore areas for fisherman use for several years. Most of the buoy systems utilized have been totally unsatisfactory. Recently, however, a system has been developed which shows great promise as one which will endure the seas and surge prevalent along the Georgia coast.

The buoy design is similar to the USCG class three steel nun buoy. The buoys now used in Georgia were constructed by the Department of Natural Resources at a cost of approximately $300 per buoy. The finished product also may be obtained from a number of local firms.

While the Georgia buoy systems have been in use for just nine months, we can begin to speculate on a sound maintenance schedule. It appears that maintenance of the buoy (scraping, painting, etc.) will be required every two to four years. Mooring chain should be serviced annually. This includes replacement of worn fittings and links of chain.

By and large, the Department of Natural Resources has been very pleased with the utility of this design. Publication of our recommendations is anticipated in the near future.

Alabama's Artificial Reef Program

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The saltwater angler in Alabama is lucky because he has a variety of species of fish and types of fishing from which to choose and generally the fishing is very good. The fishing techniques and fish vary from the pole-and-line fisherman on the bank who fishes for croaker, spot and mullet, to the fighting chair enthusiast who battles marlin and other billfish off the 100-fathom curve.

Nature has provided Alabama fishermen with good estuarine fishing, offshore trolling, and abundant shrimp, crabs and other shellfish. The one thing that Nature has failed to provide for the Alabama angler is an abundance of submerged reefs, the haunts of bottomfish such as red snapper and grouper. Only two small natural reef areas exist off the Alabama coast.

Fish are attracted to a reef because it provides a place of refuge from larger predators and also because the food supply is increased by the vertebrate organisms that live in the reef. These organisms attract smaller fish that serve as food for larger fish. However, many fish are attracted simply because the reef provides a point of reference in a bottom habitat that often is as barren as a desert. These fish are known as thigmotropic (attracted to an object by a touch stimulus).

The Marine Resources Division (formerly the Seafoods Division) of the Alabama Department of Conservation and Natural Resources has been constructing artificial reefs to compensate for the lack of natural reefs off Alabama's coast and in its bays. The offshore reefs have been constructed in 60 to 90 feet of water. These reefs attract snapper, grouper, triggerfish and other species. The reef sites also are excellent trolling locations for king mackeral, amberjack and ling. The inshore reefs in Mobile Bay are built for small-boat fishermen and attract white trout, ground mullet and speckled trout.

HISTORY OF REEF CONSTRUCTION

The Marine Resources Division of the Alabama Department of Conservation and Natural Resources was the first state organization to construct fishing reefs in the Gulf of Mexico. In 1953 the Orange Beach Fisherman's Association approached the Division with a plan for building artificial snapper banks. In the fall of that year, 250 automobile bodies were placed off Baldwin County along the 60-foot contour. Fishermen began to take snapper within six months.

Because of the success of these reefs the Department placed an additional 1,500 used car bodies offshore in 1957. These were placed in small groups on the 60-foot contour extending across the greater part of Baldwin and Mobile counties. These reefs cost the state $71,409, or less than $41 per car body for purchase and placement. These car bodies have deteriorated, but provided good fishing for a period of three to seven years.

The placing of car bodies in the western tier off Mobile County was a mistake as many were moved by storm tides and caused great difficulty to commercial shrimp fishermen. After that time reef placement was closely coordinated with the seafood industry.

In July, 1959, the Department and the Mobile County Wildlife and Conservation Association sank a 300-foot drydock 12 miles off the Mobile County coast. The drydock was placed near a barge which was sunk during World War II. The drydock produced excellent fishing and is still a productive reef. The gradual deterioration of the car bodies resulted in very heavy fishing pressure on the drydock reef and fishing success declined.

In November, 1962, 300 tons of imperfect concrete roadway culverts ranging in diameter from 2 to 6 feet and in lengths up to 10 feet were sunk off Perdido Pass. Five individual, closely-spaced reefs were created. Snapper fishing was excellent and fishing continues to be good on these reefs. In 1970 an additional 600 tons of culverts were added to this reef and a new reef was created off Ft. Morgan peninsula by sinking 600 tons of culverts. These reefs were financed by Dingell-Johnson funds through the Department's Game and Fish Division. Both areas were buoyed and produced very good snapper fishing. In December, 1972, approximately 2,000 tons of culverts were added to the Ft. Morgan peninsula reef, dropped in a one-half-mile line. Each culvert produces good catches for one boat.

In 1964, six experimental reefs were placed three to five miles southeast of Fort Morgan. The reefs were designed to test the effectiveness of one- and ten-culvert groups in three different depths (30, 40, and 50 feet) against control areas at each depth. Unfortunately, these reefs failed to provide good snapper fishing because they were located too close to the mouth of Mobile Bay where they were subject to flows of turbid water during much of the year. The reefs did produce good fishing for silver seatrout. The failure to attract large numbers of snapper led to the decision to construct reefs within the bays, since good seatrout fishing could be produced in the bays where better protection was provided for the small-boat fisherman.

The Marine Resources Division began its inshore reef program in 1971. Two 3-acre reefs have been constructed of concrete rubble. The placed approximately 2,000 tons of rubble on each reef site. One of the reefs provided a good fishery while the other was rather poor. The difference was attributed to the size of the reef material. The tires are tied four to a bundle and weighted by old chain. Each bundle is constructed so that the tires stand on their treads with the hole in the vertical plane and form a cross when viewed from above. This prevents the tires from being moved by wave action. The reef material should become encrusted with oysters within four years. Six additional inshore reefs will be constructed of tires during 1974 and 1975. The Division is presently stockpiling materials for these reefs.

In December, 1972, a 60-foot steel pushboat was sunk off Fort Morgan penisula. This boat has not been buoyed or, to our knowledge, fished. The Division will buoy it two years from the date it was sunk to compare catch statistics to those from reefs which are subjected to fishing pressure as soon as they are sunk. Two additional 175-foot barges were sunk in early 1974 near the culvert reef. Snapper moved in on the reefs within weeks, probably from the culverts located nearby.

LIBERTY SHIPS

On January 22, 1971 Alabama Congressman William Dickinson introduced HR650 to authorize the transfer of Liberty ships to the state for artificial reefs. The act was passed and was signed into law as P.L. 92-402 on August 22, 1972. Under this act, five ships were transferred to the State of Alabama in December, 1973. The ships presently are being salvaged prior to sinking. Each ship will be cut down to the 15-foot water line to allow them to be sunk closer to shore. The value of the salvageable material (all non-ferrous metals and 76 percent of ferrous metals) will pay for sinking the vessels. In addition, the salvage value produced additional revenue in the amount of $25,000 for the Division's reef program. Two of the reefs will be placed off Mobile County near the drydock and three will go off Baldwin County.

The State of Alabama has filed for transfer of an additional five ships. If these are transferred, all go off Baldwin County in waters where there is no commercial fishing.

The first five ships will be sunk before the end of 1974. If the additional ships are obtained, it is planned to sink them during 1974 and 1975. All ships will be buoyed and will have a minimum of 63 feet of water over the hulls. Each of the ships should provide fishing for a minimum of 100 years.

FUTURE PROGRAM

The Division will sink an additional seven barges and boats off-shore during 1974. These consist of old wooden tug boats and steel barges of up to 250 feet in length.

Over the next several years the Division plans to continue to sink vessels, culvert, etc. All previous work with the reefs has been done on a very meager budget and with a great deal of help from individuals and corporations which donated the materials and helped to place them offshore. The Division will sponsor a marine sportfishing license measure which has a good chance of being enacted by the Legislature. If this bill passes, funds will be available to intensify greatly the scope of the program.

Presently, some areas have been leased for oil exploration which will increase the fishing opportunity off the Alabama coast greatly.

ACKNOWLEDGEMENTS

The Marine Resources Division would like to express its appreciation for the services and reef materials donated by the following: Radcliff Materials Company, Inc.; Horton Pipe Company; Buffalo Towing Company; Otto M. Liscomb Company; Charles Adams; Russel Steiner; Captain Armand Annan; Bill Childers; Captain Leon Esfeller; the Orange Beach Fisherman's Association; Mobile County Wildlife and Conservation Association; Century Step Company; Mobile District U.S. Coast Guard; and the U.S. Navy Coastal Systems Laboratory.

North Carolina's Artificial Reef Program

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Within the next six months, North Carolina will have the most ambitious on-going artificial reef program I am aware of. We had hoped to be further along in our program by the time of this conference, but we are not. Therefore, I can only outline our plans and, in the future, if your various programs take a turn in the direction ours is going you can contact us to see how we are doing.

We have been lucky to be able to use the groundwork laid down by others. And, besides beginning by being able to profit from the best ventures, we have a good sum of money the next six years earmarked for reef work. This year we will have approximately $200,000 for our program. In addition to funds, our agency already has much of the equipment needed, such as a self-propelled 110 foot barge, a big truck, a tractor and sea-going vessels.

Only two months ago, however, the picture was even brighter and we were assured of $250,000 or more annually. Short months ago we thought our funding base was solid. It is, however, based on the sale of gasoline Our agency is to receive one-eighth of one percent of the state motor fuel tax. This amount was made available in 1973 by the North Carolina State Legislature to be used exclusively for artificial reefs. The reasoning comes from unrebated state tax on fuels used by boats. Someone asked the right people why boat taxes should go to highway use. A person can file for a return of taxes he paid on motor boat fuels, but many people do not file these claims. The story goes that someone figured the amount of unrebated taxes due to boaters equaled about one-fourth of one percent of the taxes. So in 1967 the freshwater agency began to receive half of it, or one-eighth of one percent. Then, in 1973, another one-eighth was designated for salt water use.

The freshwater agency has used their funds for access areas and boat ramps, and for boating safety programs and enforcement of boat safety regulations.

Other states, and possibly non-governmental councils, should consider this funding source. Even if our funding were to be eventually cut back badly or disappear in six years, it would remain substantial long enough for us to get a very good start and get to the stage where we could illustrate solidly what can be done. Then we would perpetuate the program with the cooperation of local governments such as Gregory McIntosh outlined earlier in the Fort Lauderdale situation.

Also, trying to profit from what we have seen in other reef operations, we have one person heading up biological and monitoring phases and another individual heading up construction and transportation phases. Also, we want to communicate the success of the reefs to fishermen, and a statistically sound creel census program is as important to us, perhaps more so, than reports of divers about all the fish down there.

We plan at least 13 ocean reefs and six estuarine reefs. The ocean reefs are spread along a 320 mile coastline. The estuarine reefs will be in 60-mile-long Pamlico Sound.

In the ocean, depths of reef sites will range from 35 to 72 feet. Distances from shore will be one and one-fourth to three miles. We are keeping the reefs within the three mile state limit so we can have some control. And, too, access by small boaters figured heavily in selecting sites for proposed reefs. If at all possible, we want the small boater to be able to get out on the reefs many days of each year. Of course bottom type, currents, surge, commercial use, etc. also were considered. We were able to keep away from areas of high intensity commercial fishing use in all areas except one. And in that area we were able to select a site that the commercial fishermen were willing to accept.

Our proposed reefs can be subjected to comparative studies, such as depth differences and the success of reefs adjacent to natural rock compared to barren-area reefs. Most of North Carolina's close-to-shore bottoms are sand and sand/silt. In the southern sector we do have a few small low profile marl outcrops with associated, or subtropical communities of sponges and soft corals and encrusting organisms.

In the estuaries, water depth at the reef sites is 10-12 feet. Salinity at one site dips to one percent and at other sites never goes below 10 percent. It appears that mean salinities will be less than 15 percent. We have two small experimental tire reefs in Pamlico Sound, one in the northern sector and one in the southern. The old standard concrete-in-the-bottom tire and five tires on top with reinforcing rods binding method is used. Units have been overboard since last April. We are monitoring monthly succession with detachable 25 square centimeter pieces of rubber.

Scrap tires will be our main component. Basically, we are using South Carolina's tire construction method as outlined earlier this afternoon by Dewitt Myatt. We will sink our first Liberty Ship within the next month. Two more are definitely coming to North Carolina, with a possibility of two others. We plan composite ocean reefs with other old boats and ships and chunks of concrete, when available. We will probably stick with tires exclusively in the estuaries.

Secondary Utilization of Areefs for Large Scale Habitat Anchorage

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It is apparent that the rapidly increasing demand for protein products from the sea on the one hand, and the decreasing fisheries yield on the other, are creating a problem which calls for a rapid and effective solution, however novel or pragmatic it may be. If then, for the purposes of this discussion, the problem area is confined to the harvesting of marine invertebrates and certain fishes it can readily be seen that the extensive employment and use of Areefs (artificial reefs) offers a technologically feasible and perhaps economically viable system for open sea mariculture.

While the basic methodology is centuries old and the work done in recent years by Turner (1), Carlisle (2), Stone (3) and others has upgraded and mechanized the techniques and quantified the results, utilization of Areefs for purposes other than simple enhancement of sport fishing areas is not a matter of current consideration. A study of the Areef literature and particularly the extensive and well organized bibliography of Steimle and Stone (4) shows that the vast majority of builders had a single primary purpose which motivated the construction of their particular Areefs. This is, of course, consistent with the fact that the sponsoring agencies for Areef construction were fishing clubs, conservation groups or recreational organizations. It is unlikely that any of these groups would have more than a passing interest in marine resources development per se.

Ocean resource utilization programs, especially in developing countries or areas, however, do have a much wider interest in Areefs. As has been pointed out in a previous paper (5) an Areef project is very effective also as a teaching tool to illustrate the various ecological and environmental aspects of marine resource development and utilization. Because of the ease with which the level of complexity of Areef construction can be matched to the technological capabilities and financial resources of the target populations it seems likely that Areefs will be built at a greater rate in the future. In many places it may be the entire oceanographic effort which an underdeveloped country or area can support. Where this is the case, it is particularly important to examine Areef design and construction from the point of view of determining what additional purposes an Areef can serve with little or no additional cost or effort.

Certainly, if the Areef is part of an ocean resource development program then the primary purpose of the Areef will be as a mariculture substrate system rather than mere enhancement of a particularly bare offshore fishing ground. Considered from this point of view, the Areef becomes large enough and the economic reasons good enough to make it feasible to put to use one of its basic and possibly heretofor overlooked characteristics which is, of course, its massive anchoring capabilities. The nature of a mariculture Areef of any reasonable economic scale is such that habitats of varying sizes and degrees of complexity will have to be integral parts of the Areef mariculture system. The mass of the Areef appears to provide the solution to the buoyancy factor which limits extensive use of large habitats. It seems then, that it will be worthwhile to discuss further the utilization of Areefs as habitat anchorages.

AREEFS-HABITAT SYSTEMS

Both habitats and Areefs have moved rapidly through the experimental or feasibility study stages and are now at the point where their integration into pragmatically oriented marine resource development programs as tools is possible and necessary. In the case of Areefs, sufficient numbers, types and sizes have been built to prove their utility and systematize their design and construction. Habitats also have been built in sufficient variety and used often enough to make it evident that man can live comfortably at various depths for long periods of time.

Let us then look at the habitat and Areef from the point of view of a production system. Consider a mariculture system in which a large Areef is constructed which has the optimum design and pattern for spiny lobster culture, for example - - a farm or hatchery for benthic marine forms, if you will. To be economically feasible, the Areef will have to cover a large area and possibly be divided into sections to provide for sequential harvesting. In this type of operation, small habitats properly spaced around the Areef sections will be required as fulltime observation stations to monitor the work areas and, probably, guard the developing "crop." Since Areef poaching on even limited experimental installations seems to be a growing problem in any kind of mariculture, guard stations are an obvious requirement in any commercial offshore project. The habitat also is required as a way station for the Areef workers - - a place for rest, air replenishment and food. Consider also that the concept of saturation diving is entering into most of the plans for sea floor development projects. Habitats then also become living quarters for the individuals involved in the Areef operations.

It becomes necessary to consider the final development of a fully integrated Areef-Habitat System. This is the case where the location of the Areef makes transportation and transfer difficult and costly on a small per unit basis and where climatic conditions make rapid spoilage of harvested products very likely without extensive refrigeration systems. The obvious answer is the transfer of the canning or packaging operation to the harvesting area, i.e., the Areef. This then implies the direct loading of the finished products to the final shipper in economical lots. At this point we are no longer talking about small habitats, but large high buoyancy installations into which many other factors enter which are well beyond the scope and intent of this paper. We will consider this last case only from the point of view of buoyancy problems and anchorage and with a reference to the Liberty Ship Areef in the final part of this paper.

BUOYANCY-WEIGHT RELATIONSHIPS

The limiting factor in the utilization of habitats appears to be the rapid increase in buoyancy which results from only a small change in usable working area. At no time, in any habitat or way station large enough to hold a diver, is the buoyancy problem negligible, and some provision always must be made for a secure and safe method of keeping the habitat in place. The importance of this factor must not be underestimated; accidental surfacing of a habitat is extremely dangerous and in the case of a saturation dive, the sudden decompression can be fatal.

The significance of the buoyancy/working area relationship can be seen readily from Table 1. Very obviously the limiting factor in habitat usage is going to be the tremendous amount of buoyancy which is inherent in the structure of the device. In the smaller habitat sizes an appreciable part of the buoyancy can be offset in the design through the use of high density materials. Since the pressure differential between the habitat atmosphere and the ambient water pressure is relatively small, the material of which the habitat is constructed need not possess the high tensile strength of pressure containers and it is entirely feasible to construct a small habitat of high density concrete, reinforced with steel if desired. A project (6) at our installation which now is in the preliminary drafting stages, for example, is for a rectangular habitat of reinforced concrete.

Specifications are:

Material	—	Reinforced Concrete - 8 in. wall (base 12 in. thickness)
Work Area	—	8 ft. x 12 ft. = 96 ft.^{2} - Height 6.5 ft.
Volume (total)	—	625 ft.^{3} - Positive Buoyancy 40,000 lbs.
Material Weight	—	44,600 lbs. (544 ft.^{3} Concrete)
Net Negative Buoyancy	—	4,600 lbs.

A structure such as this, with a negative buoyancy of close to 5,000 pounds will present a very stable configuration and should be relatively easy to fabricate, transfer (in section) and emplace. This appears, however, to be the maximum practical size for a habitat which is self-anchored, due to material and design considerations which are beyond the scope of this discussion.

ANCHORAGES

Not withstanding the tremendous advances which have been made in development of anchor-

TABLE I

Relationship between floor area and buoyancy of different size Habitats.

(1) Net weight of habitat material not included
(2) Anchorage calculated with 50% safety factor
(3) Tektite has additional water ballast tanks

HABITAT	SHAPE	SIZE	FLOOR AREA (ft^2)	VOLUME (ft^3)	BUOYANCY (1) lbs.	ANCHORAGE (2) lbs.
Way Station (1 man - temporary)	upright cylinder	4' dia. 6' hgt.	12	72	4,464	6,696
(2 man) Overnight	cylinder upright	6' hgt. 12' dia.	108	648	40,176	60,264
Tektite (30 days) (3 work areas)	2 double upright cylinder	12' dia. 18' hgt. (each)	434 (3 decks total)	3888	141,056	201,000(3)
Areef Work Habitat (proposed)	rectangle	50' L 40' W 8' H	2000	16,000	992,000	1,488,000

ages and moorings for supertankers and offshore installations, anchoring of habitats does not appear as a reasonable solution. It must be remembered that the forces of moored vessels are generally tangential to the anchorage, whereas the force of buoyancy is directly upward and this is a factor which tends to decrease the holding power considerably. Only a deadweight or a well buried anchor would function at high efficiency with a buoyant object. For purposes of comparison, various anchor systems are shown in Table 2.

Referring to approximate buoyancy values given in Table 1, it appears that direct anchorage of habitats is restricted to relatively small units (a one-man way station or a two-man overnight type) using the appropriate anchors shown in Table 2. Logistic problems of transporting and deploying the anchoring system far exceed the relatively simple matter of moving a small habitat into place. It would appear also that cost considerations will essentially eliminate the standard large anchors from the minimal budgets associated with habitat experiments. The only other alternative to anchors which has been utilized in current operational habitats has been the construction of a cage or base which was then filled with concrete rubble, iron scrap or cast iron ingots. With the current labor costs and increasingly higher prices of raw materials, even scrap in the quantities required for a reasonably large habitat becomes prohibitive in this application.

AREEF ANCHORAGE

If we now consider the Areef in the light of its methods of construction and the material used it becomes clear that we have at hand the anchorage required to support virtually any habitat we might want to use. Only one qualification need be made: habitat size and Areef size must remain in some proportion which will assure sufficient mass to neutralize the habitat buoyancy. Let us attempt to derive some relationship which can be used in design of an Areef-Habitat combination. Table 3 can be used to arrive at the buoyancy-weight relationship which is inherent in the Areef structure.

TABLE 2

Holding power of Anchors. Adapted from R.O. Ogg "Anchors" in Handbook of Ocean and Underwater Engineering, MacGraw Hill, 1969

TYPE	SIZE LBS.	HOLDING POWER (Lbs.)	CONCRETE BLOCK HOLDING POWER (Lbs.)	NOTES
Mushroom	1,000	2,000	500	Holding power based on use of optimum chain length, size, and correct mooring angle.
Mushroom	5,000	10,000	2,500	
Stockless	1,000	3,000	500	
Stockless	40,000	80,000	20,500	
Kedge	750	2,500	375	Concrete block holding power based on dead-weight + drag on bottom
Northill	100	2,600	50	
Lightweight	100	2,700 Mud	50	
Lightweight	100	19,000 Sand	50	
Lightweight	500	4,800 Mud	250	
Lightweight	500	34,000 Sand	250	
Lightweight	20,000	42,000 Mud	10,000	
Lightweight	20,000	280,000 Sand	10,000	

Without regard to the particular shape of the Areef, we now can assign a habitat buoyancy value to the Areef components:

CASE 1: A temporary or way station habitat has a buoyance value of 6,696 pounds. This can be accomplished by the use of 10 average automobile chassis which in turn results in an Areef volume of 1,500 ft.^{3} or a mass of junk cars which measures 10 x 15 x 10 feet high. Since this is a very small reef, nothing more than a way station habitat will be required.

CASE 2: Increase of the Areef size to approximately 10 times the initial construction allows the use of an overnight habitat for two men by providing buoyancy value of 60,000 pounds.

These are still relatively small Areefs and if large scale invertebrate mariculture is contemplated along with the on-site packaging operation then we are considering the emplacement of an Areef composed of 2,000 vehicles or equivalent scrap material. The area involved is approximately the size of a football field and obviously the method of securing the habitat to the Areef and distributing the buoyancy strains throughout the mass of the Areef are specific and possibly difficult engineering problems. A mariculture Areef of this size can provide a buoyancy value of well over 1,000,000 pounds, which is more than adequate to hold the proposed Areef work habitat listed in Table 1.

The interest up to this point has been to indicate the possibilities for habitat anchorage which are implicit in the design characteristics of Areefs. Further, the intention is to draw some general relationship which could be utilized in the process of laying out the Areef parameters to accomodate the habitat function as well.

THE LIBERTY SHIP AREEF-HABITAT

It would serve the purpose of this paper badly to continue consideration of additional specific cases of Habitat-Areef combinations. Each investigator has a unique situation and will adjust specific parameter to fit his own materials and problems. The mathematics and mechanics of these projects are simple to comprehend; they may possibly be difficult to implement, at least at first.

TABLE 3

Weight relationship of Areef materials.

(1) Weight submerged
(2) Habitat buoyancy plus 50% safety factor

MATERIAL	VOLUME FT^3	WEIGHT LBS. (1)	DENSITY LBS./$FT.^3$	ANCHORAGE (2) VALUE
Vehicle Engine	12	600	50	300
Vehicle Chassis	150	1200	80	600
Vehicle Baled	12	1200	100	600
Concrete Rubble	1	86	86	45
Concrete Caison (4x6)	32	2752	86	1325
Concrete Block (Heavy-Weight)	1	166	166	83

There is some value, however, in the brief consideration of one Areef-Habitat combination which appears conceptually to be the upper size limit to this type of construction. It is proposed that three surplus World War II Liberty Ships be used to provide a very large scale Habitat-Areef combination. The essential plan is to fill the holds of the ships completely with junk vehicles, sink them and use them as the anchorage for a third empty liberty ship which will be turned over and used as a factory habitat. The basic data is as follows:

- Displacement (buoyancy) - 14,000 tons per ship
- Dead weight (submerged) - 4,000 tons per ship
  Scrap filled holds - 468,000 $ft.^3$
  Density of 50 lbs. $ft.^3$ = 23,400,000 lbs. per ship
  That is 10,700 tons per ship
- Total anchorage available - 14,700 tons per ship or 29,400 for the two ships or roughly 200 percent of the buoyancy of the habitat ship.

This essentially is a rough estimate — a stimulus to further investigation rather than a specific plan. Certainly the data has been skewed in favor of a wide safety margin. It is a conceptual proposal which extends the ideas developed in this paper to an ultimate conclusion. The technology and engineering problems in a project of this magnitude are formidable but, I believe, soluble. Possibly, after a few more years experience in emplacement of Areefs and construction and extensive use of habitats, we will be in a position, and may have the need, to attempt the construction of a Liberty Ship Areef-Habitat.

It would be presumptious to suggest that the aim of this paper has been to present anything new or radically different. All of us involved in Areef construction, have, I am sure, made the observations relating to the weight utility of this material. It is hoped only that the contribution of this paper has been to pull together and correlate some of the data on Areefs and habitats in such a way that it will be useful to future planners of Areefs who may also become involved in ocean resource development programs.

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The Economic and Legal Views

SESSION CHAIRMAN: R. N. CONOLLY, Stewart & Stevenson Services, Inc., Corpus Christi, Texas

The Regulatory Policies of the United States Environmental Protection Agency Concerning the Construction of Artificial Reefs

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The legislative and regulatory responsibilities of the United States Environmental Protection Agency with regard to the construction of artificial reefs are both distinctly defined and subject to legislative interpretation. On one hand, under Public Law 92-532, the Marine Protection, Research, and Sanctuaries Act of 1972, Section 3 (c) of the law, in defining what is allowed to be disposed of in ocean waters, states that

> "Material" means matter of any kind or description, including, but not limited to . . . wreck or discarded equipment, rock, . . . excavation debris, . . . and other waste; . . . .

Thus, the substances from which artificial reefs are constructed are clearly included within the definition of "material." Yet, Section 3 (f) of that same law, in defining what the act of disposal is to include, states that

> "Dumping" . . . does not mean the construction of any fixed structure or artificial island nor the intentional placement of any device in ocean waters or on or in the submerged land beneath such waters, for a purpose other than disposal . . . .

Thus, clearly, the intentional placement of material in ocean waters (defined as those waters lying seaward of the base line of the Territorial Sea), for purposes other than deliberate disposal, (such as for the construction of artificial reefs), is not to be included in the regulations of the Ocean Dumping Act.

On the other hand, under Public Law 92-500, the massive and landmark 1972 Amendments to the Federal Water Pollution Control Act, Section 318 of the law (entitled "Aquaculture") states that

> (a) The Administrator is authorized, after public hearings, to permit the discharge of a specific pollutant or pollutants under controlled conditions associated with an approved aquaculture project under Federal or State supervision.
>
> (b) The Administrator shall by regulation, not later than January 1, 1974, establish any procedures and guidelines he deems necessary to carry out this section.

As can be seen, artificial reefs are not identified as such within the language of Section 318, (nor specifically within any other section of 92-500), and inclusion of these structures within the spirit of the language of Section 318 is an interpretive one.

OTHER APPLICABLE SECTIONS OF LAW

It is Section 3(c) of P.L. 92-532 and Section 318 of P.L. 92-500 that will be addressed in the major portion of this paper; however, there are other sections of Federal law that affect the construction of artificial reefs, and it is instructive to touch upon these briefly. First, Section 401 of 92-500 requires an applicant for a Federal permit [who proposes] to conduct any activity which may result in any discharge into navigable waters to obtain certification from the State in which the discharge originates. As will be seen from a reading of the law, a "discharge" as defined in this manner means discharge of a pollutant, and the definition of "pollutant" includes those materials from which artificial reefs are constructed. However, as also will be seen from a reading of the law, the requirements of Section 401 are included within certain portions of Section 318.

Second, Section 402 of 92-500 (entitled "National Pollutant Discharge Elimination System") requires a permit for the discharge of any pollutant "except as provided in Section 318 . . . of this Act." Thus, Section 318 is identified as a more specific and applicable case of NPDES that takes precedence over the more general permit system of Section 402.

Third, Section 3(a) of Public Law 92-402 states that

> Any State may apply to the Secretary of Commerce for Liberty Ships which, but for the operation of this Act, would be designated by the Secretary for scrapping if the State intends to sink such ships for use as an offshore artificial reef for the conservation of marine life.

Section 3(b), which follows immediately, requires the application form submitted by any State to include

> . . . a certificate from the Administrator, Environmental Protection Agency, that the proposed use of the particular vessel or vessels requested by the State will be compatible with water quality standards and other appropriate environmental protection requirements.

In order to carry out its responsibilities under P.L. 92-402, EPA has developed procedures to review and certify artificial reef projects for compatibility with water quality standards and other appropriate environmental safeguards. In developing the procedures, EPA kept in mind the policies set forth in the Federal Water Pollution Control Act Amendments of 1972. Accordingly, certification under P.L. 92-402 is granted only for "clean" ships; that is, those from which all oil and hazardous materials have been removed.

Thus, although the EPA has an environmentally protective certifying role under P.L. 92-402, the major responsibility for the Act belongs to the Secretary of Commerce (specifically, the Assistant Secretary for Maritime Affairs), and it is expected that such responsibilities will be discussed in other papers in these Proceedings.

Fourth, under Section 10 of the River and Harbor Act of 1899, "the creation of any obstruction . . . to the navigable capacity of any of the waters of the United States is prohibited," and further, "it is unlawful to build any . . . structure in any navigable water of the United States, except on plans recommended by the Chief of Engineers [of the United States Army]." Thus, any proposed construction of an artificial reef which affects transportation on the navigable waters of the United States also requires a permit from the Corps of Engineers of the Department of Defense.

Fifth, Section 307(c)(3) of Public Law 92-583, the Coastal Zone Management Act of 1972, requires an applicant for a Federal permit [who proposes]

> . . . to conduct an activity affecting land or water uses in the coastal zone of that State [to] provide . . . a certification that the proposed activity complies with the state's approved [coastal zone management] program . . .

Thus, any proposed construction of an artificial reef must meet individual state requirements in their approved coastal zone management procedures.

THE OCEAN DUMPING ACT

Having touched briefly on other sections of Federal law that affect the construction of artificial reefs, it is desirable to return to the two sections of law that were referred to in the opening portion of this paper. Although dumping for the purposes of constructing artificial reefs is specifically excluded from the regulations of the Ocean Dumping Act, it is relevant to note that the Marine Protection Branch of the Oil and Special Materials Control Division, which has the responsibility within EPA for administering Title I of P.L. 92-532, is concerned about several factors regarding the construction of artificial reefs.

The first is that at the present time there are no restrictions on construction of artificial reefs, and the placement of these reefs, from a navigational point of view, has been quite poor. When the Chief of Engineers approves, from a navigational viewpoint, an application for construction of an artificial reef, it is assumed that the reef will be placed as nearly as possible to the proposed location in the application. This has not always been the case. In at least one instance in recent months, it has been reported to EPA that the dumping has taken place as much as five miles from where the application stated it would occur, thus raising the possibility of serious navigational hazards.

The second factor arises from the basic problem of assuring that materials to be disposed of in ocean environments will be as free from pollution as possible. There are only minimal restrictions at the present time regarding these materials. The Marine Protection Branch currently is in the process of issuing permits to the United States Navy to dispose of 6 to 10 ships per year for use as target vessels. In those permits, two of the conditions of the permit are that first, all fuel tanks and lines must be emptied to the lowest point of suction, then flushed with water and again pumped to the lowest point of suction, leaving fuel tanks and lines essentially free of petroleum and other pollutants; and second, all readily detachable material capable of creating debris or contributing to chemical pollution must be removed from the hulls.

Thus, it is the belief of the EPA that any materials used in the construction of an artificial reef (other than Liberty Ships from the Reserve Fleet obtained from the Secretary of Commerce), should at least comply with the following factors: they must meet the cleanliness requirements that are part of the conditions of the permit for oceanic Naval disposal of target vessels; they must have been certified by the appropriate state or federal agency that the deposit of materials is for the purpose of enhancing fisheries; and they must be consistent with all other published ocean disposal criteria of P.L. 92-532.

THE PROPOSED AQUACULTURE REGULATIONS

Finally, let us examine that section of the law that ultimately will affect most directly the construction of artificial reefs, Section 318 of the Federal Water Pollution Control Act, as amended. In doing so, it is instructive to recall the legislative history of this section of P.L. 92-500. In the Senate bill (S. 2770) that led ultimately to 92-500, the language dealing with aquaculture was identified as Section 303; in the House bill (H.R. 11896) the language was identified as Section 318, but it was added as an amendment to the original House bill. However, the language in both Congressional versions was identical, and the Conference Committee adopted the language as written. The report of the House Public Works Committee, in reporting out H.R. 11896, contained no modifying language; however, the report of the Senate Public Works Committee, in reporting out S. 2770, stated that

> Such projects as the building of artificial reefs by use of inert bulk solids [is] an example of projects which are intended to be permitted under Federal or State supervision and approval.

Further, the language of the version as adopted includes the phrase "the discharge of a specific pollutant or pollutants." (For the full text of the section, see the introductory portion of this paper). Under Section 502(6) of the Act (entitled "General Definitions") the definition of the term "pollutant" includes "... solid waste ... wrecked and discarded equipment, [and] rock ..." Thus, it would appear that inclusion of the construction of artificial reefs is clearly within the language of that section of law as written, and Section 318 may be interpreted to include such structures.

At the present time, the regulations to establish any procedures and guidelines as required by Section 318(b), are in a draft proposed rulemaking format. It is to be emphasized that these proposed rules are in a draft state and are subject to change. The document currently is being circulated for comment on its technical accuracy and policy implications and should not at this stage be construed to represent Agency policy. It is expected that publication will occur in the Federal Register as Proposed Rulemaking within the next six weeks, following which time there will be 30 days for public comment. At the conclusion of that period, consideration for modification of the proposed rules will be given, and then within a nominal period of time (usually 30 to 60 days), the final regulations will be issued.

Nevertheless, it is possible to discuss the draft proposed rulemaking in a cursory manner at this time. The introductory section discusses the legislative authority for this section of the Act, and makes the point that the legislative history of Section 318 makes it clear that Congress intended authorized discharges under Section 318 should not contribute to water pollution outside the designated project area. Further, the Administrator's authority to permit discharges under Section 318 is subject to a requirement for public hearings. The Agency believes that the requirement of a public hearing will be satisfied if an opportunity for a public hearing is provided by the regulations. Thus no public hearing would be required if no member of the public were to request one.

In Subpart A - General, certain terms are specifically defined. Included in these definitions are

- the term "discharge of pollutants associated with an aquaculture project" means the addition or discharge of a specific pollutant(s) in a controlled manner to an aquaculture project to enhance the growth or propagation of the species under culture.

- the term "aquaculture project" means a confined water area which is managed and uses discharges of a pollutant(s) into the project area for the maintenance, propagation and/or production of harvestable freshwater, estuarine or marine plant or animal species.

- the term "to confine" means to utilize a method or plan of operation (including, but not limited to, physical confinement) which on the basis of reliable scientific evidence, is expected to insure that specific individual organisms comprising an aquaculture crop will enjoy growth attributable to the discharge of pollutants permitted under this part, and suffer harvesting within a defined geographic area.

- the term "designated project area" means those portions of the navigable waters within which the applicant for a permit pursuant to this part proposes to confine the cultivated species.

Continuing, the proposed rulemaking defines that the regulations in this part apply to those aquaculture facilities which are designed to utilize pollutants for the maintenance, growth and propagation of freshwater, estuarine and marine organisms and to develop new aquaculture crops within the United States and its territories. Further, the regulations in this part do not apply to those aquaculture facilities such as fish hatcheries, fish farms and similar projects which do not utilize discharges of wastes from a separate industrial or municipal point source for the maintenance, propagation and/or production of harvestable freshwater, estuarine or marine organisms.

In Subpart A, the rulemaking delegates the authority to issue and condition permits or to deny applications for permits to each of the Regional Administrators of the EPA.

In Subpart B - Processing of Permits, the proposed rules state that an applicant for a permit may obtain the required application forms from the Regional Administrator. These forms must be filed with the Regional Administrator of the EPA region that includes the state in which the aquaculture project will operate. This subpart further sets the application fee for a permit at $1,000 to cover the cost of processing the application and project surveillance. However, agencies or instrumentalities of federal, state or local governments will not be required to pay the fee.

In addition in this subpart, the time requirements for permit applications are established, as well as the requirements for information to be included in a permit application.

Finally, in Subpart B, the rulemaking states that no permit shall be granted until a state certification has been obtained that discharges from the designated project area would meet the requirements of Section 401 of the Act if the designated project area were a point source. In addition, the proposed rulemaking establishes procedures for action after receipt of permit applications that lack state certification. Further, the rulemaking states that an application shall be accompanied by a statement from the state fish and wildlife agency as to whether the project will be in compliance with State wildlife regulations.

In Subpart C - Criteria, Terms, and Conditions of Permits, the proposed rulemaking lists the requirements for permit issuance. It states that there will be a permit application denial if, in the judgement of the Chief of Engineers, there would be a substantial impairment of navigation by the aquaculture project; that any permit issuance must conform with guidelines established under Section 403(c) of the Act; that "any modifications caused by the construction or creation of a reef, barrier or containment structure shall not alter the tidal regimen of an estuary or interfere with migrations of unconfined aquatic species;" and that any permit issuance must conform with standards established under Section 307(a) of the Act.

Further, the rules establish that permits will be valid for five years, after which renewal application must be made. In addition, any permit shall be subject to such monitoring requirements as may be reasonably required by the Regional Administrator, and that the Regional Administrator shall require periodic reporting (at a frequency of not less than once per year) of monitoring results obtained pursuant to the permit's monitoring requirements.

Finally, in Subpart D - Notice and Public Participation, the proposed rulemaking establishes procedures for circulation of public notices, required contents of public notices, required contents of public notices of public hearings, and time frames and procedures for calling public hearings.

CONCLUSIONS

From this brief review, it can be seen that the legislative and regulatory responsibilities of the United States Environmental Protection Agency with regard to the construction of artificial reefs are, by necessity, both broad-based and narrowly precise. It is by no means a simple task to establish regulations in this involved field and also to follow closely the complex Congressional mandates. We welcome public comment on our actions.

The V. A. Fogg -- An Unplanned Artificial Reef

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CAPTAIN LOUIS SCHAEFER

Aqua Safari, Houston, Texas

On February 1, 1972, a stroke of fate created an artificial reef for Texans 43 nautical miles south of the shore of Galveston and 33 nautical miles southeast of Freeport. It is ideally located, constructed to last many decades, is not a hazard to navigation, was built at no cost to the government and has proved to be an ideal fishing spot for both line fishermen and scuba divers. This artificial reef could well be looked upon as a model for the planned development of other reefs.

On that fateful day, the V.A. Fogg, a 572-foot jumbo tanker, cleared the port of Freeport, Texas bound for the Port of Houston. She was scheduled to proceed some 50 miles out into the Gulf, purge her emptied tanks of benzene residuals and then deliver her remaining cargo of toluene to Houston. Enroute to her at-sea cleaning station, at position, Lat. 28° -35' - 54" N. and Long. 94° -49'-03" W., she was ripped open by a tremendous explosion and immediately sank, to become an artificial reef as well as a monument to the 39 men who perished with her (Figure 1).

It was 12 days after the Fogg disappeared before she was found resting on the bottom in 100 feet of water with only the top of her radar mast visible above the surface. Since she was obviously a hazard to navigation, the owners were obligated to remove that portion of the vessel which was more than 60 feet above the ocean bed. This was accomplished by explosive demolition, which effectively transformed those parts of the ship which were hazardous to navigation into additional pieces of reef.

The hull of the Fogg was built of one-inch thick plates. The force of the initial explosion was sufficient to shear the hull from the deck and split the hull plates in many places. The demolition charges opened up many more compartments in the superstructure so there is easy access into the tanks and superstructure compartments for fish life. Since the heavy steel plates offer long-term resistance to corrosion, the life of this reef can be expected to be much greater than 40 years.

The geographic location of this artificial reef is most favorable, not only because it is well out of the sea lanes, but also because it is close to adequate ports. The Fogg reef is easily accessible to charter fishing and diving boats from both Freeport and Galveston. The shorter distance from Freeport to the reef makes it more popular with Freeport skippers. Nonetheless, in good fishing weather, as many as 20 small boats from these ports have been counted over the Fogg reef.

The reason for the popularity of fishing at this reef relates to the biological productivity of the surrounding waters.

Capt. Louis Schaefer, skipper of the 65 foot offshore fishing and diving charter boat Aqua Safari, made his first trip to the Fogg with a group of divers within two weeks after she was sunk. Capt. Schaefer is both an accomplished diver and underwater photographer. Over the past two years, he has photographically recorded changes and additions to reef flora and fauna. On his first dive to the Fogg, he saw no fish. Within a few weeks he recorded the appearance of warsaw

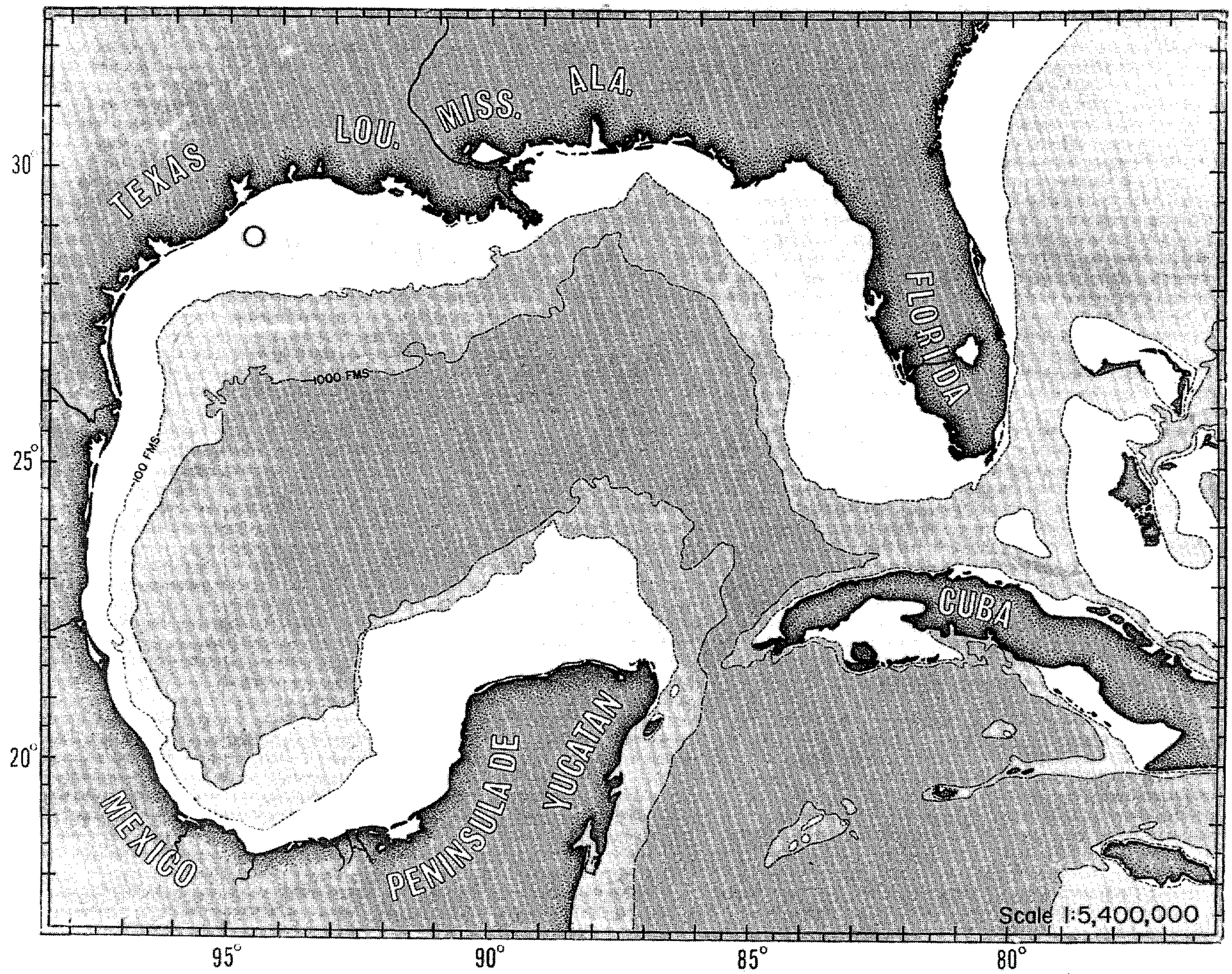

Figure 1
Chart of Gulf of Mexico showing location of
Fogg reef

groupers. Within the first few months after the ship sank, red snapper, hard tailed jacks, spade fish and the ever present barracuda appeared. Growth of the fouling organisms occurred more slowly, and became increasingly apparent after three months. Now, after two years, many forms of reef life have arrived and taken up residence in and around this new habitat. This observation is substantiated in part by the jewfish shown in Figure 2 and by the flora and fauna visible in the underwater photographs, Figures 3, 4, and 5.

Reef fishing and wreck diving have always presented a challenge to fishermen and divers alike. Capt. Schaefer has made "reef diving" a reality for fishermen and divers from all over Texas as well as from such distant places as Chicago and Jersey City, N.J. He has made more than 100 trips to the V.A. Fogg since she was converted into a reef, and has carried some 3,000 divers and fishermen. Now, diving clubs from many inland cities of Texas and elsewhere book months ahead for their chance to visit the Fogg with Capt. Schaefer.

This artificial reef has come to mean many things to many people: (1) a safe and exciting place to dive, (2) an excellent place to fish where "big ones" can be found all year around, (3) a source of support for local fishing and diving industries and, not to be overlooked, (4) a favorable ecological environment for the development of a marine community of significant size and population.

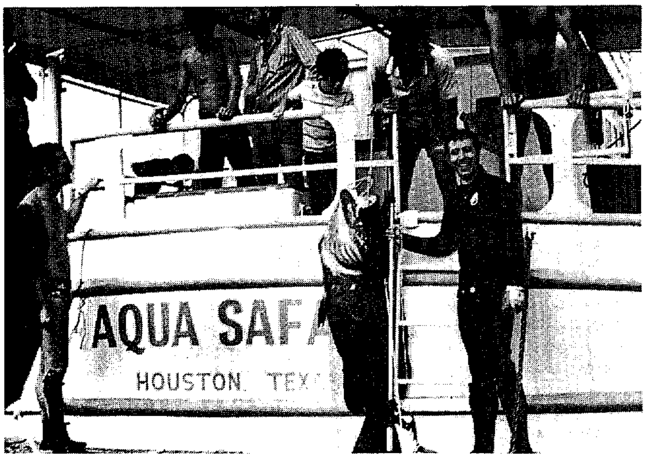

Figure 2
Divers showing large jewfish caught at Fogg reef

Figure 3
Underwater view of radar mast of V.A. Fogg through water surface - before demolition

Figure 4
Underwater view of sheared deck plates

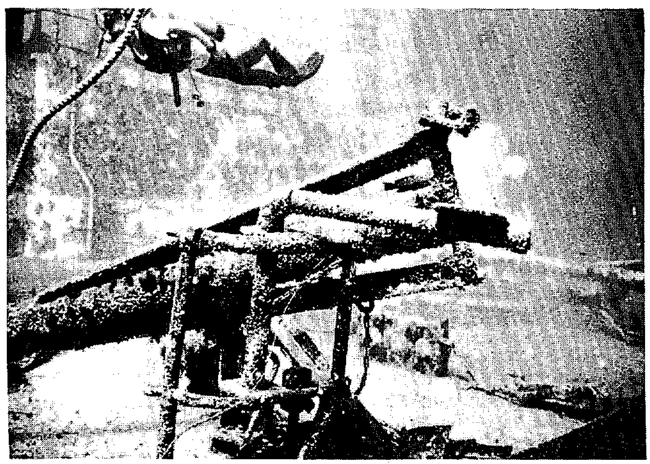

Figure 5
Underwater view of reef, diver and flora and fauna

Legal Considerations Involved in the Placement of Artificial Reefs

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This morning I would like to present to you a short discussion of the legal considerations involved in the placement of artificial reefs. Recent legislation, such as the Coastal Zone Management Act of 1972, will have the effect of increasing federal and state regulation of activities in the waters and on the submerged lands off our coasts. In order to help clarify the legal requirements for those interested in placing artificial reefs, I will briefly outline the legal procedures presently required for the placement of artificial reefs as we at NOAA see it. Then, I will attempt to relate the impact on these procedures of two important recent pieces of federal legislation which are now beginning to be implemented: The Coastal Zone Management Act of 1972 and Title III of the Marine Protection, Research and Sanctuaries Act of 1972. These acts are of particular concern to me as an attorney in the National Oceanic and Atmospheric Administration, since it is our agency which has the responsibility for administering these two laws. Finally, I will touch on some of the international legal problems associated with the placement of artificial reefs.

The first step in the procedure for placement of an artificial reef is authorization by the appropriate state or local agency, if state or local law so requires. State or local authorization is required when the reef is to be placed within waters subject to state jurisdiction: that is, generally, within the territorial sea.

A basic federal requirement for the placement of an artificial reef is that a permit be granted by the Corps of Engineers pursuant to Section 10 of the Rivers and Harbors Act of 1899. I will defer to the Corps for a detailed explanation of this act. However, I will point out that Section 10 makes unlawful the obstruction or alteration of any navigable water of the United States. A permit thereunder is required, not only for the placement of the reef, but for the placing of any fixed and floating aids to navigation in conjunction with the reef. Any such aids to navigation must, of course, also conform to U.S. Coast Guard requirements concerning marking, lighting, etc. Corps of Engineers regulations indicate that the Corps generally will not issue a Section 10 permit until the necessary state or local authorization has been received.

As we understand it, before issuing a Section 10 permit under the National Environmental Policy Act of 1969, the Corps is required to assess the potential environmental impact of the project. If the Corps decides that allowing placement of a reef may amount to a "major federal action significantly affecting the quality of the human environment," then the Corps will require the permit applicant to furnish his analysis of the environmental impacts of the proposed action. The corps will then decide whether an environmental impact statement need be prepared by them to be forwarded to the Council on Environmental Quality and other interested federal agencies for review and comment. It is at this point that NOAA becomes involved in considering the environmental impact of the application. The National Oceanic and Atmospheric Administration is deeply involved in the review of such environmental impact statements as a function of our responsibility and expertise in the area of marine resources. In addition, NOAA may be more directly involved under the provisions of the Fish and Wildlife Coordination Act. Under this Act, NOAA's comments are not limited to the environmental impacts. It also may make specific recommendations to mitigate damages to the affected fisheries resources.

NOAA recently acquired another responsibility for comment on artificial reef projects. The so-called "Ocean Dumping Act," Title I of the Marine Protection, Research and Sanctuaries Act of 1972 and regulations promulgated in connection with it, specifically exclude from the requirement for an ocean dumping permit the placement or deposit of materials for the purpose of enhancing fisheries, provided certain conditions are met. The Environmental Protection Agency, which administers the Ocean Dumping Act, requires, among other things, concurrence from NOAA that the proposed placement or deposit of materials actually is for the purpose of enhancing fisheries.

There is a separate and additional authorization procedure which must be followed by states that apply to the Maritime Administration for surplus Liberty Ships for sinking as artificial reefs. Public Law 92-402 (16 U.S.C. 1220-1220c) sets up the application procedure, which includes the securing of a certification from the Environmental Protection Agency that the proposed use of the ship requested by the state will be compatible with "water quality standards and other appropriate environmental protection requirements," (S1220(b)). The problem of possible water pollution from residues of oil and toxic cargoes in a ship is thereby directly addressed by the Act.

Fulfilling all of the requirements for an application for a Liberty Ship under P.L. 92-402 does not, however, relieve a state from the requirements of any other applicable federal law. Thus, the state is still required to secure a Section 10 permit from the Corps of Engineers, and an environmental impact statement will most likely have to be prepared with the assistance of the state.

I have described the basic legal procedures for placement of an artificial reef by private citizens or a state. The question I now shall address is: what effect will Title III of the Marine Protection, Research and Sanctuaries Act of 1972 and the Coastal Zone Management Act of 1972 have on these procedures?

First, Title III of the Marine Protection, Research and Sanctuaries Act of 1972. A moment ago I mentioned the "Ocean Dumping Act," which is Title I of this Act and is administered by the Environmental Protection Agency. Title III of this Act, however, is administered by NOAA and involves the subject of "marine sanctuaries."

Section 302 of Title III authorizes the Secretary of Commerce (this authority has been delegated to the administrator of NOAA), after consultation with other interested federal agencies and with the approval of the President, to designate as marine sanctuaries those areas of the ocean waters as far seaward as the outer edge of the continental shelf (as defined in the Convention of the Continental Shelf), of other coastal waters where the tide ebbs and flows, or of the Great Lakes and their connecting waters, which he determines necessary for the purpose of preserving or restoring such areas for their conservation, recreational, ecological or esthetic values.

After designating such an area, NOAA will issue regulations to control any activities within the area. Activities in the sanctuary authorized under other authorities will be valid only if NOAA certifies that the activities are consistent with the purposes of Title III of the Act and can be carried out within the regulations for the sanctuary.

NOAA anticipates that this law will be an invaluable instrument for the protection of unique natural underwater resources, such as perhaps, the few coral reef formations found near the United States' coasts. Once a marine sanctuary is established, any activities proposed for that area which may affect the sanctuary will be closely scrutinized and regulated. Certainly, placement of artificial reefs would be an activity which would come under close investigation as to its effect on the sanctuary. No Section 10 permit issued by the Corps of Engineers for placement of a reef would be valid in such a case unless NOAA certified to the Corps that the reef placement is consistent with the purposes of Title III of the Act and can be carried out within the regulations promulgated for the sanctuary concerned. Corps of Engineers regulations indicate that no Section 10 permit will be issued by them for activities in a marine sanctuary unless such a certificate is received.

The Coastal Zone Management Act of 1972 also is administered by NOAA. Its scope is much broader than that of Title III of the Marine Protection, Research and Sanctuaries Act, and its effect is only beginning to be felt. The basic concept of the Act is expressed by Congress in Section 301: "To encourage the states to exercise their full authority over the lands and waters in the coastal zone by assisting the states, in cooperation with federal and local governments and other vitally affected interests, in developing land and water use programs for the coastal zone, including unified policies, criteria, standards, methods and processes for dealing with land and water use decisions of more than local significance."

The "coastal zone," as defined in the Act, extends seaward to the outer limit of the territorial sea and inland "to the extent necessary to control shorelands, the uses of which have a direct and significant impact on the coastal waters."

Four sections of the Act demand our special attention: Sections 305, 306, 307 and 312. Section 305 authorizes grants to coastal states to assist in development of their management programs. Subsection (b) requires each management program to contain certain elements, among which are three of some interest with respect to artificial reef construction:

- A definition of what shall constitute permissible land and water uses within the coastal zone
- An inventory and designation of areas of particular concern within the coastal zone
- Broad guidelines on priority of uses in particular areas, including specifically those uses of lowest priority

Placement or maintenance of artificial reefs could be affected by the details of a state management plan based on such categories.

A management program developed under Section 305 is approved under Section 306, which also authorizes grants to assist in the administration of the management program.

Section 307, however, is the provision of greatest direct significance to the creation of artificial reefs. Section 307(c)(3) requires that after final approval of a state's management program, any applicant for a federal license or permit to conduct an activity affecting land or water uses in the coastal zone of that state shall furnish a certification that the proposed activity complies with the state's approved program and that such activity will be conducted in a manner consistent with the program.

Generally, no permit may be granted by a federal agency until the state concerned has concurred with the applicant's certification, or has waived its right to do so. The applicant for a Corps of Engineers permit for placement of an artificial reef must provide the required certification if he desires to place a reef in the waters of a state with an approved management program under the Coastal Zone Management Act.

Finally, in Section 312 of the Act, NOAA is authorized to make grants to coastal states to aid in the costs of acquisition, development and operation of estuarine sanctuaries for research purposes. Land and water uses in such sanctuaries would be regulated closely by the states. Naturally, any application to place an artificial reef in or close to such estuarine sanctuaries would be carefully reviewed by the state involved. NOAA anticipates close coordination between this estuarine sanctuary program and the marine sanctuary program previously mentioned.

I will, in conclusion, touch on a few of the international legal problems related to artificial reefs.

There are three areas of possible location for an artificial reef. The location of a reef may be: (1) within the territorial sea, (2) between 3 and 12 nautical miles, that is, in the contingous zone, or (3) beyond 12 nautical miles, out to the edge of the continental shelf.

Within the limit of the territorial sea, with certain exceptions, the coastal state is sovereign. Thus, generally, within the limits of the territorial sea, the coastal state may make whatever use of the seabed or water column it desires, subject only to the right of innocent passage of foreign vessels, to certain other rules of international law or to international agreements.

Construction of an artificial reef is, in this area, clearly within the competence of the coastal state. The coastal state is, however, required to give publicity to any dangers to navigation within its territorial sea of which it has knowledge.

More difficult questions of an international legal nature arise where a reef is both (A) placed beyond the limits of the territorial sea and (B) not necessary for the exploration and exploitation of continental shelf natural resources as permitted by the Convention of the Continental Shelf (done April 29, 1958, 15 U.S.T. 471 (1964), in force June 10, 1964). The same problems would attach to the construction of an artificial reef on the continental shelf within the contiguous zone as would attach beyond the contiguous zone, although within the contiguous zone the coastal state would have exclusive rights to both sedentary and free-swimming species.

The Convention of the Continental Shelf in Articles 2 and 5 confers on coastal states exclusive sovereign rights "for the purpose of exploring [the continental shelf] and exploiting its natural resources," including the right to "construct and maintain or operate on the continental shelf installations and other devices necessary for its exploration and the exploitation of its natural resources" [Arts. 2(1,2) and 5(2)].

The term "natural resources" is specifically defined in the convention as consisting of: "the mineral and other nonliving resources of the seabed and subsoil together with living organisms belonging to sedentary species [such as certain species of crabs] . . . ."

While the U.S. under this convention might exclude foreigners from placing an artificial reef on our shelf because of its interference with our exclusive right to seabed resources, it is not clear whether this convention confers a right on the U.S. to place such a structure on the shelf.

It might be argued that an artificial reef is a device used for the exploitation of the natural resources of the seabed, although the purpose of a reef may be more to attract free-swimming species of fish than sedentary species.

Even if justification under the terms of the Convention could not be derived from such an interpretation of the terms "exploitation of its natural resources," construction of an artificial reef could be considered a "reasonable use" of the high seas under general principles of international law. That such a use is "reasonable" is a question of fact which would require a consideration of, inter alia, interference with navigation, submarine cable and pipe laying, fishing and the conduct of marine scientific research.

Let me observe, however, that an expansion in the breadth of its territorial sea to 12 miles by the United States could occur as a result of the recognition of such a maximum breadth by the upcoming Third United Nations Conference on the Law of the Sea, scheduled to hold substantive sessions in Caracas this summer. Moreover, that conference may well recognize broad coastal state jurisdiction over not only the resources of the continental shelf, but also over the living resources in the water column above and over off-shore installations affecting the coastal states economic interests, including super ports, off-shore nuclear power plants and artificial reefs. Such a result would presumably moot some of the international problems I have mentioned.

Role of the Coast Guard in Artificial Reefs

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The Coast Guard's primary role in regard to artificial reefs deals with the proper marking thereof. The marking role of the Coast Guard stems from authority contained in the provisions of Title 14 U.S. Code § (Section) 81 thru 87 and 43 U.S. Code (USC) § 1333. These statutes give the Coast Guard the prime responsibility for the aids to navigation system of the United States. By aids to navigation is meant any device external to a vessel or aircraft intended to assist a navigator to determine his position or safe course or to warn him of dangers or obstructions to navigation.

Under the authority granted in 14 USC § 81, the Coast Guard establishes and maintains aids to navigation for commerce and the armed forces. Under 14 USC § 85, the Coast Guard has authority to prescribe and enforce necessary rules and regulations relative to lights and signals on fixed structures in or over the navigable waters of the United States, that is, within three miles of the coast. Under 14 USC § 86, the owner of any sunken vessel or other obstruction in navigable waters is responsible for appropriate marking thereof.

Title 14 USC § 83, a most important statute, prohibits the establishment, erection or maintenance of any aid to navigation without the Coast Guard's authority. A violator of this statute is subject to a fine of $100 per offense per day. 14 USC § 84 makes it unlawful for any person or public body to remove, change the location of, obstruct or willfully damage, make fast to or interfere with any aid to navigation either established by the Coast Guard or any aid established under authority granted by the Coast Guard in 14 USC § 83. This statute contains a fine of $500 per offense per day.

Within navigable waters of the United States, we thus have two categories of aids to navigation: first, those established and maintained by the Coast Guard and, second, those established and maintained by other parties after having been authorized by the Coast Guard as well as other agencies requiring approval.

Outside the navigable waters of the United States, under the Outer Continental Shelf Lands Act, 43 USC § 1333, the Coast Guard has authority to require marking by lights or other warning devices on islands and fixed structures or on waters adjacent thereto if those islands and structures are erected for the purpose of exploring for, developing, removing and transporting resources therefrom. The present Coast Guard regulations contained in 33 Code of Federal Regulations (CFR) Part 67 prescribe obstruction lights and fog signals to be operated as privately maintained maritime aids under the circumstances specified in the statute. Included in the regulations are the marking of spoil banks as a result of operations connected with the mentioned purposes. Examples of these latter operations would be laying of pipes and dredging of channels in connection with resource removal structures. The marking and warning devices required by the Coast Guard under these regulations are privately established and maintained but only after having been authorized by the Coast Guard.

As to artificial reefs which have as their purpose the enhancement of swimming fish population, there is some question as to whether the structure is included within the purposes which give rise to the exercise of independent Coast Guard authority to prescribe lights and other warning devices. While the Coast Guard's authority to require marking of Outer Continental Shelf artificial islands or structures appears to be circumscribed by the requirement that the purpose be the development, removal, etc. of natural resources from the sea bed or subsoil, as Mr. Clark will describe, the Corps of Engineers authority relative to the prevention of obstruction in navigable waters, which was extended to the Outer Continental Shelf by 43 USC § 1333 (f), is not so limited. Thus, the placement of any artificial island or structure in either the navigable waters of the United States or on seabed of the Outer Continental Shelf can be done only under a permit from the Army Corps of Engineers. In deciding whether to issue the permit, the Corps of Engineers considers, among other factors, the effect of the erection of a structure or artificial island on navigation. The Coast Guard is given an opportunity to comment on the application. If the Corps grants the permit, the permit itself will contain a condition that the applicant install and maintain, at his own expense, such lights and signals as may be prescribed by the Coast Guard. In some cases the Corps has specified that a buoy mark a reef and that the buoy must be lighted in a manner approved by the Coast Guard.

How does a person go about finding out whether he must mark his submerged artificial reef and the manner in which it should be marked?

The applicant must communicate with the Commander of the Coast Guard District in which the reef is located. The description of the limits of the Coast Guard Districts are contained in 33 CFR Part 3. The applicant should provide the information contained in 33 CFR § 66.01-5 to the District Commander. Included are:

- The proposed position of an aid shown on a chart along with a description of the reef
- The name and address of the person who will maintain the aid and who will be paying for that maintenance
- If a buoy is to be used, the shape, color, number or letter, depth of water and height above water
- If a lighted buoy is to be used, the color, characteristic, height above water and description of illuminating apparatus
- If a fog signal is to be used, the type and character.

The district Commander ordinarily will review the information provided by the applicant and forward a CG 2554 Form to be signed and returned by the applicant. Any additional needed information will be requested. If the type of marking is not known by the applicant; or if the proposed marking is not acceptable, the District Commander will give advice as to the appropriate marking.

The number of aids and type of marking will, of course, depend on a number of factors. Included among these are:

- The vertical clearance over the reef
- The physical size of the reef and the bottom area covered
- The proximity to shipping lanes or fairways
- The proximity to other existing reefs
- Conditions at the site.

Because of the variation in conditions, the exact type of marking required cannot be predicted.

Normally, if there is over 85 feet of vertical clearance, the Coast Guard will not require marking of the reef. However, each project must be considered on its own merits to determine the possible need for marking.

Because a large number of artificial reefs are located within the limits of the Eighth Coast Guard District which covers the bulk of the Gulf of Mexico, I will try to assist those of you from this area by giving you some general guidelines for marking reefs within our District. There may be some variations in other Coast Guard Districts. The general guidelines are:

a. If a light is required, it will generally be a quick flashing white light if there is less than 85 feet of clearance. If the clearance is greater than 85 feet over the reef and circumstances are such that a light is required it will normally be a slow flashing light. The light must be at a height of 8 feet above the water surface unless otherwise specified by the District Commander.

b. Buoys must be colored accordingly to the lateral system when returning from sea, if the buoy is to be passed on the starboard hand, it will be red - if to be left on the port hand, it will be black. It can also be red and black banded horizontally meaning it can be left on either side. The topmost color denotes the preferred side on which it should be left. The projected area is to be at least 6 square feet centered at least 5 feet above water.

c. If the buoy is in close proximity to heavily trafficked areas, a radar reflecting buoy or a fog signal may be required.

Once permission is granted to establish a buoy, the position of the buoy is published in the Light List for the use of mariners. It is most important that the buoy be maintained on this position. Should there be a vessel grounding on the artificial reef and the buoy is off station, the owner of the reef may be liable for substantial damages. If the buoy should get off station or be lost, this information must be given to the Coast Guard so that a Notice to Mariners can be issued to advise mariners of the change. Since the reef material is subject to being moved by currents and/or storms, the reef owner should periodically check to insure that the obstruction has not been moved from its charted position.

When a buoy has been established with the approval of the Coast Guard pursuant to a condition imposed by the Corps of Engineers, the Coast Guard will not ordinarily approve discontinuance of that buoy. Any discontinuance will be coordinated with the Corps of Engineers. If the Corps of Engineers has established a specific condition that the artificial reef be marked, the Corps of Engineers must agree to the deletion of that particular condition. Obviously, the Coast Guard will make its views known to the Corps of Engineers.

In summary, while the independent authority of the Coast Guard to require marking structures on the Outer Continental Shelf is limited to seabed or subsoil development and exploitation, by virtue of the standard condition in the Corps permit, the Coast Guard can require the same type of marking on the Outer Continental Shelf as in navigable waters. There is pending legislation in Congress which would remove the resource development condition which limits Coast Guard Authority under the Outer Continental Shelf Lands Act.

When whatever marking required by the Coast Guard is approved, the owner of the artificial reef, at his own expense, must establish and maintain the buoy or other marking in proper condition and on position.

In planning for any artificial reef, I suggest that early contact be made with your Coast Guard District Office so that the marking requirements can be learned and this cost factor considered in deciding whether the reef should be built.

The Role of the Corps of Engineers in Permitting Artificial Reef Construction

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The basic authority of the Secretary of the Army (acting through the Corps of Engineers) to prohibit the obstruction or alteration of any navigable water of the United States stems from Section 10 of the River and Harbor Act of March 3, 1899 (33 U.S.C. 403). The authority of the Secretary of the Army to prevent such obstructions was extended to artificial islands and fixed structures located on the Outer Continental Shelf (beyond territorial waters) by Section 4 of the Outer Continental Shelf Lands Act of 1953 (67 Stat. 463, 43 U.S.C. 1333 (f)). The Corps responsibility under these Acts is discharged through its Regulatory Permit Program; hence, the requirement for a Corps permit prior to the commencement of construction of an artificial reef regardless of whether the reef is to be located within territorial waters or on the Outer Continental Shelf.

For years, the Corps' only concern under the Section 10 Permit Program was navigation. However, commencing in 1968, the Corps adopted its public interest criteria in evaluating applications for permits. Draft regulations prescribing the policies and procedures that the Corps follows in processing and evaluating permit applications for artificial reefs were published in the Federal Register on May 10, 1973 for public review and comment. Final regulations, which incorporate many of the comments received, are expected to be published in the very near future.

While Section 10 of the River and Harbor Act of 1899 continues to be the Corps' basic authority in permitting artificial reefs, the requirements of such recent legislation as the National Environmental Policy Act of 1969 (PL 91-190), The Federal Water Pollution Control Act (PL 92-500, 86 Stat. 816), The Marine Protection, Research and Sanctuaries Act of 1972 and the Coastal Zone Management Act of 1972 are fully integrated into the Corps regulations.

Briefly stated, our regulations provide that the decision as to whether or not to issue a permit for an artificial reef will be based on an evaluation of the probable impact of the proposed reef on the public interest. The benefits which reasonably may be expected to accrue from the placing of a reef will be balanced against the reasonably foreseeable detriments. The decision of whether or not to authorize an artificial reef, and if so, the conditions under which it will be allowed, are therefore determined by the outcome of a general balancing process. That decision will reflect the national concern for both protection and utilization of important resources. All factors which may be relevant to the proposal will be considered; among those are conservation, economics, esthetics, general environmental concerns, historic values, land use classification, navigation, recreation, water quality and, in general, the needs and welfare of the people. No permit will be granted unless its issuance is found to be in the public interest.

The Corps of Engineers is a highly decentralized agency and applications for permits are processed by our various District Offices. When an application for a permit is received, supported by the information considered necessary for evaluation, the District Engineer will issue a public notice to appropriate state agencies, to concerned federal agencies, to local, regional and national shipping and other concerned business and conservation organizations and to any other interested parties. The issuance of a public notice triggers full public involvement in the review and evaluation of an application for a permit to construct an artificial reef.

In addition, the expertise of a variety of interested federal agencies is brought to bear on an application for a permit. Included in the list of Federal officials receiving a Public Notice of an artificial reef application are the field representatives of the Secretary of the Interior, the Regional Director of the Bureau of Sport Fisheries and Wildlife, the Regional Administrator of the Environmental Protection Agency, the Regional Director of the National Oceanic and Atmospheric Administration, the District Commander of the U.S. Coast Guard and the Deputy Assistant Secretary of Defense (Installations and Housing) Washington, D.C. Notice also is sent to the Atlantic Estuarine Fisheries Center of the National Marine Fisheries Service at Beaufort, North Carolina for evaluation and comment.

All comments received in response to the public notice become part of the record and are fully evaluated and given every consideration in reaching a decision to issue or deny a permit.

While each application is now evaluated from the standpoint of the public interest, certain general criteria from a navigational standpoint have developed over the years by virtue of the Corps' continued interest in navigation. The general criteria are as follows:

- No artificial reefs will be authorized in natural or improved channels and fairways in general use by navigation.

- The depths of water over proposed artificial reefs shall not be less than 50 feet below the plane of mean low water where depths in the vicinity generally exceed this depth.

- If deposition of material is authorized in areas limited by large shoals, depth of water over the material below the plane of mean low water shall not be generally less than the least depth of water over such shoal.

- The materials used in constructing artificial reefs shall be restricted to heavy non-floatable material. However, it should be recognized that metal may not meet with the approval of the United States Navy.

- Permits for the construction of artificial reefs shall include a condition for the reefs to be marked as required by the U.S. Coast Guard with costs of installation and maintenance to be borne by the permittee.

In addition to the general criteria to protect navigation, it is also the Corps' policy that if the construction is to be in navigable waters of the United States, approval must be obtained from pertinent state and local authorities before a Corps permit will be issued.

The above are criteria designed to protect navigation; however, the permit will be subject to any other special condition considered necessary to protect the general public interest. In summary, I have attempted to outline briefly the pertinent federal laws administered by the Corps of Engineers that pertain to artificial reefs. I also have attempted to impress upon you that the Corps of Engineers coordinates each application for a permit for the construction of an artificial reef with all interested federal, state and local agencies as well as conservation and navigation groups and the general public. The Corps uses the data developed by such coordination to make a decision to issue or deny a permit from the standpoint of the public interest. While artificial reefs are generally accepted as an enhancement to fish propagation, they do pose concern to general navigation and shipping interests. The site should be carefully selected to avoid navigation fairways.

Lastly, the evaluation of an application to determine if the permit should be issued or denied is often a lengthy process, especially if an environmental impact statement is required by 102(2)c of the National Environmental Policy Act of 1969, or if a public meeting is necessary to develop additional data upon which to make a decision. We strongly recommend applications be submitted at the earliest possible time in order to avoid costly delays. Under no circumstance should capital expenditures be made prior to obtaining a Corps permit.

The Corps of Engineers does not take its responsibility of evaluating an application for artificial reefs lightly. We feel our permit processing procedures provide for full public participation in the processing of an application for a permit, thereby insuring that only those projects that are truly in the public interest will go forward.

Ships and Reefs -- Are They Compatible?

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A SHIP OPERATOR'S VIEW OF CURRENT PROBLEMS

Artificial reefs are man-made submerged hazards to navigation, hidden from the eye and radar. As such, they can endanger the safety of ships, their crews, their cargoes, and those utilizing artificial reefs. The manifold liabilities are obvious. In principle, standardized maritime opposition to reef proposals could be justified. This approach is not considered desirable if, as a Conference result, the domestic and international situation can be improved.

Domestic permit procedures are understood, and AIMS participates. However, frustration is the end result of attempts to make meaningful inputs during proposal review, permit issuance and reef installation. For example, many permit requests seem to be from somewhat elusive groups; proposals are quite often submitted, revised, withdrawn, and resubmitted with little order, thereby frustrating attempts on the part of government/industry to follow developments in a logical fashion. Also, some government screening of permit requests for detail/accuracy/validity/intentions prior to invoking public process would seem to be in order. On one day a single District Engineer issued seven different public notices covering 12 proposed reefs of all types - making a total of something like 27 proposed reefs in process in that District, with 30 days for comment. There are 16 District Engineers who become involved with offshore reef proposals. Being on notice mailing lists does not insure receipt, and 7 - 10 day mail transit time is not uncommon, leaving little time for interested parties to review and respond. One reef was installed four miles from the permit location - and this does not appear uncommon - indicating the need for tighter construction controls. The shipping industry could, we believe, be helpful if offered a coordinated mechanism for doing so.

International ramifications are even more complex.

MARITIME INDUSTRY VIEWS ON ARTIFICIAL CRITERIA

Every proposal must ultimately be reviewed on individual merits and criteria. However, certain general standards for locating, sizing and marking reefs would be in order as guidance to those contemplating a permit request. From the viewpoint of deep-draft ship operators, the following are major factors in safe location and use of artificial reefs:

- Ship traffic density and familiarity with the waters.
- Types of transiting vessels, and their cargoes.
- Vessel size - length, beam, draft - and maneuvering characteristics.
- Prevailing and extreme weather/sea conditions, especially as they affect visibility.
- Water depth and related bottom contour.
- Location in relation to known historic traffic patterns, safety fairways/sea lanes, anchorages, sea buoys, pilot stations, and other deep-draft maneuvering areas.
- Easy access to reefs by pleasure craft with minimum use of deep-draft channels/lanes.
- Type of fishing craft and activity on the reef.
- Adequate reef marking - day and night - for proper radar and other navigational identification.
- Avoidance of small craft jamming of critical VHF radiotelephone channels dedicated primarily to navigational, safety, distress and calling usage such as channels 13, 16 and 22.

Careful analysis of these factors in relationship to the proposed reef will result in knowledgeable selection of minimum distances to provide adequate isolation of the reef, minimum water depth/clearance over the artificial obstruction, and maximum safety for all involved.

BETTER COORDINATED SYSTEM FOR HANDLING ARTIFICIAL REEF PROPOSALS ESSENTIAL

Having in mind the constraints implicit in working under an 1899 Act, the Corps of Engineers has done an admirable job in attempting to protect all interests to date. The complexity and multiplicity of reef proposals requires a central coordinating agency to insure meaningful participation by all government, industry, and public interests, both domestic and international. Under a number of Conventions, laws and regulations at least five government agencies - Corps of Engineers, U. S. Coast Guard, Environmental Protection Agency, National Marine Fisheries Service, National Ocean Survey - have involvement. Time is not as critical in reef permit consideration as in some other permit activity, and for this reason provision of a coordinated review mechanism is reasonable.

A regularly scheduled annual or semi-annual meeting of representatives of all legitimate interested parties to review and recommend on permit requests covering areas involving deep-draft shipping would be most helpful. Since NMFS has specifically established an artificial reef office, perhaps a logical home already exists for coordinating functions.

It is recommended that artificial reef proponents be required to:

- Be more definitive in their proposals by including full details on location, marking, sizing, usage, control over sinking construction, operational controls and other information pertinent to proper evaluation.
- Carefully select sites and be prepared to pursue permits in a logical and reasonable fashion.
- Insure that materials/hulls for reef construction are properly cleaned and certified by a recognized authority, especially in relation to oil/hazardous materials, to avoid possible liabilities on passing vessels.

It is recommended that the pertinent government agencies jointly develop a standard set of permit request details and artificial reef criteria which must be met by reef proponents if their request is to be processed. Such uniformity would be of benefit to all parties, including the proponents. AIMS stands ready to assist by providing practical inputs toward reasonable criteria. As the U. S. member of the International Chamber of Shipping, and a full participant in all matters before IMCO, AIMS can coordinate maritime industry participation in an improved system it is hoped will result from this Conference. Under today's conditions, the compatibility of ships and reefs is doubtful. We sincerely hope the above thoughts contribute in some small way toward a more compatible tomorrow.

The Commercial Fisherman's View of Artificial Reefs

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Ladies and Gentlemen, I am flattered at an invitation to appear before this distinguished group this afternoon. However, I must confess that I am no expert in the legal ramifications of locating, constructing and maintaining artificial reefs. I'll leave that to my good friends Herb Blatt, Gary Knight and other international lawyers. With your permission, I will confine my remarks to the project at hand; the creation of artificial reefs by sinking surplus Liberty Ships in the Gulf of Mexico.

My interests in artificial reefs stem from three sources. First, as a biologist, I recognize that very few techniques designed to increase the availability of wildlife species have been as successful as artificial reefs. In fact, many of the techniques used by game managers and biologists to increase the availability and abundance of wildlife are either too expensive or too temporary to be practical. This is, however, not the case with artificial reefs.

Biologists, fishermen and divers know that rock formations, drilling rigs and old wrecks are the living quarters for a host of marine species. The placement of Liberty Ship hulls on the Gulf bottom is very much like adding a wing to an apartment house in Houston. We are simply making room for more residents. Biologists have debated whether or not such management techniques actually increase the desired species or merely concentrate those already present in the Gulf. Fishermen could care less. They know they catch the kind of fish they want when they fish over the various kinds of outcroppings on the floor of the Gulf.

My second interest in artificial reefs is that of a sport fisherman. New reefs or the expansion of existing reefs are going to increase our opportunities to catch game fish in the Gulf. No question about that! Whether I can catch more of them or not is another question.

My third and greatest interest in artificial reefs is as a representative of one of the several other users of the Gulf and its estuaries, America's most valuable fishery, with landings in Texas ports in 1973 of 51.4 million pounds worth \$87.5 million at the dock. Artificial reefs are not going to benefit this industry in any way, that I can see. On the contrary, unless they are placed in areas already denied to shrimp fishing because of a bottom obstruction, either natural or manmade, they could create a serious hazard to Gulf shrimp trawling.

However, if the Liberty Ship hulls are placed on the locations finally selected by the Texas Coastal and Marine Council we do not see this as a problem to our industry. Marking the reefs with lighted bouys and maintaining such bouys is quite another matter and this problem has not yet been solved.

Some years ago an artificial reef made of car bodies was established off Port Aransas by the Texas Game and Fish Commission in cooperation with the Charter Boat Operators Association of Port Aransas. The car bodies later broke up and were distributed over a wide area in the Gulf. Many of these car bodies or parts of them found their way into the trawls of shrimp fishermen in prime fishing grounds. These shrimp fishermen are naturally concerned and suspicious when we talk about adding additional underwater obstructions to an already cluttered Gulf bottom. And they also have good reason to be concerned about the maintenance of bouys on artificial reefs. The bouy which marked the Port Aransas Reef has been missing for about ten months. (The Texas Parks and Wildlife Department has the responsibility of maintaining this bouy.) Their track record is not very good in this area, in my opinion.

Through the efforts of the Texas Coastal and Marine Council the surplus Liberty Ships were made available by the federal government to the state for use as artificial reefs. The Texas Parks and Wildlife Department was then designated as the agency responsible for maintenance. The Parks and Wildlife Department, probably because the program did not originate in their shop, showed very little enthusiasm but did agree to budget $3,500 per year for maintenance out of current operating expenses. Recognizing that $3,500 would not cover the costs involved, it was proposed that "local interests" would match these funds to make up the necessary balance.

We consider this approach entirely unsatisfactory. To my knowledge the "local interests" have not even been identified, so how can we have any kind of assurance that such financial support will be continuous, if it is, indeed, made available in the first place?

The Texas Shrimp Association and various sportsman's organizations supported the Parks and Wildlife Department's request to the 63rd Legislature for an increase in all license costs to provide more funds for such projects. We therefore feel very strongly that the Texas Parks and Wildlife Department should assume full financial responsibility for the project and not impose on local interests. The "local interests", whoever they are, are already paying their share in the form of substantial increases in license costs. Further, I expect that federal aid funds under the Dingle Johnson Aid to Fisheries Act would be available to further reduce the cost to the state.

To determine the legality of spending state funds outside the state of Texas, the Parks and Wildlife Department asked for an Attorney General's opinion. The opinion was yes, the Department could spend funds on the project provided funds were available for this purpose. However, the Department's legal council has indicated recently that current operating funds could not be used on the maintenance programs.

This, of course, is only one legal opinion and not necessarily the final one. In any event, all of us would like to see the project succeed, but to do so, a realistic method of financing will have to be developed. Probably the best method would be to make certain that adequate funds are budgeted by the Parks and Wildlife Department and appropriated by the Legislature to permit the Department to enter into a contract with a private firm to maintain the bouys. An unmarked reef that sports fishermen can't find will be of limited benefit to them and could well become a hazard to shrimp trawlers.

I would recommend to you Texans who are interested in completing this project that you make certain that the agency responsible for the maintenance of the bouys marking the reef locations be adequately funded to carry out this responsibility. I have told the leaders of my industry that this will be done. I hope you will not let me down.

Thank you, Mr. Chairman, for your invitation to visit with you today.

Discarded Tires as Artificial Reef Material

THOMAS F. MINTER

Vice President of Domestic Production, The Goodyear Tire and Rubber Co., Akron, Ohio 44316

It is a privilege to share the rostrom with the distinguished speakers on this program and to address a distinguished audience representing many countries. I am sure that your sessions have been most enlightening, and I am convinced you are making an auspicious start in sharing experience and knowledge about artificial reefs -- a most important field.

It is fitting and appropriate that this meeting is being held here in the Lone Star State. Texans have always maintained they think and act big, and are action-oriented. And that fits right in with the temperament and outlook of artificial reef builders.

One thing that attracted us at Goodyear to artificial reef projects was the innovative approach of the people who have promoted and built artificial reefs. We have found them to be people with ideas and vision and receptive to new ideas. That appealed to us.

In addition, the proposals to use discarded tires as reef building material fit right in with our research projects aimed at making scrap tires a resource, rather than a liability. When Dick Stone dropped in to talk about reefs with some of our people about four years ago, he struck a responsive chord. Goodyear research and development people were and are pursuing various means of utilizing tires that had outlived their highway usefulness. Our concern is conservation. We have created a product with some remarkably durable properties. We are seeking means to keep from squandering the wealth that remains in old tires. As you've been told, I'm sure, the United States alone has some 200 million worn-out tires that must be disposed of each year.

When a tire is bald and no longer roadworthy, it still has most of the bulk that it had when it was new. Most of the rubber and virtually all of the fibers and the metals remain. Naturally, then, the first thought is reuse or recycling of tires. Many tires are recapped to prolong their life. This may postpone consignment to the scrap heap but the time will come when the tire must be removed from service for safety's sake.

At present, a certain amount of reclaimed rubber is used in the manufacture of new tires. However, the properties of rubber after it has been reclaimed are different from new rubber. As a result, its uses are limited. The industry is hopeful that advances in rubber technology will enable us to come closer to total recycling. We anticipate that some day we may recover not only a better quality rubber but also the polyester cord material and metals from the bead and tread.

And right now, it is possible to obtain a key ingredient in rubber compounding from discarded tires. Carbon black, normally produced by the incomplete combustion of oil, may be soon produced by utilizing scrap rubber in the process. Goodyear has participated in this research. Although it is possible to obtain carbon black from old tires, until recently it wasn't practical from an economic standpoint. This situation is changing rapidly because of the shortages of oil. The rubber industry also is experimenting with a distillation process to convert scrap tires into reusable chemicals.

An artificial turf made of ground-up tires and mixed with an adhesive shows promise as a ground cover in playgrounds and around swimming pools. It can be decorative, too, inasmuch as it may be produced in a variety of colors. Ground up tires also have proved their usefulness as an asphalt additive for a variety of paving uses.

One of the great potentials of old tires, we believe, is to use them as an energy source. In fact, Goodyear soon will be using scrap tires as fuel to help produce new tires. A smokeless, odorless furnace at our Jackson, Mich., plant will burn tires to generate steam.

Rubber has a BTU value that is approximately 50 percent greater than coal. Our tire-fired boiler will burn them with great efficiency, leaving only a small amount of sterile, inert residue that we easily can dispose of in landfills. Moreover, we anticipate recovering metals, primarily zinc, from the ashes.

The Jackson furnace will consume about 3,000 tires per day . . . more than a million per year. Obviously, in certain locations, furnaces such as these will help conserve dwindling supplies of other fuels At the same time, they will help solve the waste disposal problem created by discarded tires. But using tires for fuel is economically practical only in areas where discarded tires can be obtained in sufficient quantity with reasonable transportation costs.

In addition to being a source of energy, worn-out tires have high energy absorbing capacity. This characteristic has enabled us to use tires in impact attenuator systems or crash barriers following the publication of the results of recent tests by the Texas Transportation Institute at Texas A&M University.

The energy absorbing capacity of tires has another promising application that should be of special interest to you. In cooperation with the University of Rhode Island, we are currently experimenting with scrap tires in floating breakwaters. Tires are linked by cable in various configurations in a manner similar to the crash barriers. From what we've observed to date, floating scrap tire breakwaters appear to offer an effective, durable and low cost method of protecting small boat marinas and other shore facilities. In addition to the floating breakwaters, designs for full depth structures made of discarded tires are being considered for breakwaters, seawalls, bulkheads or revetments.

In varying degrees, all of the projects and experiments I have mentioned promise to help us attain the objective of turning scrap tires from a liability to an asset. None of them, however, has yet proved as effective and productive as artificial reefs.

Our expectations for the pilot projects in which Goodyear has been involved are more than realized. In only two years we have accomplished what we set out to do. Our primary purpose was to learn if artificial reefs are one of the practical ways to alleviate the scrap tire disposal problem.

Secondly, we wanted to help develop the organizations, procedures and technology for building rubber reefs.

Finally, we hoped to reach a position from which we could share the lessons of the pilot projects with other groups interested in constructing artificial reefs.

We have cooperated extensively in terms of equipment and technical assistance with different types of organizations in four major pilot projects, all located in southern Florida. The proximity of the four projects was a great convenience to our technical personnel assigned to them. At Fort Lauderdale, certainly one of the most successful reef building programs anywhere, we began working with the non-profit Broward Artificial Reef, Inc., a broad-based community organization. You already have heard about this project from our good friend Greg McIntosh, a man who really gets things done. You know that the enterprise of Barinc proved the practicability of the Osborne Reef. Barinc demonstrated the ecological advantages of this method of scrap tire disposal which, at the same time, has regenerated game fishing off the Fort Lauderdale coast. The job was so well done that the county became a partner. The result is that this reef is one of the largest and fastest growing artificial reefs in this hemisphere.

Across the state at Marco Island, Goodyear has been providing worn-out tires and technical assistance to the Deltona Corporation in carefully controlled experiments in reef building. Deltona, developer of a planned community on the island, undertook the reef project as a part of its effort to maintain and restore the wildlife and other natural resources of the Everglades region.

The reef sites are plotted at different depths and various configurations of tire bundles are being used in an effort to determine the most productive construction methods. Other materials also are being used for comparative purposes.

The Marco Island project is under the direction of the Marco Applied Marine Ecology Station, staffed with marine biologists and other natural scientists. As a result, the reef is under continual scientific observation. The progress of the aquatic community development has been charted at every state. More than 90 species of fish have been counted at the first reef located in about 20 feet of water. We believe that the body of scientific knowledge from the Marco Island Reef will be valuable there and elsewhere.

More recently, our company has been cooperating with reef builders at Naples and Fort Myers, Florida. At Naples, the project is spearheaded by the cruise club, a group composed primarily of some very vigorous retirees. And at Fort Myers, by way of an age contrast, the project has been initiated and led by the Junior Chamber of Commerce.

Obviously, there is no single best way to organize a reef project. It can be done as a public or as a private enterprise. It can be promoted by citizens of all ages and of varied circumstances. The constant factors in all of the groups with which we have worked are a spirit or cooperation and a dedication to getting the job done, regardless of the obstacles and setbacks. And there have been plenty of them.

The organizational structures tend to evolve from the nature of the community. The common characteristics are the concerned and informed citizens who make them go. Their efforts, I'm happy to note, are attracting ever wider recognition and assistance from governments at the local, state and national level. These artificial reefs are showcase projects, demonstrating that ecological problems can be tackled effectively by cooperative community efforts.

The one limitation on the potential use of scrap tires in reefs, as for other uses, is the availability of discarded tires. Costs can be burdensome if the tires must be transported a considerable distance to the reef staging area. This is a factor that must be considered in the initial planning of a reef. Tire recapping plants and retail outlets normally are willing to contribute tires that cannot be recapped. But the cost of getting the tires to the reef can be a major item.

Some very useful data on the location of scrap tires in the United States in relation to the potential reuse facilities, including artificial reefs, have been compiled by the Rubber Manufacturers Association. These data are contained in the report "Nationwide Network for Reuse of Scrap Tires" prepared in 1971 for the Rubber Sub-Council of the National Industrial Pollution Control Council. Communities that are considering artificial reef projects would be well advised to refer to this report and to other data on the availability of tires.

In this regard, the RMA currently is negotiating with the nation's major railroads for more favorable rates on the transportation of scrap tires to reuse facilities, including reefs. If successful, we should be able to make greater use of this resource that we are just beginning to tap.

In summary, Goodyear believes that it has achieved its initial goals in regard to artificial reefs. Through our participation in the four pilot projects in the United States and as supplier of worn-out tires to reef projects in several countries, we have learned that artificial reefs are practical from the standpoint of providing an ecologically sound method of scrap tire disposal. Tires on the ocean floor have proved to be durable and non-polluting . . . and excellent material for reef construction. Moreover, the cost factors are favorable in comparison with other methods of scrap tire utilization. The 1971 study made for the RMA projected capital investment requirements and operating costs for artificial reef building that made reefs among the most attractive alternatives for tire reuse. Our experience has borne this out.

Secondly, we believe that we have participated in developing organizational procedures for reef building that may be adapted by other communities. At the same time, our engineers have developed machinery and methods for ventilating and bundling scrap tires that have proved most satisfactory.

Finally, we have reached the position of being able to share our experiences in a variety of reef building projects. To this end, we have prepared a kit entitled "Building a Tire Reef" that we hope will be a useful guide to groups that are considering reef projects. Copies of this kit are available to you at the Goodyear exhibit here at the conference. We would welcome your reaction to it.

Additionally, we are prepared to furnish, without charge, detailed plans for building the compacter and punch that have been designed by our engineers. These plans will be furnished on request to organizations that have the necessary approvals for reef construction and are ready to proceed.

Goodyear has expended a substantial budget for capital expenses in reef projects. And we consider it money well spent. Now, however, we believe that we can best serve the interests of the greatest number of communities by sharing the experience we have gained and by providing plans when requested.

Texas' Artificial Reef Program

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Artificial reef building in Texas waters has been in progress for about 15 years. While some oyster reefs were created in Galveston Bay prior to this time, the first three offshore reefs, constructed of old automobile bodies, were built in 1958 by the Texas Parks and Wildlife Department. They were located 10 miles offshore from Freeport, seven miles off Port Aransas and six miles off Port Isabel, all in 60 feet of water.

In 1962 and 1963, new reefs were built off Galveston and Port Aransas of concrete and clay pipes of various sizes. This material produced nearly permanent reefs of sufficient bulk to attract fish, yet prevented easy shifting by water currents. In 1968, several steel barges were added to the Port Aransas reef with a second new reef of steel barges built farther offshore. The Galveston reef is located approximately 10 miles offshore in 60 feet of water and has a 50-foot clearance from water surface.

Inside Texas bays, several reefs have been built. Although most of these reefs are built of oyster shell, they attract fish in the same manner as reefs built of other materials. Most of them have a low profile of one to two feet and are in eight to ten feet of water.

In addition to the Texas Parks and Wildlife Department, the Sportsmen's Clubs of Texas, Inc., Boating Trade Association of Metropolitan Houston and other fishing and diving groups have been responsible for constructing other nearshore and bay reefs.

Sport fishing is by far the major reason for the accelerated interest in artificial reefs. Where rocky coasts, coral reefs and jagged banks are not found, artificial structures have been placed in many areas to increase the fish population.

In recent years scuba diving has become a real attraction to many water sports enthusiasts. Part of this attraction has been due to the creation of additional underwater exploration sites -- artificial reefs. The adventuresome spirit of the scuba diver has placed him in the forefront of those with an interest in underwater reefs. While some divers are interested in spear-fishing, others are interested in observing, exploring and photographing the underwater sights, including both the reef structure and the marine life surrounding it.

MATERIALS

One of the fundamental specifications of a reef is that it must provide surface area for the encrustation of small marine organisms. Cracks, crevices and other hiding places for shelter and protection of smaller fish also are necessary.

Tires

Automobile tires are the most widely used material for artificial reef construction at the present. They work well, are available in great quantities, are relatively inexpensive, last indefinitely and do not pollute.

Used tires are in great abundance all along the Texas Gulf coast. Disposal of used tires has become a major problem. A check in 1973 with the City of Houston and Harris County authorities indicated no specific policy with regard to tire disposal except that they cannot be burned within the city or county nor can they be carried to the city or county solid waste disposal areas. Most tire dealers pay from 10 to 15 cents per tire to have them hauled away.

There are more than three million used tires available annually along the Texas Gulf coast with nearly two million in the Houston-Galveston area. There is little or no cost in obtaining the tires. They must, however, be stabilized in some way to keep them from floating away from the reef site and becoming a shipping or trawling hazard.

Preparation costs vary with the different configurations used. Some configurations use reinforcing rods running through several tires and ballasted by completely filling the base tire with concrete. One cubic yard of concrete fills 16 or 17 base tires. The ballast tire weighs about 240 pounds when dry. The unit can then be rolled onto a barge for the trip to the reef site. The cost of building this configuration in 1968 was $2.87 per unit or about 35 to 40 cents per tire.

Compressing tires into tight, small bundles helps to keep them in position after being placed on the reef site and provides more area for the protection of fish as well as for encrusting organisms to attach themselves.

Current cost figures for constructing a 12-tire configuration with concrete for use at a site off the coast of Florida is $6 or about 50 cents per tire. This includes the use of a compacting machine to compress the tires, tying with nylon tape and transporting by barge about three miles offshore. The initial cost of the compactor is around $8,500.

Concrete Pipe

Broken concrete pipe, concrete blocks and concrete rubble have been used with very good success as artificial reef material. Damaged concrete pipe is available in large quantities in most of the larger cities along the Texas coast at a cost covering transportation only.

Limitations in using concrete pipe, blocks and rubble include the necessity of using handling equipment to load the material on a barge at the dock and also to unload at the reef site.

A desirable feature in preparing concrete pipe is the tying together of several pieces of pipe with cable or cement. This helps to secure the pipe after it is placed on the ocean floor and prevents scattering by water movements. This does, however, give added expense to preparation and handling.

It is estimated that the cost for transporting a 120 x 40 foot barge load of concrete pipe consisting of 378 pieces of 36 inch x 6 foot pipe from Houston and unloading in Galveston or West Bay would be about $3,200. For offshore sites, this cost would increase about five times. Costs would be approximately the same for transporting other similar materials. It is possible, however, that a portion of this cost might be eliminated by a company donating the use of a barge and tug for a project of this kind. This has been done on occassions.

Unless the concrete pipe and other similar material are available near the coast, transportation costs might prohibit its use as reef material.

Automobile Bodies

Discarded automobile bodies make an excellent artificial reef, but with limitations. They must be tied together for stability against rough waves, especially in shallow water and hurricane-prone areas. They do not last long in sea water and must be replaced after three to five years. They are easily scattered if the tying cable pulls loose or when it rusts away. The scattered car bodies can get caught in shrimpers' nets and cause considerable damage and loss to the shrimper.

The old car bodies used for reefs by the Texas Parks and Wildlife Department during the late 1950's cost about $20 each. Additional expenses were incurred for cleanup, assembly and transporting to reef site. The car bodies were prepared by burning all the non-ferrous material and three to five were tied together in bundles with a steel cable. The bundles were pulled off the barge, rather than lifted with a crane, and dropped on the seabed. Evidently in this operation some of the cables either broke or pulled loose from the car bodies. High winds and rough waves were then able to move some of the single car bodies away from the reef site.

Oil Well Platforms

Offshore oil well platforms are scattered throughout the Gulf along the Texas and Louisiana coasts. While in use for oil production, these structures also provide excellent habitats for fish. When the wells cease to flow, removal of platforms is an expensive operation. It was estimated that this cost in 1969 was approximately $1 million for a typical production platform. Due to inflation and other higher costs, current and future expenses undoubtedly would be greater. After the platform legs are cut off approximately 14 feet beneath the mud line, the platform then must be hauled to shore and salvaged. The cost of labor (in 1973) involved in dismantling the platform in dry dock was greater than the salvage value of the material. Some of the major oil companies have indicated they might be willing to remove an abandoned platform, haul it to a reef site and dump it near the existing reef materials to be used as additional reef material at no cost to the state.

As of January 1, 1973, there were 2,751 active multiwell platforms, single well platforms and other platforms in the Louisiana/Texas Gulf. While it is obvious that many of these are not ready for abandonment, experience shows that several are abandoned each year.

Two possibilities of using active oil well platforms in conjunction with an artificial reef should be explored further. In one method, automobile tires are strung on cables extending downward and enclosed within the legs of the platform. Obviously, the cables should be plastic or some other non-corroding material.

Another use of active platforms is to band tires together and place them between two separate platforms. Some of the usual procedures for stablizing tires at a reef site should be used. The idea for using platforms in this way originated with Gene Shinn of Shell Oil Company.

Certain legal problems may arise with the use of active offshore platforms that would need to be resolved. Above all, caution should be used by visitors to the platform reef when oil company personnel are working.

Other Materials

There are other, less desirable materials that should be mentioned. Some solid by-product materials such as slag, dredge-spoil and gypsum are available in abundance at low or no cost but are unsuitable for use alone due to their nature.

In a close, tight-fitting material, there are no voids left for shelter for fish nor voids for marine life to attach itself in abundance. This type of material usually is unstable and subject to current movements. It also has a tendency to increase the turbidity of the water which discourages many fish from being attracted to it.

Development of artificial seaweed has been attempted recently by different research groups. Anchoring and containing the seaweed in one area have been extremely difficult in most experiments.

SOCIO-ECONOMIC BENEFITS

An artificial reef program must promise to stimulate significantly a particular area economically in order to make its construction worthwhile. To determine the net benefits, various costs (materials, transportation, installation, marking reefs with buoys and maintenance of buoys and reefs) must be compared to benefits derived from increased fishing activity. Some general estimates of costs have been given previously. Additional revenues and industrial expansion resulting from the fishing industry, recreation and tourism and other supporting activities will encourage additional employment, generating more income.

The main purpose of artificial reefs is to increase fishing productivity. It becomes essential, therefore, to determine the portion of increased productivity attributable to a reef, since the remainder of economic activity will depend solely on increased fishing production. Once a productivity increase has been firmly established and information has been disseminated adequately, tourists and fishermen will be attracted to form the basis for industrial expansion, employment and revenues.

A proposed method for calculating rising fishing activities is to interview a predetermined sample of fishermen on site before and after reef installation. A concurrent count of fishermen and related fishing activities will be estimated to reveal the influx of new fishermen due to a reef's installation. Industrial growth can be measured in the form of newly-located industries, changes in sales volume, value added, employment, income and revenues during a given time period. Further indicators include construction of new recreational and related facilities; increased number of boats docked in local harbors; increased expenditures on charters, admission fees, food, lodging, gas and oil, bait, ice and tackle; and increased numbers of cars arriving and parking within an area. Maintenance and repair expenditures provide further evidence of rising port and shipping activities.

Stone, Buchanan and Parker of the National Marine Fisheries Service and Hart obtained data from two separate studies in Morehead City, North Carolina and Murrells Inlet, South Carolina which indicated some additional economic impact on the two areas.

From an evaluation of the Murrells Inlet artificial reef project, quantitative visual estimates of fish abundance were made. Based on visual observations, it was found that the new fish population increased 300 to 1,800 times a few months after reef construction.

Charter boats, head boats, fishing piers and rented slips and boat storage space accounted for just under $2.7 million of spending by non-residents of Morehead City, North Carolina. Of this total, about $1.4 million remained in the county economy in the form of direct and indirect contributions to the personal income of county residents.

Social benefits derived from an artificial reef program are multiple and can be identified most effectively by a survey and personal interviews with the citizens of a community. Increased income injected into a region by tourists may enhance the area's economic base. Increased community wealth may increase the tax base thereby permitting better community development, such as improved housing, education and public facilities, and make the community more attractive to additional tourist groups and industries. The tremendous recreational potential evolving from such a reef program will provide individuals with a versatile number of options for use of his free time.

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