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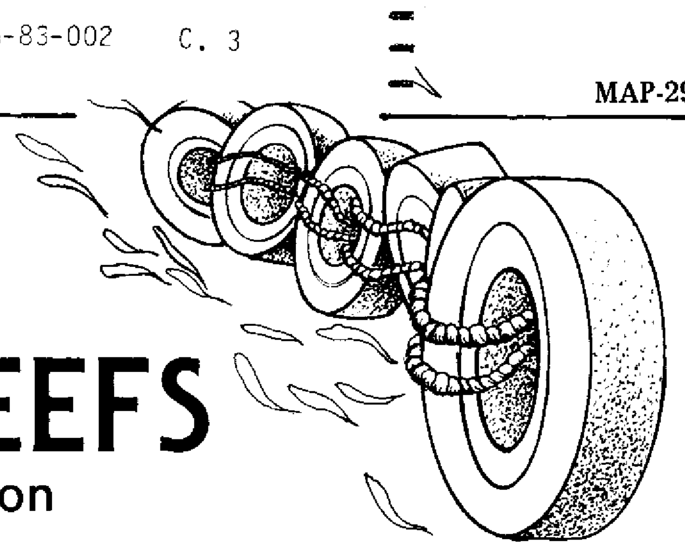


ARTIFICIAL FISHING REEFS
Materials And Construction

Dr. Heyward Mathews

INTRODUCTION

Artificial reefs, when sited and built correctly, have long been known to attract food and game fishes into areas easily accessible to fishermen. The effectiveness of reefs, however, depends greatly on the site, the type of materials used, depth, configuration, and local oceanographic conditions. In some instances, considerable amounts of time and money have been spent only to have the reef later destroyed or become less useful than expected.

The purpose of this publication is to survey the more common types of artificial reef materials in use today and to discuss some of the advantages and disadvantages.

Artificial reefs can be divided into three general categories: 1) Bottom reefs; 2) Mid-water reefs; and 3) Surface attractors.

Bottom Reefs

Artificial reefs built directly on the sea floor are by far the most common type of reefs built in the United States today. These reefs can be subdivided into two main categories: low density and high density materials.

Low density materials, have low mass to volume ratio such as scrap tires; white goods, such as old stoves and refrigerators; and car bodies. High density materials include concrete, heavy fiberglass, steel, and other dense materials that generally do not need additional ballast to remain in place on the sea floor.

Low Density Materials

Scrap Tires: The use of scrap car and truck tires for artificial reef building in this country probably began in the late 1950's and early 1960's. Tires once worn past the recapping point are readily available and generally can be obtained in large quantities at no cost other than transportation and preparation. They are almost impervious to decay in sea water, so the life expectancy of a tire in sea water is probably hundreds of years.

Scrap tires have been used in a wide variety of configurations throughout the country, but they have become probably the most troublesome of reef materials. A car tire weighing some thirty pounds in air will often weigh only five to eight pounds in water. Consequently no matter how many tires are put together in a bundle, the whole structure will still be very easily moved by wave surge or bottom currents. As a result, tire reefs have caused some problems in Florida and on the Pacific Coast when built where storm surges can dislodge the units.

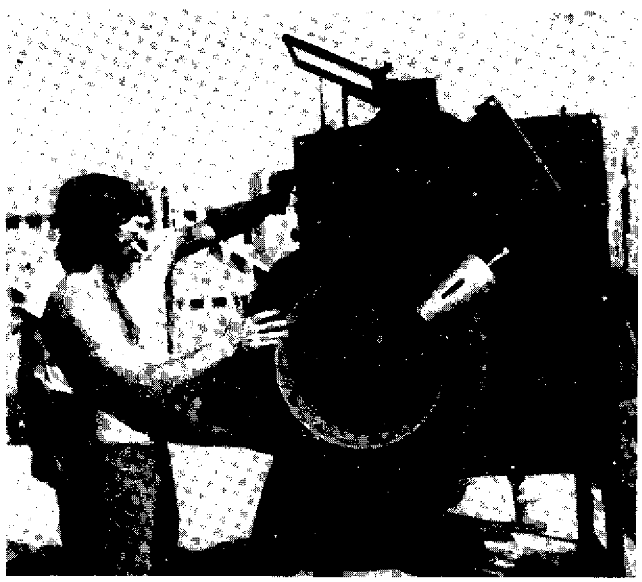
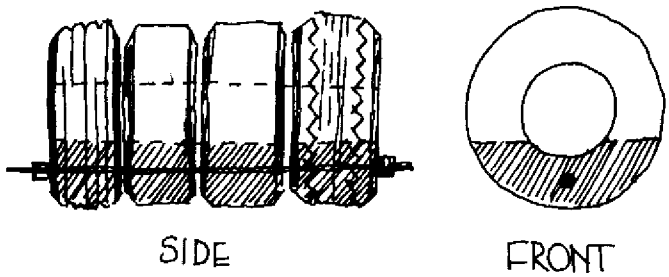


Fig. 1 Tire Cutter

In addition, a single passenger car tire will trap enough air to hold up to twenty-five pounds of concrete if some type of vent is not cut into the top. Venting of trapped air has been done by using a hole saw, chain saw, hydraulic or pneumatic punch, or by splitting the tire completely in half with a tire cutter (Fig. 1).

Once all air is allowed to escape, the tires must then be bound to provide a profile up off the bottom as well as inside hiding places. Single tires produce very poor results. On a hard bottom, single tires will not remain in place during periods of heavy bottom surge or strong currents.

One of the earliest and most common tire units consists of three or four tires standing upright with a reinforcing rod through the bottom and concrete poured into the bottom to cover the rod completely (Fig. 2).



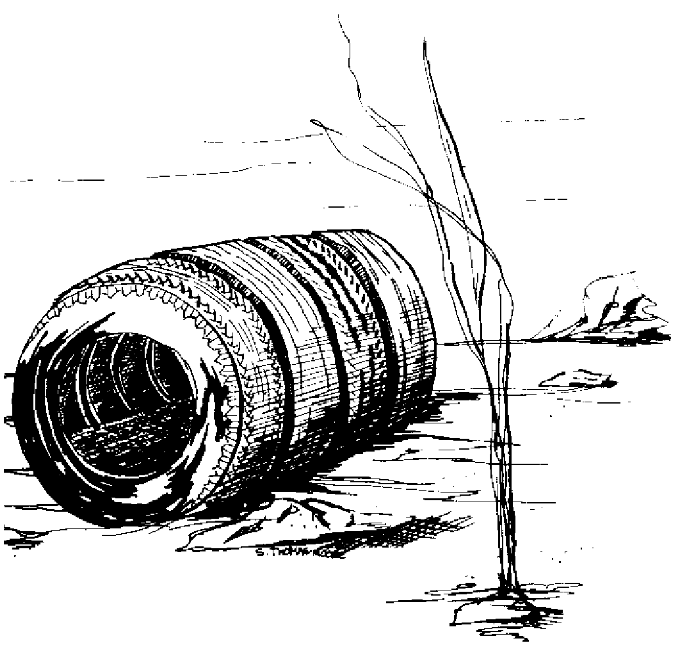


Fig. 2 Typical 4-Tire Unit (Drawing: S. Thomas Moore)

Two people can easily load it onto a barge or similar vessel using a 4-foot section of 1-inch pipe as a handle. This type of tire unit requires a considerable amount of time and labor as well as the cost of the concrete and reinforcing rods. Also, since these units do not pile up well, they offer only a low profile habitat which is not as effective as one with a higher profile. To achieve maximum effectiveness, these units should be dropped as close together as possible. The dropping vessel should be anchored, or a float dropped, and all units dropped around the float. If possible, the vessel should be anchored fore and aft to avoid scattering the units. This type is most stable when positioned on sand bottom so it can sink six to ten inches into the substrate.

Fig. 3 Ft. Pierce Tire-Concrete Unit

An effective modification is one developed by the Ft. Pierce Recreation Department, Ft. Pierce, Florida. Twelve tires were positioned upright in a wooden form. Approximately one-half cubic yard of concrete was poured around and inside the tires to form a 3-by 9-foot concrete slab from which the tires project upward (Fig. 3). Individually, this unit does not offer much advantage over the single four-tire unit, but it does lend itself well to multi-unit structures. In depths of 50 feet or more, this type of multi-unit appears to be rather effective. It would probably not be very cost-effective, however, if the concrete had to be purchased.

The cost of this particular unit was kept down by placing the forms at a concrete plant and filling them with leftover concrete from returning trucks. Pinellas County, Florida, has obtained numerous buoy sinkers in a similar way by placing a mold at a concrete plant.

Other multi-tire units have been used around the country, some standing up three and four tires high. These have had limited success in fresh water lakes without long wave action but tend to fall over in coastal waters and lose much of their effectiveness. They are not very cost effective when the labor costs are added and have a limited life span when reinforcing rods are used to hold the structure upright because the rods eventually rust and the unit falls apart.

White Goods: Discarded stoves, refrigerators, bath tubs, commodes, washing machines, and similar appliances, at first seem like good reef materials because they are readily available in moderate quantities and the porcelain does slow down the destruction by rusting in sea water.

The problem is, however, that stoves and refrigerators have large amounts of insulation that provide air traps. If concrete ballast is used, then much of the inside space is filled. White goods also provide rather limited hiding spaces for fish, even when the doors are removed, because fish will generally avoid "dead-ends." At one time, it was thought that the encrusting organisms would establish a firm base that would remain even after the metal rusted away. This may be true in tropical areas where coral growth is very rapid, but even in south Florida, the entire profile is lost in two to four years when the thin metal deteriorates. Experience has shown that white goods are not worth the labor involved in their collection, preparation, and transportation to the site in terms of years of use and fish habitat produced. Some states, like Florida, have simply refused to permit white goods for artificial reefs.

Car Bodies: Some of the first artificial reefs in the United States were made using old car bodies. Alabama and Florida once had several large car body reefs that for some years were very effective fish attractors. Unfortunately, the metal in these car bodies was thin and often already badly rusted even before they were placed in the ocean. These reefs soon rusted away to small sections that sank into the substrate, often leaving no trace whatsoever after five to seven years.

Recent changes in the pollution laws require that prior to dumping, the rear ends, transmissions, and engines be de-greased. In addition, all seats and headliners must be removed, so the labor cost soon becomes excessive. Also, car bodies have thinner metal than in the early 1960's, so modern car bodies have an even shorter life span in sea water.

As with white goods, it has been proven that the idea that marine growth over the metal prolongs the life of car bodies is in error. Car body reefs are simply not cost effective and are very short lived.

High Density Materials

Concrete Culvert: The use of concrete culvert probably began in the mid and late 1960's. It can be obtained in most urban areas where road construction is common, and broken or chipped sections of concrete pipe can often be obtained at no cost from manufacturing plants.

Concrete culvert has a very long life span in sea water. So, if properly sited, a culvert reef will remain effective for several thousand years at least. For best results, the culvert should be piled up as high as possible, preferably 8 to 12 feet above the bottom. Often the effectiveness of culvert can be increased by placing a smaller diameter culvert inside a larger one. Care must be taken to avoid placing solid culvert up on end; this will provide a stagnant water area that will collect only silt. Additionally, fish tend not to go down into such a blind alley. Consequently, when culvert is dropped from a barge, it should be released so it will land at an angle or horizontal. This is particularly a problem with short sections of 48-inch and larger diameter pipe.

If the unloading vessel cannot be anchored fore and aft, then a marker buoy should be used to insure the entire load is placed in a pile. Even a small swing of the vessel at anchor will result in considerable scatter and a drop in effectiveness. A successful configuration built in Pinellas County, consists of circular clusters 30 to 50 feet in diameter spaced 50 to 70 feet apart. Culvert reefs are permanent and require relatively limited amounts of labor; however, they do require heavy equipment to load and unload.

In Pinellas County, an artificial reef construction program has become a permanent municipal function. New road construction bid specifications require that all old culvert removed be made available to the reef project. The contractor provides the loading at the construction site, and county trucks transport the culvert to the waterside staging area. In heavily urbanized areas where landfill space is limited, construction companies are often willing to transport old culvert to a staging area free of charge. Concrete culvert is probably one of the most effective reef materials in use throughout Florida and elsewhere around the country.

Bridge Rubble: One of the least expensive types of artificial reef material is concrete and steel rubble from bridges. This material is not always available but whenever a large bridge is slated for removal high priority should be given to making a reef from the rubble. Often building a reef from the old bridge is the most economical means of disposal because it can be removed directly from the bridge site and dumped by barges in larger sections than would be possible with truck transported land disposal. As with culvert, the key is to achieve a high profile by careful off-loading on the reef site. When possible, it is advantageous to have reef building personnel on board the vessel to insure that the material is off-loaded in a way that insures maximum profile. If the materials are scattered on the bottom, then most of its effectiveness as a fish habitat will be lost.

With concrete materials, this type of reef has an infinite life span when built on an appropriate site. It can be built off high energy shorelines, but should not be combined with any breakwater or erosion control structures because the shallow depths required for erosion control are less than optimum for fishing reefs. Steel bridge structures are also very effective as reefs but have a shorter life span in sea water. The heavy steel used in bridges generally has a life span of twenty to thirty years, long enough to justify its transport cost in most locations. Wooden bridge pilings, however, are normally not recommended for reefs because of their low density on the bottom and a tendency to shift during periods of heavy wave surge.

Pre-formed Designs: Several pre-formed concrete reef structures have been used with some success around the country. Back in the mid-1960's, a common reef structure was the "Japanese Pill Box" design. This structure was a copy of some early designed units built in Japan and consisted of a concrete box 4 feet wide, 10 feet long, and 3 feet high with large diameter holes in all sides (Fig. 4).

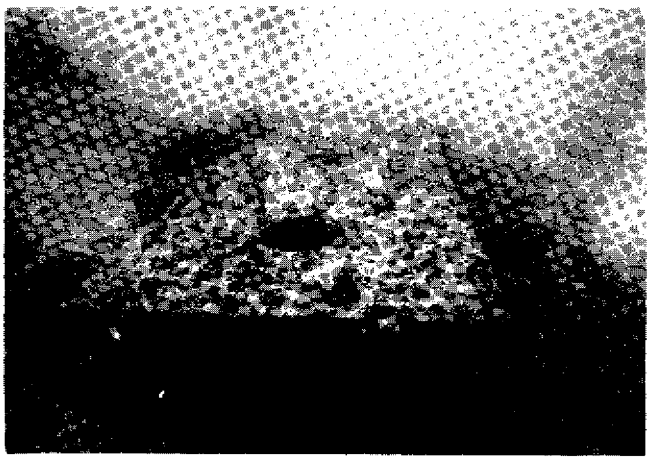


Fig. 4 Japanese "Pill Box" Unit (Photo courtesy Dr. Dan Sheehy) Copyright - Aquabio Inc. 1981.

These units were not only rather expensive to construct, but they also required careful handling in both on-loading and off-loading at the reef site. Since they were rectangular in shape, they could, in theory, be stacked up to provide excellent profile. In actual practice, however, this ideal configuration was seldom achieved. Modern equivalents to these custom built units can often be found at a construction site as junction boxes for large diameter culvert. Similar units have been used with pyramid or dome shapes. At present prices for concrete and labor, these units are expensive and probably not cost-effective when compared with other materials.

A six-pointed concrete unit, similar to a child's jack, has been used off south Florida. However, this unit was only effective when interlocked into some type of structure that extends some distance off the sea floor. Actually placing these on the bottom into such a configuration requires careful planning and specialized equipment.

In Japan, where most of these designs originated, very large barges are used with enormous cranes capable of placing whole structures on the bottom in one lift.

Mineral Waste Aggregates: This is a relatively new type of reef material utilizing fly-ash from coal fired power plants. Using a patented process, chemicals are mixed with the fly-ash to produce a substance that hardens much like concrete. This material appears to be stable in sea water and can probably be formed into a variety of structures; however, the initial tests have been with solid square and rectangular shapes (Woodhead, 1979). This material offers some exciting possibilities for the future because construction costs can be kept down and a waste product recycled.

Fiberglass/Reinforced Plastic: This material has been used extensively in Japan and was recently introduced into the United States by Aquabio, Inc. Presently it is being evaluated by Aquabio, Inc. under a grant from the National Marine Fisheries Service.

The fiberglass reinforced plastic (FRP) material has the advantage of being impervious to sea water and possesses very high strength. A variety of designs use this material. The most common is a series of open weave cylinders stacked up in a pyramid structure four cylinders high (Fig. 5). The whole pyramid is fiberglassed together into a single unit and then concrete is poured into the bottom cylinder for ballast. Air bags are used to provide flotation for the units during towing out to the site where the air is released and the whole unit sinks to its place on the sea floor. The "open space" aspect of this unit makes it very effective as a fish attractor and apparently will have an infinite life span when sited correctly. Since it is presently only manufactured in Japan, it is not yet readily available in Florida.

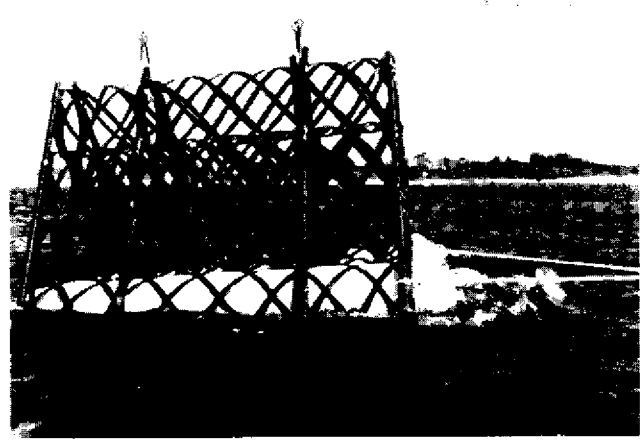


Fig. 5 Fiberglass Reinforced Plastic Reef Unit (Photo courtesy Dr. Dan Sheehy) Copyright - Aquabio Inc. 1982.

Discarded Fiberglass Structures: In Florida, there are numerous boat building firms that construct fiberglass hulls. One part of this industry involves large fiberglass molds to cast the hulls. When the hull design is changed, the old mold is disposed of, and can often be obtained free for reef materials. These have been used very effectively in Pinellas County and, again, they should have a very long life span in sea water. Often these hull molds, and used or damaged fiberglass hulls, can be greatly improved by cutting various size holes all along the structures while maintaining their overall strength.

P.V.C. Reefs: The use of polyvinylchloride pipe is not a new idea. In Destin, Florida, commercial fishermen collect scrap plastic pipe sections which they put together in the form of "Christmas trees" and set into concrete bases. These units can be easily transported by small boats, and, if they are arranged properly in water deep enough to avoid wave action, they can be very effective fish attractors.

Another design, the "Prentis Reef," has been patented but as yet, not adequately tested. It involves a six-sided PVC junction in the 3-4 inch diameter range from which a large "tinker toy" design can be constructed above water and then placed on the bottom. This "open space" design has worked well in Japan, but so far, this particular unit has not been tested regarding its durability. A small PVC unit has been used off Destin, consisting of a 6 to 10-foot tall "Christmas tree" of scrap PVC pipe set in a 5 gallon bucket of cement. These units can be easily dropped from small boats and, if dropped close together in a cluster, can be very effective. They can, however, be easily damaged by boat anchors.

Ships and Barges: These are undoubtedly the oldest type of artificial reef material and still very effective and popular. Steel and fiberglass hulls are the most durable and effective, while wooden hulls have a shortened life span and require more ballast to remain in place on the sea floor.

Surplus Liberty ships were once readily available but that source appears to be nearing an end. Early use of Liberty ships, however, were not all successes although these experiences contributed to better reefs later on. For example, the Florida Department of Natural Resources (DNR) was in charge of sinking five Liberty ships in the mid 1970's. They contracted with salvage firms to cut the hulls down to 12 feet above the keel prior to sinking. The result was a "400+ foot long steel bathtub." Once the ship hulls had collected sand, they resembled low steel walls in a sea of bare sand. The fish attraction effectiveness from these early sinkings is minimal. Later in the 1970's, Florida DNR sank a single Liberty ship with the hull intact and with some holes cut in the sides for open space. While this was not as effective as several Liberty ships sunk by the Texas Game and Fish Commission, it was a great improvement over those first failures.

Most fish species will not venture into a dark closed compartment, particularly one with only a single exit. For this reason, all ships and vessels should be opened up prior to sinking. If possible, all compartments should have as many holes cut as possible without removing the structural strength members to allow free movement of water and light into the hull. The location of the stringers and support beams will determine the size and shape of such openings. Where possible, the entire superstructure should be left intact. If this is not possible, then often a superstructure can be constructed using tires on chains extending up from the deck, much like the mid-water attractors discussed in the next section.

If the drop site has a strong current, tidal or otherwise, the hull should be oriented at right angles to this current. This positioning allows the reef to provide some shelter for smaller fish in the lee of the hull; and, since most of the fouling organisms are filter feeders, allows maximum exposure to plankton drifting past the site.

Sinking of hulls by explosives has, in the past, provided a spectacular show for the press and TV reporters and does have the advantage of opening up hulls below the water line. The disadvantage is that liberal use of explosives can often damage a hull structurally to the extent that it soon falls apart. Explosives should be used sparingly. If a hull can be opened up with cutting torches prior to sinking, it can be sunk by pumping or opening up the sea cocks.

Coast Guard regulations require all oil and other hydrocarbons be removed and inspected prior to the actual sinking. The hull should be anchored securely at the site to prevent its moving during the sinking, which often takes longer than expected.

Oil Platforms: Oil companies have long advertised their offshore platforms as great fish attractors, and they do attract fish because they have the "open space" aspect that the Japanese have long ago proved to be best for most food and game fish species.

These steel platforms will probably last thirty to fifty years, but are rather large, so they must be used in waters with depths in excess of 100 feet, which may exclude some areas of Florida's gulf coast. Once they have become obsolete, they must be removed from the sea floor. The first of these was sunk in 170 feet of water off the Florida panhandle in September, 1982 (Fig. 6).

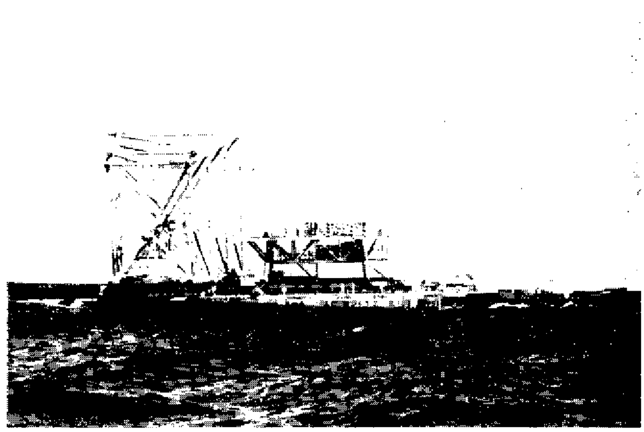


Fig. 6 Tenneco Oil Platform Offloading off Pensacola, FL. (Photo courtesy Dr. Dan Sheehy) Copyright - Aquabio Inc. 1982.

Mid-Water Attractors

This type of artificial reef is a relatively new idea pioneered along the Atlantic Coast by the South Carolina Wildlife and Marine Resources Department.

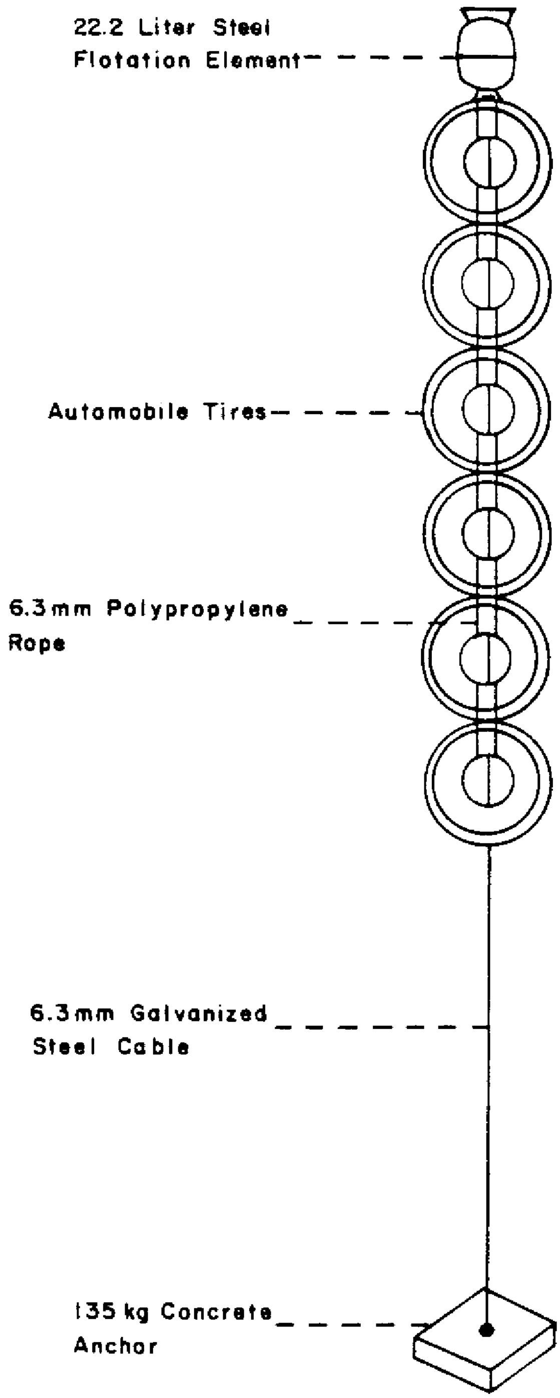


Fig. 7 Tire Mid-water Reef (Hammond, 1977)

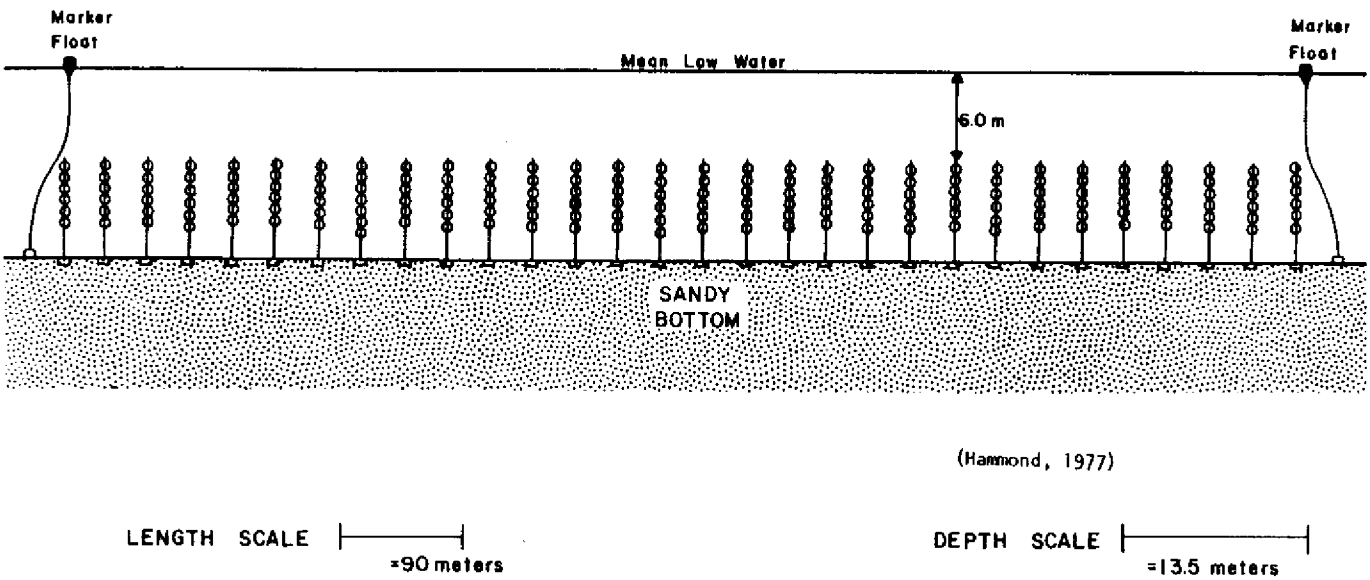
The main purpose is to attract schools of bait fish, mainly sardine-like fish, which in turn attract large numbers of pelagic fish. The original design used off South Carolina was a series of passenger car tires suspended on a stainless steel cable. A concrete anchor at the base of the string held it in place, and a float at the other end held the five-tire unit upright off the bottom (Fig.7). These units were then placed approximately 50 to 100 feet apart in a long line or "trolling alley" (Fig. 8). Fishermen could then troll down the line of attractors by lining up the two buoys at each end of the line (Hammond, 1977).

Later modifications of this design used scrap dragline cable obtained free from construction contractors and crane companies. A car tire filled with concrete makes an excellent anchor with a ring or reinforcing bar loop protruding up from the center. The use of a car tire for the mold of the sinker allows it to be rolled up a plank onto the deck of the barge or even a small boat. The cable is then clamped to the sinker and three to seven tires are strung along the cable using holes cut in top and bottom with a hole saw or knife. The float at the top is a pair of old 20-pound freon bottles obtained free of charge from air conditioning contractors (they cannot be reused). These metal containers, when painted, will last from 18 months to two years in sea water. This is a deliberate "weak link" in the system to prevent the tires from ever floating to the surface and becoming a navigation hazard. Long before the cable rusts through, the freon bottles will rust enough to let out the air and sink to the bottom. Once on the bottom, the unit becomes a benthic fish attractor. Relatively inexpensive to build, they can be replaced every two years.

When used in a "trolling alley" these units have had great success in offshore waters, particularly for such species as mackerel, amberjack, cobia, barracuda, and other pelagic species. The number of tires used and the length of the cable depends upon the depths of water available. In general, they should extend up off the bottom approximately one-half the depth, if possible, without creating a hazard to navigation.

Often ship hulls or other types of bottom reefs can be greatly enhanced by addition of several dozen mid-water units.

"Fish Aggregating Devices" (FADs): This type of mid-water attractor is made of light-weight structures suspended up from the bottom on nylon ropes. These devices have been successful in Japan and are presently being tested in this country. Like the mid-water units used off South Carolina, these reefs attract large schools of bait fish; in turn, pelagic fish feed on these large concentrations of bait fish. FADs probably do not have the long life spans of bottom reefs, but they are cheaper and easier to deploy.



(Hammond, 1977)

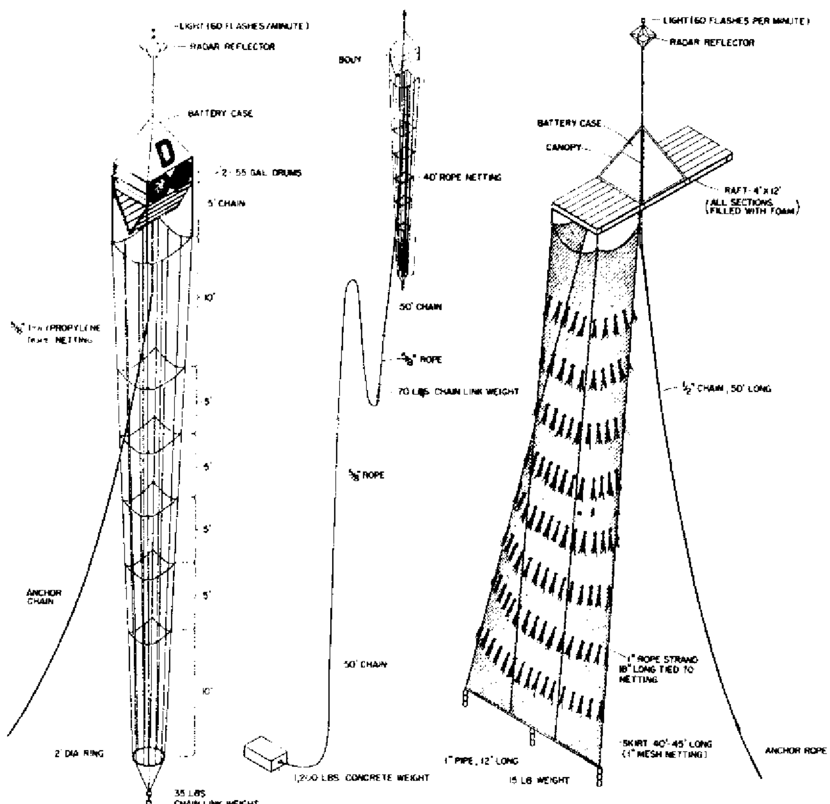
Fig. 8 Mid-water Trolling Alley

Surface Attractors

In areas where the lack of a substantial continental shelf limits the use of bottom and mid-water reefs, surface aggregating devices have been used. Hawaii has experimented with several types of these units. (Those pictured in Fig. 9 were developed by the National Marine Fisheries Service.) These units do not have the long life spans of most bottom reefs, but have proven very effective in attracting bait fish and pelagic game and food fish (Matsumoto, 1981).

One maintenance problem with surface attractors is that they must have both lights and radar reflectors. They are also more vulnerable to storm damage. Florida waters generally have adequate shelf areas so the surface attractors may prove

The aggregating devices consisted of a buoy made of two 55-gal oil drums which supported a canopy above to house the battery pack, a radar reflector and light, and a 45-ft long rope netting suspended beneath the buoy. Later improvements included the use of a raft in place of the 55-gal drums. The mooring system consisted of 50-ft chain lengths at the anchor and buoy, a 1,200-lb concrete block anchor, an anchor line of 5/8-inch polypropylene rope, and sufficient weight at the top third of the anchor line to keep the line submerged at all times.



Fish aggregating device, Model I.

Fish aggregating device, Model II.

(Matsumoto, 1981)

Fig. 9

more expensive to maintain and not as cost effective when compared with bottom and mid-water reefs.

Inshore Reefs: Most artificial reefs in Florida waters have been located offshore in areas accessible only to medium and larger size pleasure craft. Inshore reefs to provide benthic fishing for small boat and pier fishermen have been constructed in several parts of Florida with limited success. Inshore reefs attract smaller individual fish than an offshore reef, and the total fish populations attracted to these shallow estuarine reefs do not equal those offshore.

In areas where a large user group does not have the type of boats necessary to venture offshore, inshore reefs may provide an important addition to existing fishing resources. In Miami's Biscayne Bay, for example, a fishing pier was constructed and then an artificial reef of old culvert was added around the end of the pier. Due to poor site selection, this particular project was not a great success; but, if done properly, this can be an effective way to return some limited fish habitats to an estuary already damaged by dredge and fill activity.

Due to the lack of wave surge, car tires can often be utilized in these inshore reefs if adequate ballast is used. These reefs can be built in waters as shallow as 5 to 7 feet when not adjacent to boat channels and if well-marked. These shallow reefs have less maintenance cost because they can be marked with permanent concrete pilings rather than buoys that must be repaired and replaced every few years. Great care, however, must be used in site selection on these shallow water inshore reefs to avoid disruption of existing estuarine communities.

* * *

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